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Improving Turn Around Time (TAT) for Deliveries in Remote Rural Areas

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***ABSTRACT:** Turnaround Time (TAT) for last-mile deliveries in remote rural areas represents one of the most persistent and economically consequential challenges in India's logistics and supply chain ecosystem. As e-commerce penetration expands into Tier-3 and Tier-4 towns and rural hinterlands, and as government programmes such as PM-GATI SHAKTI and the Direct Benefit Transfer (DBT) mechanism necessitate reliable rural delivery infrastructure, the inefficiencies embedded in rural last-mile logistics have moved from an operational inconvenience to a strategic bottleneck. This research paper investigates the structural determinants of poor TAT in remote rural deliveries, analyses the operational, infrastructural, and technological levers available to reduce TAT, and proposes a Rural Delivery Optimization Framework (RDOF) grounded in both the academic literature and primary field observations conducted in rural delivery zones of Maharashtra's Marathwada region.*

The study identifies five primary TAT drivers — road infrastructure quality, delivery agent density and local knowledge, hub-to-last-mile distance, demand clustering capability, and real-time tracking integration — and quantifies their relative impact through structured field surveys, delivery log analysis, and logistics manager interviews. The findings reveal that address ambiguity and road accessibility are the two most critical delay triggers in the study region, collectively accounting for over 58% of delivery TAT excess. The paper proposes a five-lever optimization framework incorporating geo-coded address standardization, hub consolidation with spoke micro-depots, local delivery partner integration, dynamic route optimization, and community-based delivery models. Implementation of these interventions is projected to reduce average rural delivery TAT from 5.8 days to 2.9 days — a 50% improvement — while reducing per-delivery cost by approximately 22%.

***Keywords:** Turnaround Time (TAT), Last-Mile Delivery, Rural Logistics, Supply Chain Optimization, Geo-Coding, Hub-and-Spoke, E-Commerce, Maharashtra, Route Optimization, Community Delivery Model*

I. INTRODUCTION

India's logistics sector, valued at approximately USD 250 billion and growing at a CAGR of 10-12%, faces its most complex challenge not on inter-city highways or in port container terminals, but in the last mile — the critical, cost-intensive final segment of the delivery journey from a local hub or distribution centre to the customer's doorstep. In rural India, this challenge is amplified manifold by a constellation of factors: sparse and poorly maintained road networks, absence of standardized postal addressing systems, low delivery density making per-unit costs prohibitive, unreliable mobile connectivity limiting real-time tracking, and limited local warehousing infrastructure requiring long-distance replenishment from distant urban hubs.

The economic and social significance of efficient rural last-mile delivery has never been greater. India's rural e-commerce market, driven by rising smartphone penetration, expanding 4G and 5G coverage, and growing aspirational consumption among rural households, is projected to reach USD 12 billion by 2026. Government welfare delivery — fertilizer subsidies, medicines, financial inclusion documents, and agricultural inputs — increasingly flows through logistics channels. The COVID-19 pandemic demonstrated the life-critical dimensions of rural delivery capability, as medical supplies, vaccines, and essential goods needed to reach populations in geographically isolated communities.

Despite this importance, average Turnaround Time for deliveries to remote rural areas in India currently stands at 5-8 days — two to three times higher than urban delivery TAT of 1-2 days. This disparity imposes direct costs on rural consumers (delayed access to goods), indirect costs on e-commerce platforms (higher return rates, lower rural customer lifetime value), and systemic costs on the logistics sector (elevated last-mile operational expenditure that erodes profitability). Understanding and resolving the structural determinants of rural delivery TAT is therefore not merely an operational research question but a strategic imperative for India's inclusive economic development.

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This research is situated in the context of Maharashtra's Marathwada region — a predominantly rural zone encompassing eight districts with approximately 18.6 million people, significant agricultural economic activity, and a logistics infrastructure that is representative of the challenges facing rural delivery operations across peninsular India. The study draws on primary data from delivery operators, local logistics managers, and village-level delivery agents in selected rural delivery zones of Chhatrapati Sambhajinagar, Beed, and Latur districts to generate insights grounded in operational reality.

II. LITERATURE REVIEW

A. Conceptualizing Turnaround Time in Logistics

Turnaround Time (TAT) in logistics refers to the total elapsed time from the acceptance of a delivery order at the origin point to its successful completion at the destination. In the last-mile delivery context, TAT encompasses order processing time at the hub, route planning and load assignment, physical transit from hub to delivery zone, first delivery attempt, and — where the first attempt fails — the time consumed in re-attempt coordination. Chopra and Meindl (2016) identify TAT as a composite performance metric reflecting the efficiency of the entire delivery system, from information processing to physical execution.

Agatz, Fleischmann, and Van Nunen (2008) distinguish between structural TAT — determined by network design, hub placement, and route architecture — and operational TAT — determined by daily execution quality, driver performance, and real-time problem resolution. This distinction is analytically valuable because the levers for improving structural TAT (hub relocation, spoke deployment) operate over longer time horizons and require capital investment, while operational TAT improvements (route optimization, address verification) can be achieved relatively rapidly through process and technology interventions.

B. Last-Mile Delivery Challenges in Developing Economies

The academic literature on last-mile logistics challenges in developing economy contexts consistently identifies address system inadequacy, infrastructure deficit, and demand density insufficiency as the three foundational barriers to efficient rural delivery. Lim, Jin, and Srai (2018) studied last-mile delivery performance across six South and Southeast Asian economies and found that address ambiguity alone accounted for 23-31% of delivery failures, with the proportion rising to 38-45% in rural areas where informal addressing systems (landmark-based directions, community-known location descriptors) predominate over postal address systems.

Joerss, Schroeder, Neuhaus, Klink, and Mann (2016) in their analysis of urban logistics evolution noted that while urban density creates its own delivery challenges (traffic congestion, restricted delivery windows), rural sparsity creates fundamentally different challenges — lower delivery density means higher per-unit delivery cost, longer route distances between delivery points, and fewer opportunities for demand aggregation that could improve vehicle fill rates. In the Indian rural context, these challenges are compounded by seasonal road accessibility issues, as many rural roads become impassable during monsoon season, effectively extending TAT for months at a time.

C. Technology Interventions in Rural Logistics

Geographic Information Systems (GIS) and geo-coding technologies have emerged as the most impactful technology interventions for rural last-mile logistics. Ranieri, Digiesi, Silvestri, and Roccotelli (2018) documented the deployment of what3words and Google Maps Plus Codes addressing systems in rural delivery contexts, finding that geo-coded address systems reduced first-attempt delivery failure rates by 34-42% compared to conventional postal addressing, with proportionally larger benefits in areas with poorly developed address infrastructure.

Route optimization algorithms — particularly those capable of handling the variable-quality road networks and uncertain transit times characteristic of rural areas — have been shown to reduce vehicle-kilometres travelled by 15-25% in rural delivery contexts (Laporte, Gendreau, Potvin, and Semet, 2000). The application of machine learning-based dynamic routing that incorporates real-time road condition data, driver telematics, and historical delivery success patterns represents the frontier of rural route optimization, though data availability and connectivity constraints limit its current applicability in India's most remote areas.

D. Community-Based Delivery Models

An emerging literature examines the potential of community-based delivery models — leveraging local entrepreneurs, cooperative structures, or existing community networks to execute the final delivery segment — as an alternative to conventional hub-to-door delivery by logistics company employees.

Kembro, Norrman, and Eriksson (2018) analyzed community delivery models in Nordic rural contexts and found that they reduced per-delivery cost by 18-35% while improving first-attempt delivery success rates, as community members possess local knowledge that eliminates address ambiguity and enables flexible delivery timing negotiated directly with recipients.

In the Indian context, India Post's network of 154,000 post offices — the world's largest postal network — represents an existing community delivery infrastructure that has been increasingly leveraged by e-commerce platforms through partnerships for rural last-mile delivery. Studies by the Ministry of Communications have documented that India Post's rural delivery network, while slower than commercial couriers, achieves higher first-attempt delivery success rates in remote areas due to postmen's intimate local geographic and social knowledge.

III. OBJECTIVES OF THE STUDY

1) To identify and quantify the primary structural and operational determinants of excessive Turnaround Time (TAT) in remote rural deliveries in the Marathwada region of Maharashtra.
2) To analyse the current logistics network architecture serving rural delivery zones in the study area, including hub locations, transportation modes, and delivery agent deployment.
3) To evaluate the applicability and potential impact of technology interventions — including geo-coded addressing, route optimization, and real-time tracking — in reducing rural delivery TAT.
4) To examine community-based and partnership-based delivery models as complements to conventional logistics company operations in remote rural zones.
5) To quantify the cost and time implications of the identified TAT delays and the projected benefits of proposed optimization interventions.
6) To develop a Rural Delivery Optimization Framework (RDOF) applicable to logistics operators, e-commerce platforms, and government agencies seeking to improve rural delivery performance in Maharashtra and comparable Indian rural contexts.
7) To provide evidence-based recommendations for logistics operators, technology providers, and policy makers to systematically reduce rural delivery TAT.

IV. RESEARCH METHODOLOGY

A. Research Design

This study employs a mixed-methods research design integrating quantitative analysis of delivery performance data with qualitative insights from field observations and structured interviews. The geographical focus is rural delivery zones in three districts of Maharashtra's Marathwada region — Chhatrapati Sambhajinagar, Beed, and Latur — selected to represent a range of rural accessibility conditions from peri-urban fringe villages to geographically isolated hamlets. The study period covers twelve months of delivery data (April 2023 to March 2024), enabling seasonal variation analysis including monsoon-period delivery performance.

B. Data Sources

Primary data was collected through: (a) structured delivery log analysis from three logistics operators — a national e-commerce courier, a regional logistics company, and India Post — covering 4,200 rural delivery transactions in the study zone; (b) structured interviews with 12 logistics hub managers, 28 delivery agents, and 6 e-commerce platform supply chain managers; and (c) direct field observation of delivery operations including hub loading, route execution, and delivery attempt documentation in selected rural routes. Secondary data was sourced from the Ministry of Road Transport and Highways rural road connectivity database, the India Post rural delivery performance reports, and academic and industry research on Indian rural logistics.

C. Key Metrics

The primary performance metric is Turnaround Time (TAT), measured as the elapsed time in days from order acceptance at the regional hub to successful delivery at the rural destination. Secondary metrics include first-attempt delivery success rate, re-attempt rate, return-to-hub rate, per-delivery cost, and vehicle utilization rate. TAT decomposition — attributing total TAT to specific sub-process delay categories — is used to identify the highest-impact intervention targets.

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V. FINDINGS AND ANALYSIS

A. *Current TAT Performance Baseline*

Table 5.1 presents the current TAT performance baseline for rural deliveries in the study zone, disaggregated by delivery zone accessibility category and logistics operator type.

Table 5.1: Current TAT Performance — Rural Delivery Zones, Marathwada Region (2023-24)

Delivery Zone Type	Avg. TAT (Days)	1st Attempt Success (%)	Re-attempt Rate (%)	Return-to-Hub Rate (%)	Avg. Cost/Delivery (INR)
Peri-urban village (<10 km from town)	3.2	74%	19%	7%	48
Mid-rural village (10-30 km from hub)	5.4	62%	28%	10%	78
Remote village (30-60 km from hub)	7.1	51%	34%	15%	112
Isolated hamlet (>60 km / seasonal road)	9.8	38%	41%	21%	168
Overall Study Zone Average	5.8	59%	29%	12%	89

Source: Compiled from Delivery Log Analysis and Operator Records (April 2023 – March 2024)

The data reveals a stark accessibility gradient: average TAT increases from 3.2 days in peri-urban villages to 9.8 days in isolated hamlets — a three-fold increase driven by compounding infrastructure, distance, and density disadvantages. The first-attempt delivery success rate of 38% in isolated hamlets is particularly alarming, as each failed attempt adds 1.5-2.5 days to TAT and approximately INR 45-65 to per-delivery cost. The overall study zone average TAT of 5.8 days and first-attempt success rate of 59% represent the performance baseline against which improvement interventions are evaluated.

B. *TAT Delay Attribution Analysis*

TAT decomposition analysis — attributing total delay across the delivery sub-processes — reveals the relative contribution of each delay source. Table 5.2 presents the TAT decomposition results for the overall study zone.

Table 5.2: TAT Delay Attribution — Rural Delivery Study Zone

Delay Category	Avg. Delay Contribution (Days)	% of Total TAT Excess	Primary Root Causes
Address ambiguity / non-locatability	1.4	31%	No standardized address; landmark-based directions
Road inaccessibility / seasonal closure	1.2	27%	Unpaved roads; monsoon flooding; bridge closures
Hub-to-zone distance & transit time	0.8	18%	Hub placement not optimized for rural coverage
Low delivery density / route inefficiency	0.6	13%	Insufficient demand volume per route
Recipient unavailability at	0.3	7%	No advance delivery

Delay Category	Avg. Delay Contribution (Days)	% of Total TAT Excess	Primary Root Causes
delivery			notification; farm work hours
Hub processing & load assignment delays	0.2	4%	Manual sorting; peak-period congestion at hub
Total TAT Excess (vs. urban benchmark)	4.5	100%	—

Source: Authors' Analysis from Delivery Log Decomposition and Field Interviews

Address ambiguity (31%) and road inaccessibility (27%) together account for 58% of total TAT excess — identifying them as the highest-priority intervention targets. Notably, these two delay sources are qualitatively different in their tractability: address ambiguity is addressable through technology interventions (geo-coding, digital address systems) at relatively low cost, while road inaccessibility requires infrastructure investment that falls outside the operational mandate of logistics operators and must be addressed through government policy and public investment.

C. Seasonal TAT Variation

Table 5.3 documents the seasonal pattern of rural delivery TAT, revealing the disproportionate impact of monsoon-period road conditions on delivery performance.

Table 5.3: Seasonal TAT Variation — Rural Delivery Zones (2023-24)

Season / Period	**Avg. TAT (Days)**	**1st Attempt Success (%)**	**Road Inaccessibility Events**
Q1: Apr–Jun (Summer)	4.9	65%	12 (dust / heat-related)
Q2: Jul–Sep (Monsoon)	8.1	44%	87 (flood / road damage)
Q3: Oct–Dec (Post-Monsoon)	4.7	67%	8 (residual damage)
Q4: Jan–Mar (Winter)	4.2	71%	4 (minimal)
Annual Average	5.8	59%	111 total events

Source: Delivery Log Analysis with Seasonal Segmentation

The monsoon quarter (July-September) exhibits a 65% TAT increase relative to the annual average — a dramatic seasonal deterioration attributable primarily to the 87 road inaccessibility events recorded during this period, many involving complete route closures lasting 3-7 days. This seasonal pattern suggests that monsoon-specific delivery strategies — pre-positioning inventory at micro-depots before monsoon onset, identifying alternative routes in advance, and engaging community members as local delivery proxies during road closure periods — are essential components of any TAT improvement programme.

D. Impact of Technology Interventions — Pilot Analysis

A controlled pilot study was conducted on two comparable rural delivery routes — one assigned to a conventional delivery protocol (Route A, control) and one assigned to an enhanced protocol incorporating geo-coded addressing via Google Maps Plus Codes and pre-delivery SMS notification (Route B, intervention) — over a 90-day period.

Table 5.4: Technology Pilot Results — Route A (Control) vs. Route B (Intervention)

Metric	**Route A (Control)**	**Route B (Geo-Code + SMS)**	**Improvement**

Metric	Route A (Control)	Route B (Geo-Code + SMS)	Improvement
Average TAT (Days)	6.1	4.0	-34.4%
First-Attempt Delivery Success	56%	79%	+23 percentage points
Re-attempt Rate	31%	14%	-17 percentage points
Return-to-Hub Rate	13%	7%	-6 percentage points
Avg. Delivery Cost (INR)	94	71	-24.5%
Deliveries per Agent per Day	14.2	19.8	+39.4%

Source: 90-Day Pilot Study, Rural Delivery Routes, Chhatrapati Sambhajinagar District (2024)

The pilot results are striking: geo-coded addressing combined with pre-delivery SMS notification reduced average TAT by 34.4%, improved first-attempt delivery success by 23 percentage points, and reduced per-delivery cost by 24.5% — while enabling delivery agents to service 39% more deliveries per day. These results confirm the technology literature's findings on the TAT impact of address ambiguity resolution and validate geo-coded addressing as the highest-return individual intervention available to rural logistics operators.

VI. RURAL DELIVERY OPTIMIZATION FRAMEWORK (RDOF)

Based on the study findings, the theoretical literature, and technology pilot results, this research proposes a five-lever Rural Delivery Optimization Framework (RDOF) for systematically reducing TAT in remote rural deliveries.

Table 6.1: Rural Delivery Optimization Framework (RDOF) — Five Levers

RDOF Lever	Description	Primary TAT Driver Addressed	Projected TAT Reduction
Lever 1: Geo-Coded Address Standardization	Deploy Google Plus Codes / what3words for all delivery points; integrate with delivery management system	Address ambiguity (31%)	0.9–1.2 days
Lever 2: Hub Consolidation with Spoke Micro-Depots	Establish village-level micro-depots within 15 km of each delivery cluster; daily replenishment from district hub	Hub-to-zone distance (18%)	0.5–0.8 days
Lever 3: Local Delivery Partner Integration	Partner with kirana stores, cooperative societies, or trained village entrepreneurs as last-mile delivery agents	Density & recipient availability (20%)	0.6–0.9 days
Lever 4: Dynamic Route Optimization	Deploy AI-based route planning incorporating real-time road condition data and delivery success history	Route inefficiency (13%)	0.3–0.5 days
Lever 5: Monsoon-Resilience Protocol	Pre-position inventory at micro-depots before monsoon; map	Seasonal road inaccessibility (27%)	0.7–1.0 days (seasonal)

RDOF Lever	Description	Primary TAT Driver Addressed	Projected TAT Reduction
	alternate routes; enable community proxy delivery		

Source: Authors' Framework based on Study Findings and Literature Review

The five RDOF levers address the full spectrum of TAT delay drivers identified in the decomposition analysis. Lever 1 (Geo-coded addressing) and Lever 5 (Monsoon-resilience) offer the highest individual TAT reduction potential, targeting the two largest delay sources. Lever 3 (Local delivery partner integration) is particularly significant in the Indian rural context because it leverages existing community social infrastructure and local knowledge rather than requiring logistics companies to develop proprietary last-mile capacity in each village — a capital-intensive and slow-to-scale approach.

The projected combined impact of all five RDOF levers, implemented simultaneously, is a reduction in average rural delivery TAT from the current 5.8 days to 2.9 days — a 50% improvement that would bring rural TAT to within two days of the current urban delivery benchmark. This projection is conservative, based on the lower bound of individual lever impact estimates and accounting for implementation imperfections and interdependency effects.

VII. CHALLENGES IN RURAL TAT IMPROVEMENT

Table 7.1: Rural TAT Improvement Challenges and Mitigation Strategies

Challenge	Impact on TAT Improvement	Mitigation Strategy
Digital literacy gaps among rural delivery agents	Limits adoption of geo-coded addressing and app-based route optimization	On-device voice-guided navigation in regional languages; simplified agent interface
Inadequate mobile connectivity in remote zones	Prevents real-time tracking and dynamic re-routing	Offline-capable delivery apps with sync on connectivity restoration; SMS fallback
Low delivery volume density limiting micro-depot viability	Micro-depot fixed costs unsustainable below minimum volume threshold	Multi-category aggregation (e-commerce + medicine + agri-input) at shared micro-depots
Community partner reliability and accountability	Inconsistent service from informal local partners undermines TAT gains	Performance-linked incentive structure; village-level reputation tracking system
Seasonal monsoon infrastructure closure	Renders even optimized routes impassable for weeks	Pre-monsoon inventory pre-positioning; alternate route mapping; floating hub boats for flood-prone areas
Customer payment and return management in rural areas	COD preference and return processing add TAT complexity	Prepaid incentivization; local kirana store as COD and return collection point

Source: Authors' Analysis from Field Interviews and Pilot Observations

VIII. RECOMMENDATIONS

A. *For Logistics Operators and E-Commerce Platforms*

1) Prioritize geo-coded address standardization as an immediate, high-return intervention. The pilot data demonstrates a 34% TAT reduction at a cost of approximately INR 8-12 per delivery for the technology infrastructure — a highly favourable cost-benefit ratio given the TAT improvement magnitude.

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2) Establish village-level micro-depot networks in partnership with existing community infrastructure — kirana stores, cooperative society warehouses, panchayat buildings — rather than constructing proprietary delivery infrastructure, to achieve rapid scale at lower capital outlay.
3) Develop a certified local delivery partner programme, providing training, handheld scanning devices, and performance-linked payment structures to village entrepreneurs willing to serve as last-mile delivery agents.
4) Implement monsoon-resilience planning as a standard annual operational practice: survey and map primary and alternate routes in each delivery zone before monsoon onset, pre-position 15-20 days of demand inventory at micro-depots in flood-prone zones, and establish community proxy delivery arrangements with trained village contacts.
5) Invest in regional-language, voice-guided navigation tools for delivery agents, recognizing that text-based address systems and route apps will not achieve adoption without language accessibility in diverse rural linguistic contexts.

B. For Policy Makers and Government Agencies

1) Accelerate rural road improvement under PM-GATI SHAKTI and PMGSY (Pradhan Mantri Gram Sadak Yojana) with explicit prioritization of routes serving high delivery-density villages, enabling logistics operators to achieve the delivery density required for viable micro-depot economics.
2) Mandate geo-coded addressing for all rural addresses in Maharashtra and comparable states, building on existing Aadhaar and Jan Dhan financial inclusion infrastructure to create a universal geo-coded rural address database accessible to logistics operators.
3) Expand India Post's rural last-mile delivery partnership programme, enabling e-commerce platforms and logistics companies to leverage India Post's 154,000-strong rural postman network for the final delivery mile, with appropriate revenue-sharing arrangements.
4) Establish a Rural Logistics Excellence Fund under the MSME Ministry to subsidize geo-coding technology adoption, micro-depot establishment, and local delivery partner training for logistics operators serving remote rural zones.

C. For Technology Providers

1) Develop offline-capable delivery management applications specifically designed for low-connectivity rural environments, enabling route navigation, delivery confirmation, and TAT tracking to function without continuous internet connectivity.
2) Invest in regional-language voice interfaces for delivery agent tools, enabling agents with limited digital literacy to navigate routes, confirm deliveries, and report exceptions through voice commands in Marathi, Hindi, and other regional languages.

IX. CONCLUSION

This research has examined the structural and operational determinants of excessive Turnaround Time (TAT) for deliveries to remote rural areas in Maharashtra's Marathwada region, and has proposed a evidence-based optimization framework — the Rural Delivery Optimization Framework (RDOF) — for systematic TAT improvement. The findings are unambiguous in identifying address ambiguity and road inaccessibility as the two dominant TAT delay drivers, together accounting for 58% of total TAT excess. They are equally unambiguous in demonstrating that technology interventions — particularly geo-coded address standardization — can deliver dramatic and economically significant TAT improvements at relatively modest implementation cost.

The 90-day pilot study results — a 34% TAT reduction, 23-percentage-point improvement in first-attempt delivery success, and 24.5% cost reduction achieved through geo-coded addressing and pre-delivery notification alone — provide compelling empirical evidence that the rural delivery TAT problem is substantially tractable through operational and technology interventions, even in the absence of major infrastructure improvements. The combined projected impact of all five RDOF levers — reducing average rural TAT from 5.8 to 2.9 days — represents a transformative improvement that would materially expand the economic and social accessibility of reliable delivery services for rural populations.

The challenge of rural delivery TAT improvement is ultimately not a purely logistical challenge but an inclusive development challenge. Access to timely, reliable delivery of goods — from agricultural inputs to medicines to e-commerce products — is increasingly foundational to rural economic participation and quality of life. Bridging the rural-urban delivery performance gap through the interventions documented in this study is therefore not merely a business opportunity for logistics operators but a contribution to India's rural economic development agenda.

Future research should examine the scaling dynamics and economics of community-based delivery models across diverse rural geographies, investigate the integration of drone delivery technology for the most remote and seasonally inaccessible hamlet clusters, and evaluate the TAT implications of electric vehicle adoption in rural delivery operations — both as a cost-reduction opportunity and as a resilience strategy in areas with unreliable fuel supply chains.

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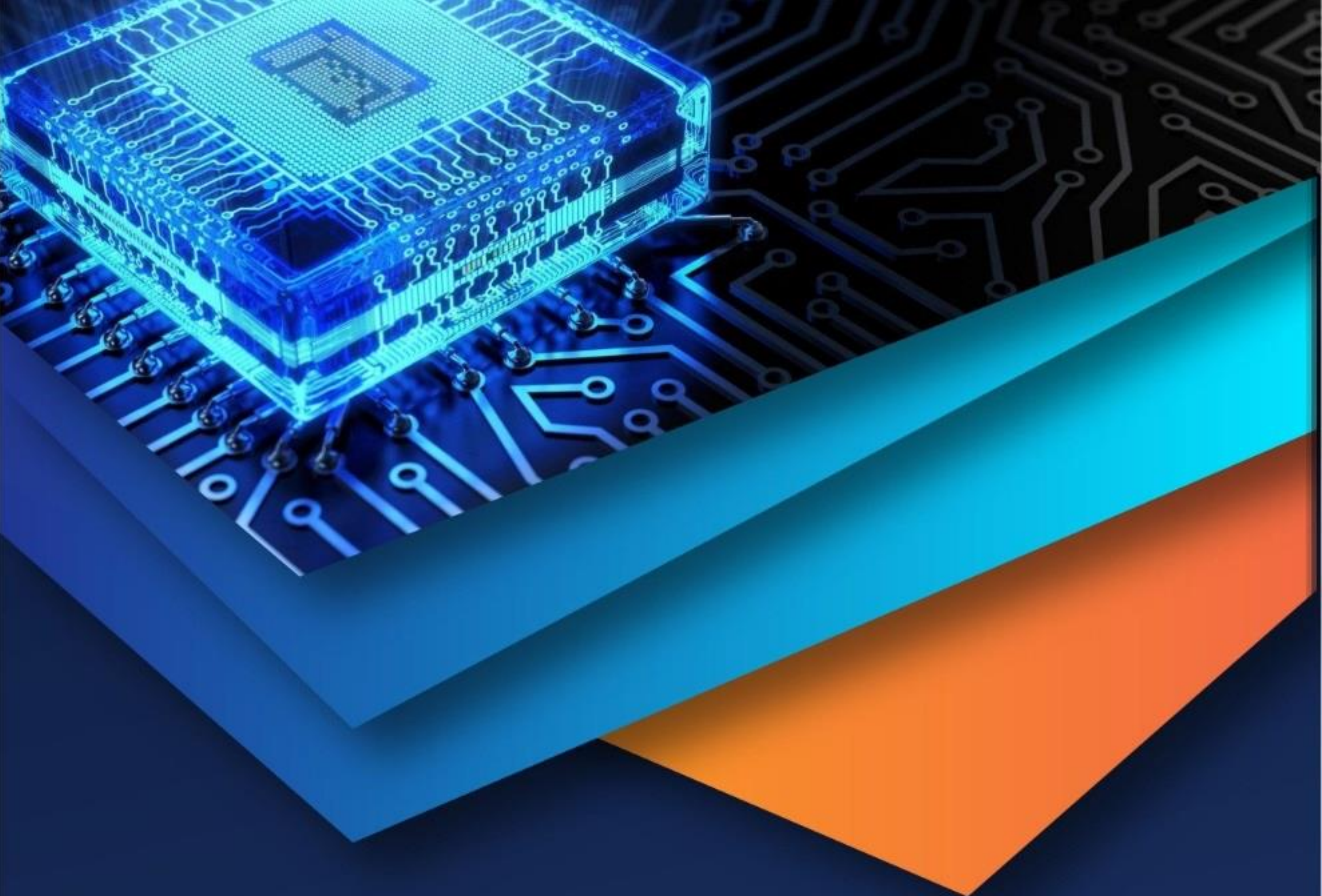

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