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Prioritization of Material Wastage Factors and Quality-Management Practices in Construction Projects Using Relative Importance Index

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Abstract: Material wastage is a persistent challenge in construction projects because it affects project cost, schedule performance, work quality, productivity, and environmental sustainability. This study identifies and prioritizes the major factors influencing material wastage and evaluates quality-management practices that can reduce avoidable waste in construction projects. A structured questionnaire was prepared from literature-based factors and validated through expert review before main data collection. The survey responses were analyzed in aggregate form using frequency analysis and the Relative Importance Index (RII) method. The findings indicate that supervision and workforce-related factors form the most critical category affecting material wastage. Rework due to poor workmanship, improper material handling, lack of site supervision, frequent design changes, and poor project planning emerged as the leading causes. The impact analysis showed that material wastage primarily results in rework or repair, project delay, cost increase, and poor work quality. Material inspection before installation, regular site inspections, toolbox talks, worker training, and coordination meetings were identified as important quality-management practices for waste reduction. An integrated material waste reduction and quality-management framework is proposed to support practical implementation at construction sites. To maintain confidentiality, results are presented only as aggregated statistical findings without disclosing respondent identities, organization names, project names, or raw survey data.
Keywords: Material wastage; quality management; construction projects; Relative Importance Index; QA/QC; waste reduction; site supervision.

I. INTRODUCTION

The construction industry consumes large quantities of materials and therefore plays a significant role in resource utilization, project economy, and environmental performance. Material wastage refers to the loss, damage, misuse, surplus, or unnecessary disposal of materials during construction. Since construction materials generally represent a major portion of total project cost, even small levels of wastage can lead to substantial financial losses. In addition to cost impacts, wastage affects productivity, project schedule, work quality, site safety, and sustainability.

Construction material wastage is commonly caused by inaccurate estimation, design changes, over-ordering, delayed delivery, improper handling, poor storage, weak supervision, and rework due to poor workmanship. These issues are closely connected with quality-management practices because defective work, poor inspection systems, and inadequate worker training often result in avoidable material consumption. Therefore, material wastage should not be treated only as a housekeeping problem but as an integrated material management and quality-management issue.

This paper presents a survey-based analysis of material wastage factors and quality-management practices in construction projects. The study ranks the identified factors using the Relative Importance Index method and proposes a practical framework for reducing wastage through improved planning, procurement, handling, storage, supervision, and QA/QC practices.

II. LITERATURE REVIEW

Construction material wastage is a multi-dimensional problem influenced by design decisions, procurement practices, site handling, storage conditions, workforce behavior, and quality-control systems. Previous studies indicate that construction waste is not created at one isolated stage; rather, it develops through a chain of decisions and site activities from planning to execution (Ajayi et al., 2017; Luangcharoenrat et al., 2019; Kar & Jha, 2023). Therefore, this review groups the literature into planning, procurement, handling, storage, supervision, and quality-management dimensions.

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A. Planning and Design-Related Waste

Planning and design decisions strongly influence the quantity and type of waste generated during construction. Inaccurate quantity take-offs, incomplete drawings, delayed design decisions, poor scheduling, and frequent design changes create rework and material surplus. Luangcharoenrat et al. (2019) reported that design and planning-related factors are significant contributors to construction waste generation in building projects. Similarly, Saad et al. (2022) emphasized that decisions taken during the design process influence downstream waste during procurement and construction execution. BIM-based tools can reduce such errors by improving quantity estimation, visualization, coordination, and clash detection before work begins (Sampaio et al., 2023).

B. Procurement and Supply Chain-Related Waste

Procurement-related waste occurs when materials are over-ordered, delivered late, supplied in incorrect specifications, or purchased without adequate coordination with site requirements. Ajayi et al. (2017) identified effective procurement planning, supplier coordination, and material ordering control as important success factors for minimizing construction waste. Kar and Jha (2023) further observed that material management practices have a direct influence on material availability and waste reduction in construction projects. These studies show that procurement should not be treated as a separate administrative activity; it must be linked with planning, inventory control, site progress, and quality requirements.

C. Material Handling and Transportation-Related Waste

Material handling is another important source of waste, particularly for fragile or finishing materials such as tiles, glass, blocks, plumbing fixtures, and electrical components. Improper unloading, repeated shifting, unskilled handling, lack of suitable handling equipment, and careless site movement increase the possibility of breakage, spillage, and damage. Tansel (2020) highlighted that growing material demand and low recycling rates make efficient material use increasingly important. In construction projects, careful handling practices, appropriate equipment, and worker training are therefore essential to reduce avoidable material losses.

D. Storage and Site Management-Related Waste

Poor storage practices lead to deterioration of material quality before installation. Exposure to rain, sunlight, moisture, dust, and unsuitable stacking conditions can damage materials such as cement, steel, timber, blocks, gypsum boards, paint, and finishing items. Travnicek et al. (2022) emphasized the importance of safe storage and preventive practices for reducing losses in material storage environments. In construction sites, improper housekeeping and inadequate storage planning also create congestion, increase material movement, and raise the risk of damage. Hence, storage control is a practical requirement for reducing waste and maintaining quality.

E. Supervision, Workforce, and Rework-Related Waste

Human-related factors such as poor workmanship, lack of supervision, lack of worker training, and negligence are repeatedly identified as major contributors to construction waste. Weak supervision allows errors to continue until later stages, resulting in rework, demolition, repair, and additional material consumption. Ajayi et al. (2017) observed that effective site management and procurement coordination are necessary for waste minimization. Luangcharoenrat et al. (2019) also highlighted the influence of managerial and site-level factors on construction waste generation. These findings support the view that waste reduction depends not only on material availability but also on workmanship quality and site supervision.

F. Quality-Management Practices for Waste Reduction

Quality-management practices provide preventive controls for reducing waste. QA/QC checklists, material inspection before installation, incoming testing, document control, method statements, toolbox talks, regular site inspections, and corrective and preventive actions (CAPA) help detect errors before they result in waste. Kar and Jha (2023) showed that improved material management contributes to better material availability and waste reduction. Sampaio et al. (2023) also indicated that collaborative BIM-based tools improve project coordination, which can reduce design and execution mismatches. Thus, integration of quality management with material management is necessary to control waste at planning, procurement, storage, handling, and execution stages.

G. Research Gap Identified from Literature

The literature indicates that material wastage has been studied from different viewpoints, including design, procurement, storage, handling, sustainability, and quality control. However, many studies focus on individual waste factors rather than integrating material wastage with quality-management practices. There is also a need for practical ranking-based studies that help construction professionals prioritize the most critical causes of waste. The present study addresses this gap by identifying and ranking wastage factors using the Relative Importance Index method and by proposing an integrated material waste reduction and quality-management framework.

III. RESEARCH METHODOLOGY

A questionnaire-based empirical research design was adopted. The material wastage factors were first identified from the literature and grouped into five categories: planning, procurement, handling, storage, and supervision/workforce. The questionnaire also included items related to the impact of wastage and quality-management practices for waste reduction. A five-point Likert scale was used, where 1 represented very low impact and 5 represented very high impact.

The questionnaire was reviewed by civil engineering and construction industry experts to confirm relevance, clarity, technical accuracy, and completeness. Based on expert suggestions, the questionnaire was improved by clarifying rating instructions, refining wording, adding an impact item on rework/repair, and including a separate section on quality-management practices. The final survey responses were collected from construction professionals and analyzed using frequency analysis and RII.

Figure 1. Research methodology flow

The Relative Importance Index was calculated as: $RII = \Sigma W / (A \times N)$, where W is the weight assigned by respondents, A is the highest possible rating, and N is the number of respondents.

A. Data Confidentiality and Ethical Consideration

The study presents only aggregated statistical findings. No individual respondent name, organization name, project name, site-specific record, or raw questionnaire response is disclosed. The collected data were used only for academic analysis and professional improvement.

IV. RESULTS AND DISCUSSION

The analysis was carried out on questionnaire responses from 84 construction professionals. The following results are reported only in summarized form to maintain confidentiality and to focus on research-level interpretation.

A. Respondent Profile Summary

Table 1. Respondent profile summary

Parameter	Summary
Total valid responses	84
Respondent categories	Site engineers, contractors, project managers, quantity surveyors, and procurement officers
Project types represented	Residential, commercial, industrial, infrastructure, and mixed projects
Analysis methods	Frequency analysis and Relative Importance Index

B. Category-wise Priority of Wastage Factors

The category-wise average RII values show that supervision and workforce-related factors are the most critical contributors to material wastage. This indicates that workmanship quality, worker training, supervision, and compliance with procedures have a strong influence on waste generation during execution. Planning, handling, and procurement factors also recorded very high priority levels.

Table 2. Category-wise average RII values

Category	Average RII	Priority Level
Supervision & Workforce-related	0.868	Very High
Impact of Material Wastage	0.852	Very High
Planning-related	0.843	Very High
Handling-related	0.833	Very High

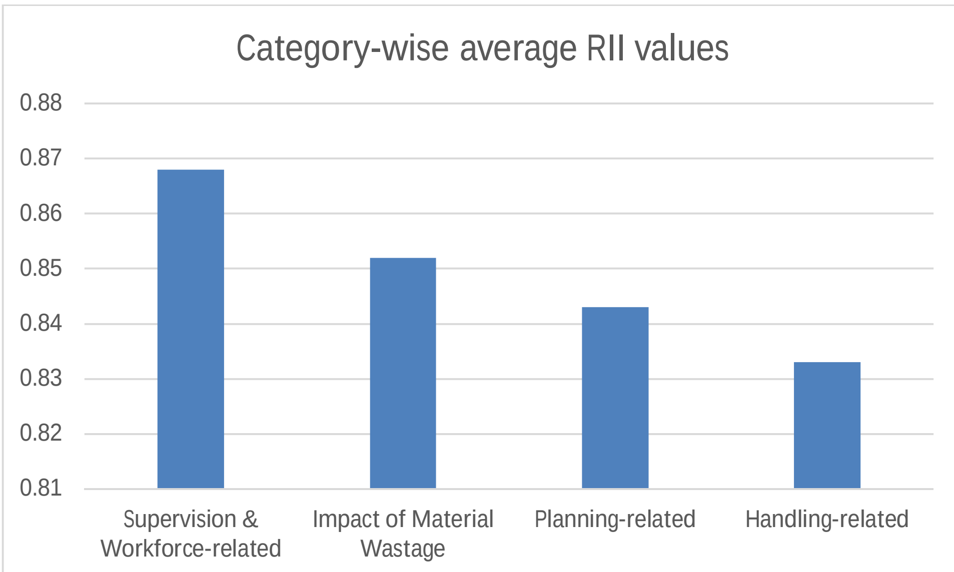

Figure 2. Category-wise average RII of material wastage factors

C. Top Critical Material Wastage Factors

The top-ranked factors show that material wastage is not generated from a single source. It is the combined result of poor workmanship, improper handling, lack of supervision, design changes, and planning weaknesses. Rework due to poor workmanship was found to be the highest ranked factor, demonstrating the strong connection between quality defects and material wastage.

Table 3. Top critical material wastage factors

Rank	Critical Factor	RII
1	Rework/repair due to material wastage and quality issues	0.908
2	Rework due to poor workmanship	0.903
3	Lack of site supervision	0.900
4	Improper material handling on site	0.900
5	Frequent design changes	0.898
6	Poor project planning	0.898

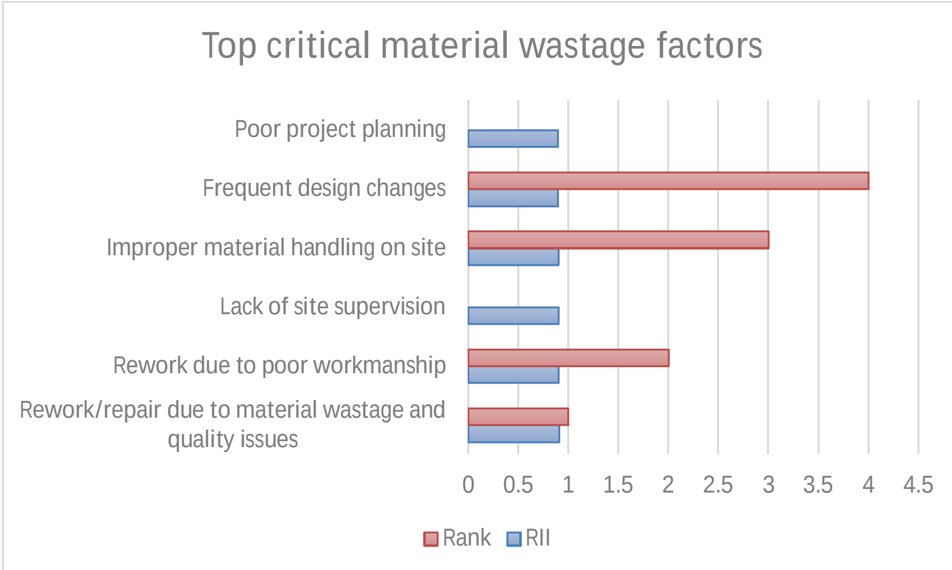

Figure 3. Top critical material wastage factors

V. IMPACT OF MATERIAL WASTAGE ON PROJECT PERFORMANCE AND RECOMMENDED REMEDIES

A. Category - Impact of Material Wastage: Factor- Rework/repair due to material wastage and quality issues

The factor achieved the highest overall RII of 0.908

- Direct consumption of additional cement, steel, blocks, tiles, finishes and other materials.
- Demolition and disposal of rejected work, leading to additional waste-handling and environmental burden.
- Labour and equipment are diverted from planned activities, reducing productivity and disrupting the construction sequence.
- Repeated work increases cost, extends activity duration and may damage adjoining completed work.
- Frequent rework reduces client confidence and can lead to disputes, claims and delayed handover.

Recommended remedies

- Introduce inspection and test plans with mandatory hold points before concrete placement, plastering, waterproofing, tiling, finishing and concealment of services.
- Approve first-work samples or mock-ups before repetitive execution so that errors are corrected at the beginning rather than after large quantities are completed.
- Maintain a rework register recording location, activity, quantity, cause, responsible party, corrective action and estimated cost.
- Use non-conformance reports (NCRs) and corrective and preventive action (CAPA) with defined closure dates and verification by QA/QC personnel.
- Track the first-pass inspection approval rate and rework cost as monthly project KPIs.
- Conduct weekly root-cause reviews of recurring defects and communicate lessons learned to supervisors, subcontractors and workers.

B. Category -Supervision & Workforce-related : Factor - Rework due to poor workmanship

The factor achieved the highest overall RII of 0.902

Defective work increases rejection, repair and replacement quantities.

- Poor finishes and dimensional inaccuracies may affect subsequent trades, creating cascading rework.
- Productivity falls because supervisors and skilled workers spend time correcting completed work.
- Quality failures can reduce durability and serviceability if defects are concealed rather than properly rectified.
- Subcontractor disputes may arise over responsibility for repair cost and delay.

Recommended remedies

- Prepare a trade-wise competency matrix and conduct basic skill tests before deploying masons, bar benders, carpenters, tilers, waterproofing teams and finishers.
- Provide method demonstrations, approved samples and visual work instructions in the language understood by workers.

- Conduct daily toolbox talks focused on the quality risks of the upcoming activity, not only on safety.
- Use stage-wise checklists signed by the worker or subcontractor supervisor and verified by the site engineer.
- Introduce a subcontractor quality score covering first-pass approval, defect frequency, rework hours and compliance with method statements.
- Pair less-experienced workers with competent trade leaders and provide immediate feedback during execution.

C. Category: Supervision & Workforce-related : Factor - Lack of Site Supervision

The factor achieved the highest overall RII of 0.900

Errors are detected late, when correction requires more demolition and replacement.

- Workers may use incorrect methods, materials or dimensions without timely guidance.
- Quality records and inspection requests may be incomplete, weakening traceability.
- Poor coordination between trades can cause damage to completed work and repeated activities.
- Safety, housekeeping and material-control practices may also deteriorate where supervision is weak.

Recommended remedies

- Prepare a supervision deployment plan based on the number of active work fronts, critical activities and subcontractor teams.
- Define inspection responsibilities through a responsibility matrix covering site engineer, supervisor, QA/QC engineer, consultant and subcontractor.
- Use daily activity permits or start-work checklists confirming approved drawings, materials, method statement, manpower and required inspection points.
- Schedule supervisor presence during high-risk activities such as reinforcement placement, concrete pouring, waterproofing, services concealment and finishing.
- Use digital photographs, inspection records and location-based checklists for traceability.
- Review missed inspections, repeat defects and delayed NCR closures during weekly project meetings.

D. Category: Handling-related : Factor - Improper Material Handling on Site

The factor achieved the highest overall RII of 0.900

Breakage of blocks, tiles, glass, sanitary fixtures and precast components.

- Deformation or corrosion risk for reinforcement and metal items due to unsuitable lifting or placement.
- Spillage and contamination of cementitious, chemical and finishing materials.
- Additional labour and equipment time for repeated shifting and replacement.
- Shortages at the work front, emergency purchases and schedule disruption.

Recommended remedies

- Prepare a site logistics and material-flow plan showing delivery routes, unloading zones, storage areas, lifting arrangements and issue points.
- Use suitable handling equipment such as trolleys, pallet trucks, cranes, slings, lifting frames and protected racks.
- Store materials as close as practical to the point of use to reduce repeated movement.
- Define handling and damage responsibility at unloading, storage and issue stages.
- Train workers in lifting, stacking and movement requirements for fragile, moisture-sensitive and high-value materials.
- Record handling damage by material type and supplier/subcontractor, and review recurring causes monthly.

E. Category - Planning-related : Factor- Frequent Design Changes

The factor achieved the highest overall RII of 0.898

Previously purchased materials may become excess, unsuitable or obsolete.

- Completed work may require cutting, dismantling, relocation or reconstruction.
- Revised quantities create emergency procurement, price variations and delivery disruption.
- Design changes affect multiple trades and can create cascading schedule delays.
- Uncontrolled revisions increase the risk of teams working from superseded drawings.

Recommended remedies

- Establish a formal design-freeze milestone before procurement and commencement of major work packages.

- Conduct multidisciplinary constructability and coordination reviews involving architectural, structural, MEP, procurement and execution teams.
- Use BIM or coordinated overlay drawings for clash detection where project scale permits.
- Implement a controlled request-for-information (RFI) and design-change procedure with revision number, issue date, affected quantities, cost impact, time impact and approval authority.
- Withdraw superseded drawings from site and maintain a single controlled digital drawing register.
- Do not execute a change until its material, cost and schedule consequences are reviewed and formally authorized, except for urgent safety-related cases.

F. Category - Planning-related : Factor - Poor Project Planning

The factor achieved the highest overall RII of 0.898

- Materials may be over-ordered, under-ordered or delivered before suitable storage and work fronts are available.
- Activities may start without approved drawings, preceding work or inspections, increasing the likelihood of demolition, modification and rework.
- Labour and equipment may remain idle or be repeatedly reassigned, reducing productivity and increasing indirect cost.
- Emergency procurement and schedule recovery measures may increase purchase price, transport cost, overtime and quality risk.
- Poor sequencing can damage completed work, create trade interference and delay subsequent activities.

Recommended remedies

- Prepare a realistic baseline programme linked to approved drawings, quantities, procurement lead times, labour, equipment and inspection requirements.
- Use a rolling three- or four-week look-ahead plan and release each work front only after drawings, materials, access, manpower, preceding work and QA/QC hold points are confirmed.
- Maintain a constraint register for pending drawings, approvals, decisions, materials, subcontractor interfaces and access issues, with a responsible person and target closure date.
- Link purchase orders and delivery dates to the look-ahead schedule and actual storage capacity to avoid premature delivery, shortages and emergency purchasing.
- Establish design-freeze and formal change-control procedures; assess the quantity, cost, time and waste impact of every major change before authorization.
- Conduct weekly integrated planning meetings involving the project manager, planning engineer, site team, QA/QC, procurement, design representatives and key subcontractors.
- Compare planned versus actual quantities and track Percentage Plan Complete, unresolved constraints, material shortages, rework and waste as regular performance indicators.

Figure 4. Proposed integrated material waste reduction and quality-management framework

VI. PRIORITIZED IMPLEMENTATION ROADMAP

Time frame	Priority actions	Responsible roles	Expected output
0–30 days	Create design-change register, rework register and material-damage register; identify critical work fronts; approve checklists and hold points.	Project manager, planning engineer, QA/QC engineer, site engineers	Baseline data and immediate control over unrecorded changes, defects and damage.
31–60 days	Conduct trade competency assessment; introduce mock-ups, first-work approval and handling training; review supervision allocation.	Construction manager, subcontractors, QA/QC team, safety/logistics team	Improved workmanship, earlier defect detection and reduced handling losses.
61–90 days	Analyse root causes, compare locations/work packages, score subcontractors and suppliers, and standardize corrective actions.	Project manager, quality head, commercial team, planning team	Measurable reduction in rework, stronger accountability and continuous improvement.
Ongoing	Review KPIs monthly and update preventive actions based on recurring defects and waste records.	Senior management and project review committee	Sustained waste reduction and improved quality performance.

VII. OVERALL CONCLUSION

The detailed analysis confirms that the highest RII values are not isolated findings; they represent a connected management and execution problem. All respondents rated each of the five factors as High or Very High, showing strong agreement that these issues require immediate attention. Rework/repair is the most important overall impact, while the dominant local drivers differ: design changes in Pune, poor workmanship in Sangli, and lack of supervision together with rework in Kolhapur. Improper material handling remains consistently high across all locations.

Therefore, the most effective waste-reduction strategy is preventive rather than corrective. Projects should control design revisions before execution, strengthen supervision, verify worker competency, improve material logistics, and use stage-wise QA/QC with measurable rework and waste indicators. Applying these remedies according to location-specific priorities can reduce material losses, avoid repeated work, improve productivity and enhance project cost, time and quality performance.

VIII. FUTURE SCOPE

1) Future studies may quantify actual material-wise wastage percentages for cement, steel, aggregates, blocks, tiles, and finishing materials.
2) The proposed framework may be tested on live construction projects to evaluate practical effectiveness.
3) Advanced analysis such as correlation or regression may be used to examine the relationship between QA/QC practices and wastage reduction.
4) Digital tools such as BIM, QR code tracking, RFID, and inventory management systems may be studied for real-time material control.

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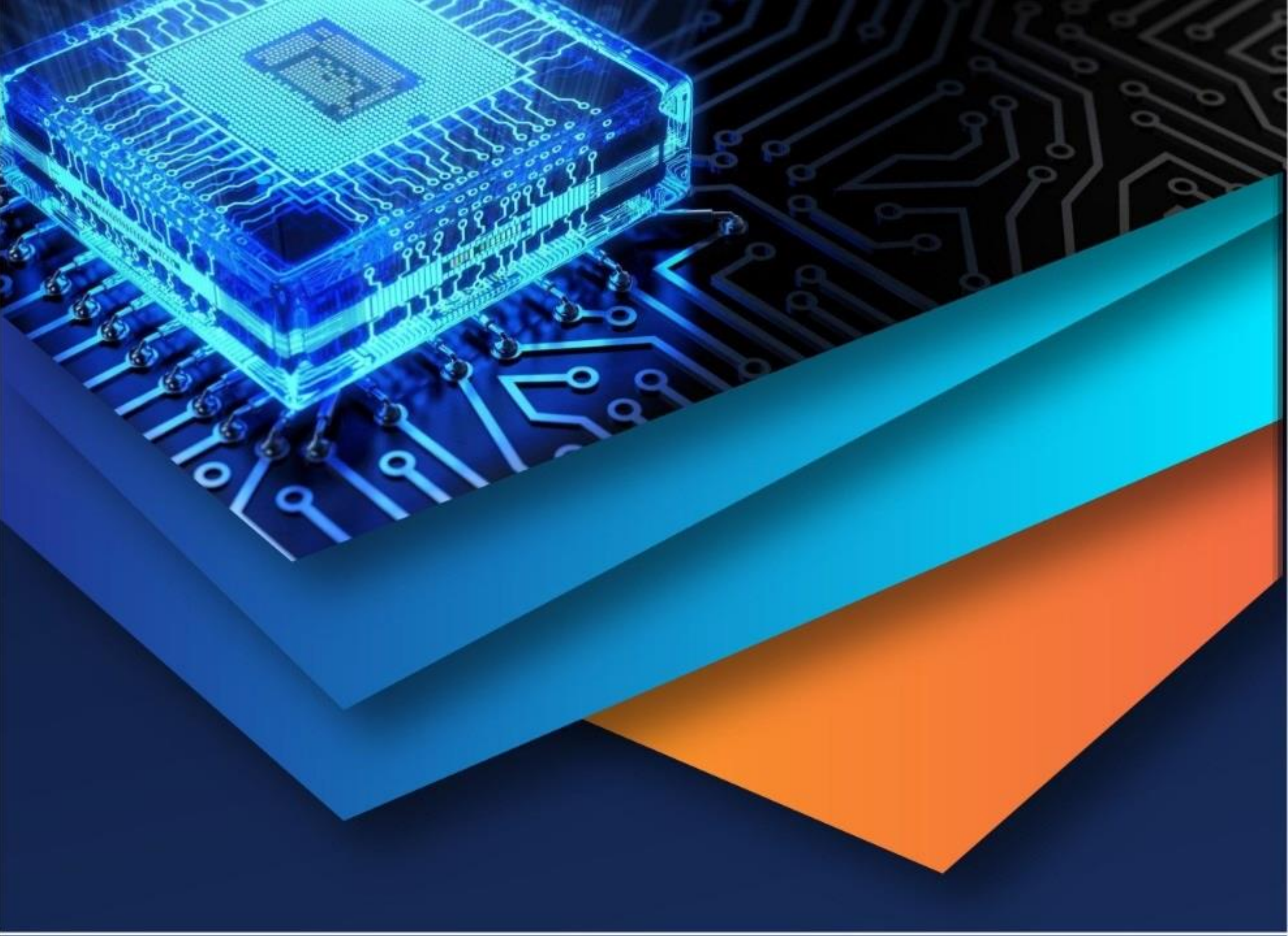

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