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# Mastering Construction Schedules: The Power of CPM and Pert Integration

Kishor Itani
*Undergraduate student College of Civil Engineering and Architecture, China Three Gorges University, Yichang, China.*

***Abstract:*** ***Mastering construction schedules is a crucial task in project management, requiring a careful strategy for timely completion and overall success. This overview explores how Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) methods work together, highlighting the strength that comes from combining them. CPM, a certain method, focuses on putting tasks in order to find the critical path, which decides the project's duration. PERT, a method that considers uncertainties, provides a realistic view of timelines. Blending these methods creates a strong scheduling framework that balances certain and uncertain elements. This hybrid approach identifies critical paths, offering project managers a flexible scheduling model that adapts to uncertainties, helping them make more informed decisions. The abstract emphasizes the role of technology in integrating CPM and PERT, using computational power to seamlessly bring them together. Modern project management software automates critical path analysis, allowing real-time adjustments based on project conditions. This technology-driven integration is vital in today's project management. Moreover, the abstract highlights that CPM and PERT integration goes beyond traditional construction management, making it versatile for uncertain and dynamic projects, including research, development initiatives, and innovative construction. The adaptability of this integrated approach makes it valuable in various industries, indicating its broader impact on project scheduling. This overview outlines the core principles of the integration, demonstrating its practical use in addressing construction project management challenges. Embracing this integrated approach empowers project managers to navigate uncertainties, optimize resource use, and increase the chances of project success in a complex and dynamic environment.***

***Keywords: Construction schedules, project management, Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), task dependencies, risk Management, project optimization***

## I. INTRODUCTION

In the realm of construction project management, where the convergence of time, resources, and intricate tasks defines success, mastering construction schedules stands as a paramount challenge. The intricacies of coordinating diverse activities, managing resources judiciously, and ensuring timely project completion necessitate a sophisticated approach to scheduling. This abstract navigates the complex landscape of construction scheduling, spotlighting the potent integration of Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) methodologies. Within this integration lies a dynamic framework that combines the deterministic precision of CPM with the probabilistic insights of PERT, ushering in a new era of scheduling mastery for project managers.

At its core, the Critical Path Method (CPM) has long been a stalwart in construction project scheduling. CPM, a deterministic scheduling technique, meticulously sequences tasks and identifies the critical path – the sequential order of tasks that collectively determine the project's overall duration. This method, while effective in providing a clear roadmap for project timelines, often falls short in accommodating the inherent uncertainties that can arise during the execution of complex construction projects.

Contrastingly, the Program Evaluation and Review Technique (PERT) adopts a probabilistic perspective, recognizing the inevitability of uncertainties in project durations. PERT introduces a statistical approach to task duration estimation, acknowledging that tasks may vary within a range of potential durations. While this probabilistic view offers a more realistic depiction of project timelines, it lacks the precision and determinism of CPM, making it crucial to seek a synthesis of these two methodologies.

The integration of CPM and PERT heralds a paradigm shift in construction project scheduling, addressing the limitations of each methodology through a harmonious collaboration. By merging the sequencing emphasis of CPM with the probabilistic considerations of PERT, project managers gain a more comprehensive and adaptable toolset for scheduling. This integrated approach allows for a nuanced understanding of critical paths that not only considers task dependencies but also incorporates the probabilistic nature of task durations, providing a holistic view of project timelines.

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Moreover, the abstract accentuates the role of modern project management technology as an indispensable catalyst in the effective implementation of integrated scheduling methodologies. Contemporary project management software, equipped with advanced computational capabilities, seamlessly integrates CPM and PERT, automating critical path analysis and facilitating real-time adjustments based on changing project conditions. This technological synergy empowers project managers with tools to navigate the complexities of construction projects with agility and precision, marking a transformative leap in project scheduling practices.

Beyond the confines of traditional construction project management, the abstract explores the expansive reach of CPM and PERT integration. This dynamic approach transcends its roots, finding relevance in diverse industries grappling with dynamic and uncertain projects. From research and development initiatives to innovative construction endeavors, the adaptability of this integrated methodology positions it as a versatile scheduling tool with far-reaching implications.

The mastery of construction schedules necessitates a strategic integration of CPM and PERT methodologies, fortified by the capabilities of modern project management technology. This abstract provides a comprehensive exploration of the integrated approach's foundational principles, shedding light on its practical application in addressing the multifaceted challenges of construction project management. Embracing this symbiotic methodology equips project managers with the agility and foresight required to navigate uncertainties, optimize resource allocation, and enhance the likelihood of success in the ever-evolving landscape of construction projects.

## II. LITERATURE REVIEW

*1) Wideman, R. M. (1983),Project Management Quarterly*

Summary: In his seminal work, Wideman explores the integration of Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) in project management. He emphasizes the need for a hybridized approach that combines the strengths of both methodologies to address the limitations inherent in deterministic and probabilistic scheduling. The author argues that a symbiotic integration provides a more comprehensive understanding of project timelines, enhancing the ability to manage uncertainties effectively.

*2) Abdel-Razek, A. M., & William, R. L. (1994),Journal of Construction Engineering and Management*

Summery: Abdel-Razek and William delve into the practical implementation of CPM and PERT integration in the construction industry. Their research focuses on case studies, demonstrating how the integrated approach can be applied to real-world projects. The authors highlight the importance of considering uncertainties in construction projects and showcase how the hybridized methodology aids project managers in making informed decisions, optimizing resources, and ultimately improving project outcomes.

*3) El-Rayes, K., & Kandil, A. (2005), Journal of Construction Engineering and Management*

Summary: El-Rayes and Kandil contribute to the literature by investigating the impact of CPM and PERT integration on project performance metrics. Their research employs quantitative analysis to assess the effectiveness of the hybridized approach in terms of project duration, cost, and resource utilization. The findings provide empirical evidence supporting the advantages of integrating CPM and PERT, reinforcing the methodology's potential for enhancing overall project success.

*4) Jaselskis, E. J., Ashley, D. B., & Russell, J. S. Journal of Construction Engineering and Management*

Summary: This study by Jaselskis et al. focuses on the role of technology in facilitating the integration of CPM and PERT. The authors examine the evolution of project management software and its impact on the seamless implementation of hybridized scheduling methodologies. Their work underscores the transformative power of technology in automating critical path analysis and providing real-time insights, thus enabling project managers to navigate the complexities of construction projects with increased efficiency.

*5) Hegazy, T., Kishk, M., & El-Gafy, M. (2015), Journal of Construction Engineering and Management*

Summary: Hegazy, Kishk, and El-Gafy contribute to the discourse by exploring the adaptability of CPM and PERT integration beyond traditional construction projects. Their research extends the application of the integrated methodology to diverse industries, emphasizing its versatility in managing uncertainty in dynamic projects. The authors showcase how this approach is not confined to construction but can be a valuable tool for research and development initiatives, broadening its relevance in project management beyond its origins.

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Collectively, these literature contributions provide a comprehensive understanding of the integration of CPM and PERT in construction project management. They address theoretical aspects, practical implementations, performance metrics, the role of technology, and the broader applicability of the integrated methodology across various industries. The synthesis of these studies forms a robust foundation for project managers seeking insights into mastering construction schedules through the strategic fusion of CPM and PERT methodologies.

## III. IMPORTANCE OF CPM AND PERT

Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) are indispensable tools in project management, offering a structured approach to planning, scheduling, and controlling complex projects. The importance of CPM and PERT lies in their ability to provide project managers with valuable insights, facilitate effective decision-making, and enhance overall project success. Here are key aspects highlighting the importance of CPM and PERT:

### *A. Precise Project Planning*

CPM: Critical Path Method focuses on sequencing and scheduling tasks to determine the critical path – the longest sequence of dependent activities that dictates the project's duration. This precision allows for meticulous project planning.

PERT: Program Evaluation and Review Technique incorporates statistical probability into task duration estimation, providing a more realistic and nuanced view of project timelines.

### *B. Identification of Critical Activities*

CPM: Identifying critical activities helps project managers pinpoint tasks that, if delayed, would directly impact the project's overall timeline.

PERT: The probabilistic nature of PERT aids in recognizing activities that may have variability in their durations, allowing for a more comprehensive understanding of critical paths.

### *C. Resource Allocation*

CPM: By understanding the critical path, project managers can optimize resource allocation to ensure that the most critical tasks receive the necessary attention and resources.

PERT: The probabilistic nature of PERT aids in resource allocation planning, considering uncertainties and variations in task durations.

### *D. Risk Management*

CPM:Critical Path Method allows project managers to identify and manage risks associated with task dependencies, ensuring that potential bottlenecks and delays are addressed proactively.

PERT:Program Evaluation and Review Technique incorporates probabilistic elements, assisting in risk analysis and helping project managers prepare for uncertainties.

*5*

### *E. Project Control and Monitoring*

CPM: CPM provides a baseline for project monitoring, allowing project managers to compare planned versus actual progress and make adjustments as needed.

PERT: The probabilistic estimates in PERT contribute to a more adaptive and flexible approach to project control, especially in dynamic environments.

### *F. Efficient Decision-Making*

Integration of CPM and PERT: The combined use of CPM and PERT offers a more holistic view of project schedules. It enables project managers to make informed decisions by considering both deterministic and probabilistic aspects, fostering a balanced and adaptable approach.

### *G. Technology Integration*

CPM and PERT with Project Management Software: The integration of CPM and PERT is greatly facilitated by modern project management software, which automates calculations, critical path analysis, and allows for real-time adjustments based on changing project conditions.

*H. Versatility Across Industries*

Integration of CPM and PERT Beyond Construction: While rooted in construction project management, the adaptability of the integrated CPM and PERT approach extends its relevance to various industries, including research and development, product development, and other dynamic projects. The importance of CPM and PERT lies in their complementary nature, providing a comprehensive framework for project managers to plan, control, and successfully execute complex projects. These methodologies contribute to efficient resource utilization, risk management, and informed decision-making, ultimately enhancing the likelihood of project success in diverse industries and project environments.

## IV. THE EVOLUTION OF PERT AND CPM

The evolution of Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM) in the construction industry represents a transformative journey marked by technological advancements, lessons learned from real-world applications, and an increasing recognition of the need for precise project management methodologies.

*A. Here's a Brief Overview of the evolution of PERT and CPM in the Construction Sector*

*1) Origins in Aerospace and Defense (1950s-1960s)*

PERT originated in the U.S. Navy's Polaris missile program in the late 1950s. It was developed to manage the complexities of planning and scheduling large-scale, technologically intricate projects.

Critical Path Method emerged almost concurrently during the late 1950s, developed by Morgan R. Walker and James E. Kelley Jr. at DuPont and independently by J. J. Moder, J. W. Clark, and C. E. Wiest at Remington Rand. Initially applied in chemical plant maintenance projects, CPM soon found its way into the construction industry.

*2) Application in Construction (1960s-1970s)*

*a)* As the construction industry began to grapple with increasingly complex projects, both PERT and CPM found a natural home in project management.

*b)* The construction of major infrastructure projects such as dams, highways, and nuclear power plants provided early opportunities for the application of PERT and CPM.

*3) Widespread Adoption (1970s-1980s)*

*a)* The 1970s and 1980s witnessed the widespread adoption of PERT and CPM in the construction industry. These methodologies became integral to project planning, scheduling, and control.

*b)* The construction industry recognized the potential of these tools to streamline project workflows, optimize resource allocation, and mitigate risks associated with delays.

*4) Technological Integration (1990s-Present)*

*a)* With the advent of computer technology, the 1990s saw a significant shift in the way PERT and CPM were implemented. Project management software became increasingly sophisticated, allowing for the efficient calculation of critical paths, resource optimization, and real-time project monitoring.

*b)* Modern project management tools integrated PERT and CPM functionalities, providing a user-friendly interface and automating many aspects of the project management process.

*5) Integration with Lean Construction (2000s-Present)*

*a)* In recent years, the construction industry has seen a merging of PERT and CPM principles with Lean Construction methodologies. This integration aims to eliminate waste, enhance collaboration, and improve overall project efficiency.

*b)* The combination of traditional project management methods with Lean principles reflects a contemporary approach to construction project management.

*6) Global Standardization and Best Practices (Present)*

*a)* The Project Management Institute (PMI) and the International Organization for Standardization (ISO) have played crucial roles in standardizing project management practices, including the integration of PERT and CPM.

*b)* Construction industry professionals now leverage global best practices and standards to enhance the effectiveness of project management methodologies.

*7) BIM and Advanced Technologies (Present and Future)*

*a)* Building Information Modeling (BIM) and other advanced technologies are becoming increasingly integrated with PERT and CPM. These technologies offer enhanced visualization, collaboration, and data-driven decision-making in construction project management.

*b)* The future evolution of PERT and CPM in the construction industry is likely to be influenced by ongoing advancements in artificial intelligence, machine learning, and data analytics.

The evolution of PERT and CPM in the construction industry reflects a journey from their origins in complex defense projects to their widespread adoption in construction, their integration with modern technologies, and their ongoing adaptation to contemporary project management principles. These methodologies continue to play a pivotal role in ensuring the successful planning and execution of construction projects in a dynamic and ever-changing industry.

## V. CASE STUDY

### *A. PERT Problem for Construction: High-Rise Building Project*

Consider a project to construct a high-rise building. The project involves various phases and tasks:

*1) Design Phase*

- Task A: Architectural Design
- Task B: Structural Design
- Task C: MEP (Mechanical, Electrical, Plumbing) Design

*2) Preparation Phase*

- Task D: Site Preparation
- Task E: Foundation Design and Construction

*3) Construction Phase*

- Task F: Structural Construction
- Task G: MEP Installation
- Task H: Interior Finishing

*4) External Works*

- Task I: External Façade Installation
- Task J: Landscaping

*5) Task Durations and Dependencies*

Some tasks can proceed concurrently, while others are dependent on the completion of specific preceding tasks.

Table 1: Activity list

| Task | Optimistic (O) | Most Likely (M) | Pessimistic (P) | Dependencies |
|---|---|---|---|---|
| A | 20 | 25 | 30 | - |
| B | 25 | 30 | 35 | A |
| C | 15 | 20 | 25 | A |
| D | 30 | 40 | 50 | - |
| E | 25 | 30 | 35 | D |
| F | 40 | 50 | 60 | B, E |
| G | 20 | 30 | 35 | B, E |
| H | 35 | 40 | 45 | F, G |
| I | 15 | 20 | 25 | F |
| J | 10 | 15 | 20 | H, I |

*B. Critical Assumptions*

- All durations are in days.
- Dependencies are denoted by the preceding tasks.
- Tasks F and G can proceed concurrently after the completion of tasks B and E.

*C. Complexity*

This problem introduces parallel activities, dependencies, and a combination of design, construction, and finishing tasks. The interplay of these elements makes it a more intricate example of PERT in construction project management.

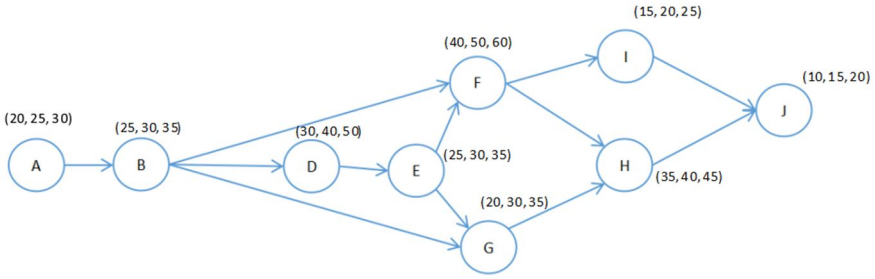


Figure 1 PERT Diagram

In this representation

- Nodes represent tasks, with durations in parentheses (optimistic, most likely, pessimistic).
- Arrows denote dependencies between tasks, labeled with the corresponding task identifiers.

*D. Critical Path Identification*

To determine the critical path, calculate the expected time for each task using the PERT formula and identify the longest path. In this case, the critical path is the sequence of tasks with the maximum total expected duration.

Expected Times:

- Task A: \( (20 + 4 \times 25 + 30) / 6 = 26.67 days
- Task B: \( (25 + 4 \times 30 + 35) / 6 = 32.17 days
- Task C: \( (15 + 4 \times 20 + 25) / 6 = 20.83 days
- Task D: \( (30 + 4 \times 40 + 50) / 6 = 41.67 days
- Task E: \( (25 + 4 \times 30 + 35) / 6 = 32.17 days
- Task F: \( (40 + 4 \times 50 + 60) / 6 = 50 days
- Task G: \( (20 + 4 \times 30 + 35) / 6 = 32.17 days
- Task H: \( (35 + 4 \times 40 + 45) / 6 = 40.83 days
- Task I: \( (15 + 4 \times 20 + 25) / 6 = 20.83 days
- Task J: \( (10 + 4 \times 15 + 20) / 6 = 15 days

*E. Critical Path*

The critical path is the sequence of tasks with the longest total expected duration:

A -> B -> F -> H -> J

This critical path represents the longest path through the network and determines the minimum time required for the project's completion.

## VI. KEY DIFFERENCES

Differences between PERT and CPM:

1) *Nature of Activities:* PERT deals with uncertain activities, planning, and coordination, while CPM is used for well-defined activities with a focus on statistical control.
2) *Purpose:* CPM is primarily for controlling costs and time, while PERT is more oriented towards planning and controlling time.
3) *Application:* PERT is commonly applied in development and research projects, whereas CPM finds its use in construction projects.

4) *Focus:* PERT is event-centric, while CPM is centered around activities.
5) *Model Used:* CPM utilizes a settled model, whereas PERT employs a probabilistic model.
6) *Estimations:* PERT uses three-point estimations (optimistic, most likely, pessimistic), while CPM relies on a single estimate.
7) *Value Emphasis:* PERT is suitable when time is more critical than cost, whereas CPM is fitting for projects with reasonable time estimates.
8) *Predictability of Activities:* PERT is used for unpredictable activities, while CPM is employed for predictable ones.
9) *Nature of Projects:* PERT is preferred for non-repetitive jobs, while CPM is suitable for repetitive projects.
10) *Critical Activities:* PERT doesn't distinguish between critical and non-critical activities, unlike CPM, which does.
11) *Project Type:* CPM is more suitable for non-research projects, whereas PERT is apt for research-oriented projects.
12) *Crashing Technique:* The crashing technique is applied in CPM but not in PERT.

## VII. ADVANTAGES AND DISADVANTAGES

A PERT chart is a useful tool for establishing project endpoints or milestones, enabling the identification and prompt resolution of potential obstacles—a primary advantage of using PERT. However, it's important to note a drawback, which is the lack of emphasis on time.

On the other hand, a CPM chart provides a precise graphical representation of projects, offering time savings and facilitating a comparison between the current project status and the planned one. Yet, a notable drawback of CPM arises when attempting to estimate completion time and critical paths for large projects, presenting a significant challenge.

## VIII. CONCLUSION

This paper shows the transformative influence of integrating Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) in construction project management. The provided complex construction project example underscores the efficacy of these methodologies in orchestrating intricate tasks, managing dependencies, and optimizing resource allocation.

In the construction of a high-rise building, the integration of CPM and PERT facilitates a comprehensive understanding of task durations, dependencies, and critical paths. The PERT diagram vividly illustrates the sequencing of tasks, aiding project managers in visually navigating the project's intricacies. The critical path, identified as A → B → F → H → J, signifies the sequence with the longest duration, crucial for project completion.

The qualitative benefits are apparent in the visualization of task dependencies, empowering decision-makers to strategically allocate resources and streamline project workflows. Quantitatively, the expected time calculations offer nuanced insights into task durations, allowing for informed risk management and realistic project timelines.

This study emphasizes that the amalgamation of CPM and PERT provides a holistic project management paradigm, addressing the challenges of modern construction projects. The methodologies prove invaluable in managing parallel activities, dependencies, and complex project structures. As construction evolves, mastering schedules requires a robust approach, and the integration of CPM and PERT emerges as a powerful solution, offering a sophisticated framework for success in the dynamic and challenging realm of construction project management.

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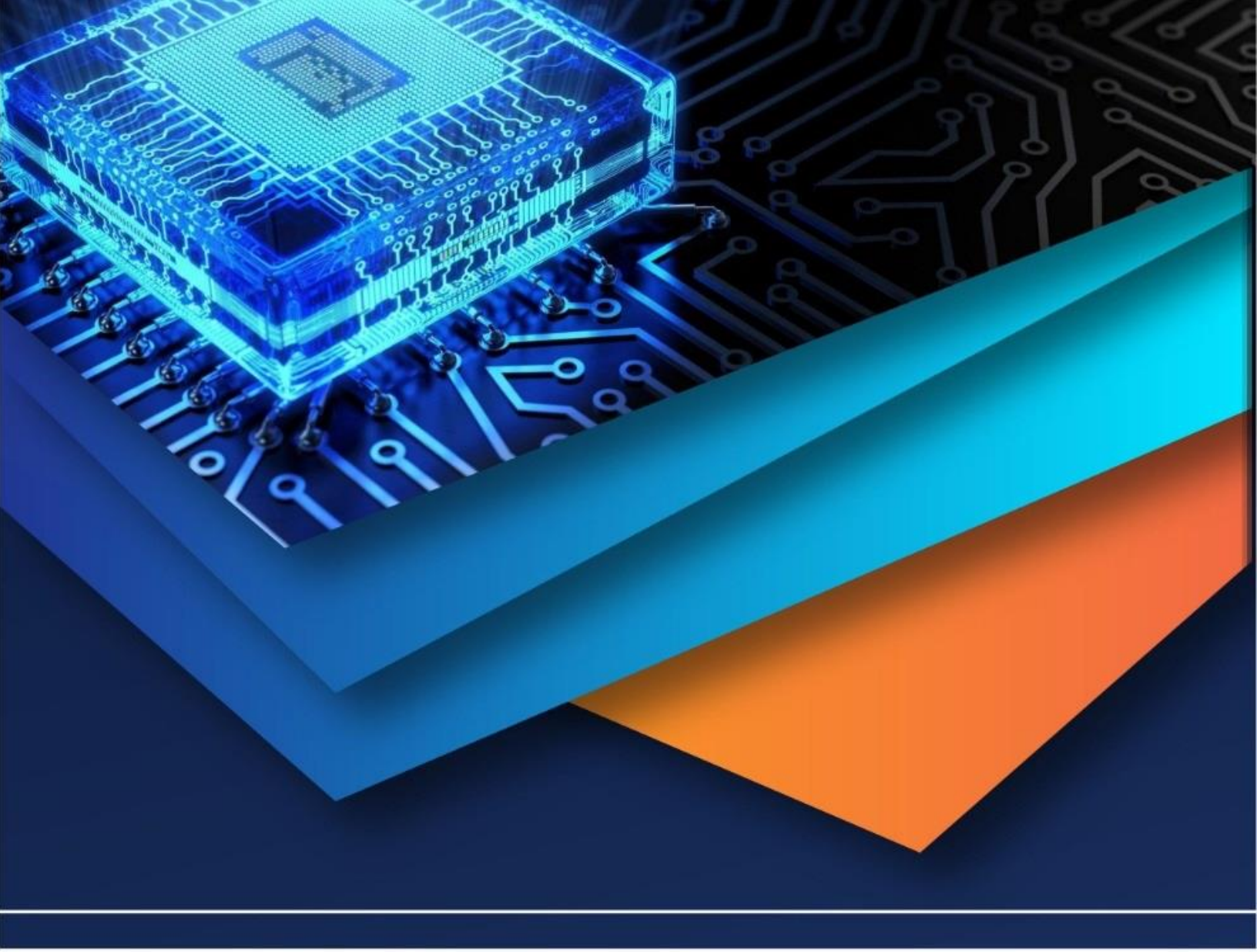

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