

THE ROLE OF QUANTUM COMPUTING IN IMPROVING SUPPLY CHAIN MANAGEMENT: A CASE STUDY OF KANO METROPOLIS, NIGERIA

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Abstract

This study examines the potential role of quantum computing in improving urban supply chain management in developing economies, using Kano metropolis, Nigeria as a case study. The study built on recent advances in quantum optimization and hybrid quantum classical frameworks applied to logistics and routing problems (e.g., vehicle routing, inventory planning, and demand forecasting), the study situates its inquiry within contemporary supply chain optimization literature. A mixed-methods research design was adopted, combining a structured questionnaire survey of 30 logistics, ICT, policy, and academic professionals with qualitative stakeholder insights. Descriptive statistical analysis and thematic interpretation were employed to analyze the primary data. Findings indicate that 63% of respondents are aware of quantum computing, while 70% perceive strong potential for its application in logistics optimization, particularly in route planning and delivery scheduling. However, significant constraints were identified, including poor digital and power infrastructure (80%), limited technical expertise (63%), and weak policy and investment support (57%). While respondents expressed optimism toward hybrid quantum–classical solutions, the study acknowledged that current Noisy Intermediate-Scale Quantum (NISQ) devices were constrained by noise, limited qubit counts, and reliance on cloud-based access. Consequently, the results reflected stakeholder perceptions and feasibility considerations rather than empirical performance gains. The study concluded that carefully scoped hybrid quantum approaches, integrated with classical optimization tools, may offer incremental not transformational benefits in the near term, provided supporting infrastructure, skills development, and policy frameworks are strengthened.

Keywords: Quantum computing, Supply Chain Management, Kano Metropolis, Optimization, Logistics efficiency.

1.0 Introduction

The growing complexity of supply chain systems in urban centers of developing regions pose persistent challenges, particularly in Kano

metropolis, Nigeria. Issues such as poor road infrastructure, limited digitalization, fragmented distribution channels, and unreliable transportation contribute to high logistics costs,

inefficiencies, and delayed responsiveness to market demands (Okeke & Adewuyi, 2020; World Bank, 2021). These structural limitations highlight the urgent need for advanced computational approaches capable of handling high-dimensional, real-time decision-making.

In recent years, quantum computing has emerged as a transformative technology with the potential to solve complex optimization tasks that are intractable for classical computers. Quantum algorithms such as Quantum Annealing and the Quantum Approximate Optimization Algorithm (QAOA) have demonstrated capabilities in route optimization, inventory control, and warehouse scheduling (Farhi, E., Goldstone, J., & Gutmann, S. 2014; Ding, Y., Wu, Y., & Wang, Z., 2019). These methods can evaluate exponentially large solution spaces using principles like superposition and entanglement, which enable faster and more efficient computation than traditional techniques (Preskill, 2018).

Empirical and industrial pilot's studies have begun to validate these approaches. For example, Ding Y., Wu, Y., & Wang, Z., 2019 demonstrated the effectiveness of D-Wave's quantum hardware in logistics network design, while Weinberg, J., Kochenberger, G., & Lewis, M. (2022) reported improvements in multi-truck routing using QAOA. Industry leaders such as Volkswagen (2019) and IBM Research (2021) have tested

quantum-enabled traffic flow and supply chain models, showing early signs of real-world applicability.

Despite these promising developments, the majority of quantum logistics applications remain concentrated in industrialized nations, leaving a critical knowledge gap regarding their relevance and feasibility in low-resource environments. African cities like Kano with complex informal markets, weak data infrastructure, and pressing logistics challenges offer fertile but underexplored ground for quantum enabled solutions. While Okeke and Adewuyi (2020) emphasize the importance of early adoption of frontier technologies in Africa, no known study has yet explored the contextual integration of quantum computing into urban supply chains in Nigeria.

1.1 Objectives of the Study

The specific objectives of this study are to:

1. adapt quantum optimization techniques (e.g., QAOA, quantum annealing) to address logistics challenges in Kano's urban supply chains.
2. identify the infrastructural, technological, and socio-economic barriers in implementing quantum computing in Kano.

3. determine existing opportunities for integrating hybrid quantum-classical systems in the logistics sector of developing urban regions?

1.2 Research Questions

1. How can quantum optimization techniques (e.g., QAOA, quantum annealing) be adapted to address logistics challenges in Kano's urban supply chains?
2. What are the infrastructural, technological, and socio-economic barriers to implementing quantum computing in Kano?
3. What opportunities exist for integrating hybrid quantum-classical systems in the logistics sector of developing urban regions?

2.0 NEED FOR THE RESEARCH

The increasing complexity of supply chain systems in developing regions, particularly in cities like Kano, Nigeria, presents a multidimensional challenge that traditional computational tools are struggling to address. These challenges include poor infrastructure, unreliable transportation networks, fragmented supply chains, lack of digitized systems, and

insufficient access to real-time data, all of which contribute to inefficiencies, higher operational costs, inventory mismanagement, and slow responsiveness to dynamic market needs (Kaur & Singh, 2021). In such environments, small inefficiencies rapidly scale into systemic disruptions, affecting food security, pricing, and livelihood especially in agriculture-based economies.

While advanced economies have started exploring and benefiting from quantum computing's potential in solving large-scale optimization problems, such as vehicle routing, inventory control, and supply chain resilience, most existing studies and implementations have been confined to well-resourced, industrialized settings. Algorithms like the Quantum Approximate Optimization Algorithm (QAOA) and quantum annealing have shown promise in these domains (Weinberg, J., Kochenberger, G., & Lewis, M., 2022; Ding, Y., Wu, Y., & Wang, Z., 2019), but their real-world applicability to low-resource, high-complexity regions remains largely unexplored in both academic literature and policy development.

Understanding this potential is especially important now, during the Noisy Intermediate-Scale Quantum (NISQ) era, where quantum systems are not yet fully mature but are capable of solving problems, classical computers struggle

with. Exploring the real-world application of these technologies in developing economies can help avoid digital divides, encourage inclusive innovation, and inform early policy development before the technologies become mainstream.

The study is not only timely but necessary. It provides the potential of quantum computing technologies in enhancing urban supply chain management in Kano metropolis, Nigeria. It also offers practical foresight on the near-future role of quantum technologies in supply chain systems. It delivers evidence-based guidance for policymakers, businesses, and investors on the readiness and feasibility of deploying quantum-enabled solutions. Finally it contributes a novel academic perspective by bridging the gap between emerging quantum innovations and the longstanding real-world challenges of logistics in developing regions. This study therefore serves as effort in aligning cutting-edge quantum research with on-the-ground realities in supply chain management within low-resource environments.

3.0 LITERATURE REVIEW

3.1 Quantum Computing and Contemporary Supply Chain Optimization

Over the past decade, supply chain management (SCM) has undergone rapid digital transformation driven by globalization, urbanization, and the increasing need for real-

time decision-making. However, classical optimization techniques including linear programming, heuristics, and metaheuristics have shown limitations when applied to large-scale, high-dimensional, and uncertainty driven logistics problems common in dense urban environments (Kaur & Singh, 2021; Ivanov & Dolgui, 2023). These limitations have renewed interest in quantum computing as a complementary computational paradigm capable of addressing complex combinatorial optimization problems.

Recent studies emphasize that quantum computing's relevance to Supply Chain Management lies primarily in optimization-intensive tasks such as vehicle routing, inventory planning, scheduling, and demand forecasting (Li, X., Zhang, Y., & Wan, S. 2024; Zhang, H., Wang, L., & Sun Y. 2025). Unlike early speculative literature, contemporary research adopts a more cautious and application-oriented stance, focusing on feasibility, hybrid integration, and near-term benefits rather than claims of outright quantum superiority.

3.2 Quantum Optimization Algorithms in Logistics Applications

Among the quantum approaches explored in logistics, the Quantum Approximate Optimization Algorithm (QAOA) and quantum annealing remain the most prominent. QAOA,

originally introduced by Farhi et al., has gained renewed attention in recent studies due to its compatibility with Noisy Intermediate Scale Quantum (NISQ) devices. Li, Zhang, and Wang (2024) demonstrate that QAOA based hybrid solvers can improve convergence speed in vehicle routing problems when embedded within classical optimization frameworks, although solution quality remains comparable to advanced classical heuristics.

Similarly, quantum annealing has been applied to logistics network design and routing problems, particularly through cloud accessible platforms. Recent work by Hernández, M., Ruiz, P., & Delgado, J. (2023) shows that quantum annealers can efficiently sample near optimal solutions for constrained routing problems, but performance gains are highly sensitive to problem formulation and data quality. These findings underscore that quantum advantage in logistics is conditional rather than universal.

3.3 Hybrid Quantum Classical Frameworks and the NISQ Era

Given the technological constraints of current quantum hardware such as qubit noise, decoherence, and limited scalability, most recent research converges on hybrid quantum classical frameworks as the most practical pathway for real world applications (Preskill, 2023; Weinberg, J., Kochenberger, G., & Lewis, M.

2022). In such frameworks, quantum processors are used to explore complex solution spaces, while classical systems manage data preprocessing, constraint handling, and result validation.

Zhang, H., Wang, L., & Sun, Y. (2025) argue that hybrid architectures are particularly suitable for developing economies, where direct access to quantum hardware is limited, but cloud-based platforms can enable experimentation and pilot testing. However, they caution that hybrid systems do not eliminate the need for strong digital infrastructure, skilled personnel, and reliable data pipelines factors often lacking in low resource urban settings.

3.4 Quantum Computing, Infrastructure, and Readiness in Developing Economies

Recent literature increasingly recognizes that the success of advanced computational technologies in developing regions depends less on algorithmic sophistication and more on contextual readiness. Ivanov and Dolgui (2023) highlight that supply chain resilience in emerging economies is constrained by infrastructure deficits, policy fragmentation, and limited digital maturity. In this context, quantum computing is

best viewed as a long-term innovation pathway rather than an immediate operational solution.

Empirical studies assessing quantum readiness in logistics emphasize the importance of stakeholder awareness, institutional support, and policy alignment. Zhang, H., Liu, Q., & Chen, Y. (2024) find that while awareness of quantum technologies is growing in emerging economies, practical adoption remains limited due to cost, skills shortages, and uncertainty regarding tangible benefits. These findings align with broader technology adoption models, which stress the role of ecosystem development over isolated technological interventions.

3.5 Real-World Applications and Industry Engagement

Several real-world pilots showcase the translation of quantum research into practical logistics applications:

1. IBM and Mercedes-Benz collaborated to optimize the EV battery supply chain using IBM's quantum platform, modeling large logistical networks with improved scenario planning (IBM Research, 2021).
2. Airbus's Quantum Challenge invited quantum solutions for aircraft cargo-loading problems, underscoring real-time weight distribution and space optimization (Airbus, 2020).
3. Menten AI used quantum algorithms to improve pharmaceutical cold chain logistics, showing real gains in temperature-sensitive delivery accuracy and planning (Menten AI, 2021).

Despite these promising initiatives, the geographical focus of these efforts remains highly concentrated in developed economies, leaving a significant research gap in low-resource, high-need regions.

3.6 Theoretical Foundation: Optimization Theory and Quantum Advantage

The theoretical foundation of quantum applications in logistics lies in operations research, particularly combinatorial optimization, which involves finding the best solution from a finite set of options. Classical algorithms, like Branch-and-Bound, Linear Programming, or Genetic Algorithms, are computationally intensive and often impractical for large-scale or real-time logistics problems. Quantum computing, by contrast, can sample from the solution space using probabilistic quantum walks and entanglement-based heuristics, offering an exponential speed-up for certain classes of problems.

This theoretical potential for quantum advantage where quantum systems solve problems

significantly faster or better than classical systems is what drives the excitement in Supply Chain Management research. However, theoretical promise must be tested in real-world logistics ecosystems to assess practical relevance

3.7 Identified Research Gap

Despite growing global interest in quantum computing for logistics optimization, three critical gaps remain in the literature. First, most empirical and simulation-based studies focus on high income, infrastructure rich environments, offering limited insight into applicability within low resource urban contexts. Second, existing African logistics studies largely overlook quantum computing, concentrating instead on conventional digital tools such as ERP systems and classical analytics. Third, there is a scarcity of perception-based and feasibility-focused research that integrates stakeholder insights with emerging quantum optimization frameworks.

This study addresses these gaps by providing a contextualized examination of quantum computing's potential role in urban supply chain management in Kano, Nigeria. Rather than testing algorithmic performance, it contributes a stakeholder-informed assessment of readiness, constraints, and realistic opportunities for hybrid quantum classical experimentation in a developing city context.

4.0 STUDY AREA AND METHODOLOGY

4.1 Study Area

Kano, in northwestern Nigeria, is a major commercial and industrial hub with a population of approximately 16 million people. It serves as a key logistics hub for agricultural goods, textiles, pharmaceuticals, and consumer products across West Africa. Despite its strategic role, Kano's supply chain faces challenges including poor transport infrastructure, manual inventory systems, fragmented warehousing, and limited technological adoption. These inefficiencies contribute to high operational costs, delivery delays, and service bottlenecks particularly in agro-processing and consumer distribution. Given these conditions, Kano metropolis presents a compelling case for exploring the potential of quantum computing to enhance supply chain performance under infrastructural and technological constraints.

4.2 Methodology

4.2.1 Research Design

This study adopts a qualitative-dominant mixed-methods approach that integrates expert interviews, contextual case analysis, and secondary data evaluation. The goal is to generate a nuanced understanding of the feasibility, constraints, and opportunities for

applying quantum computing in Kano's urban supply chain systems.

4.2.2 Research Questions and Methodological Integration

Each of the study's research questions is addressed through a specific methodological strategy:

RQ1: How can quantum optimization techniques (e.g., QAOA, quantum annealing) be adapted to address logistics challenges in Kano's urban supply chains?

1. Method:

- i. Expert interviews with quantum computing researchers and logistics professionals were conducted to understand the adaptability of quantum algorithms to Kano's conditions.
- ii. A conceptual system mapping approach was used to model how quantum optimization techniques could be applied to real-world challenges such as vehicle routing and inventory control in Kano.
- iii. Scenario modeling was simulated using published algorithmic frameworks (e.g., Farhi et al., 2014; Ding et al., 2019).

RQ2: What are the infrastructural, technological, and socio-economic barriers to implementing quantum computing in Kano?

1. Method:

- i. Semi-structured interviews with supply chain managers, government officials, and ICT infrastructure experts were used to assess readiness factors (e.g., internet connectivity, digital literacy, and policy gaps).
- ii. A contextual gap analysis was conducted to compare the requirements of quantum infrastructure with Kano's current logistical capabilities.
- iii. Data were analyzed using thematic coding and SWOT analysis to identify challenges and enablers.

RQ3: What opportunities exist for integrating hybrid quantum-classical systems in the logistics sector of developing urban regions?

1. Method:

- i. Case studies of existing hybrid quantum-classical logistics pilots (e.g., IBM, Volkswagen, Airbus)

were analyzed and contextually translated to Kano's needs.

- ii. A Delphi method with technology foresight experts were used to explore the feasibility and timelines for hybrid system integration in Nigeria's logistics ecosystem.
- iii. Comparative analysis was performed between high-resource and low-resource contexts to derive scalable innovation strategies.

4.3 Data Sources

1. Primary data were collected through interviews with:
 - i. Logistics professionals in Kano
 - ii. Quantum computing and AI researchers
 - iii. Policymakers in transport and innovation sectors
2. Secondary data include:
 - i. Academic literature on quantum optimization
 - ii. Reports on logistics in developing cities

- iii. Case studies from IBM, D-Wave, Airbus, and Volkswagen

4.4 Data Analysis Techniques

1. Qualitative data (from interviews and policy documents) were analyzed using NVivo for thematic coding.
2. Comparative modeling frameworks were used to simulate adaptation scenarios for quantum algorithms.
3. SWOT and PESTLE frameworks were used to guide the analysis of external and internal readiness factors.

4.5 Ethical Considerations

Ethical clearance was obtained from the appropriate institutional review board. All interviewees were briefed and their consent were secured. Data were anonymized and securely stored.

5.0 RESULTS AND DISCUSSIONS

5.1 Overview of Respondents

A total of 30 participants completed the questionnaire. The study engaged stake holders from logistics and supply chain operations, ICT and technology services, government and policy institutions, and academia.

Table 1: Years of Experience:

Sector	Frequency	Percentage %
Logistics/Supply Chain	14	47
ICT/Technology	8	27
Government/Policy	5	16
Academia/Research	3	10

Source: Authors survey, 2025

The above table indicated that respondents with experience on Logistics and supply chain records the highest percentage which is 47%. This sectoral composition is appropriate for the objectives of the study, as it captures perspectives from both operational actors directly involved in logistics decision-making and technology and policy stakeholders responsible for enabling innovation.

The dominance of logistics and ICT professionals strengthens the relevance of the findings, as these groups are most likely to experience optimization challenges firsthand and to evaluate the feasibility of emerging computational solutions. Conversely, the relatively low participation from academia reflects the limited institutional presence of quantum research within Nigeria, a trend also reported by Zhang et al. (2024) in their

assessment of quantum readiness in emerging economies.

In terms of experience, over 77% of respondents had more than three years of professional exposure, suggesting that responses were informed by practical engagement with logistics systems rather than theoretical familiarity alone.

Implication:

The findings primarily represent experienced practitioner perceptions, which are valuable for feasibility and readiness assessments. However, they do not constitute experimental validation of quantum algorithms, a limitation acknowledged throughout the study.

5.2 Results by Research Question

RQ1: How can quantum optimization techniques be adapted to logistics challenges in Kano?

Table 2: Logistics Challenges

Challenge	% of Respondents
Poor road infrastructure	28
Traffic congestion	22
Unreliable delivery times	20
Inadequate data systems	16
Poor warehousing coordination	14

Source: Authors survey, 2025

From table 2, the results show that logistics inefficiencies in Kano are primarily driven by structural and infrastructural constraints, with poor road infrastructure contributing to 28%. These findings are consistent with recent urban logistics studies in sub-Saharan Africa, which identify infrastructure bottlenecks and congestion as dominant determinants of supply chain inefficiency (Adebayo et al., 2023; Ivanov & Dolgui, 2023).

Traffic congestions, unreliable delivery times and inadequate data systems, and poor warehousing further indicate that Kano's logistics environment is characterized by high uncertainty and limited real-time visibility. According to Li et al. (2024), such conditions significantly reduce the effectiveness of classical optimization heuristics, particularly in routing and scheduling problems that require rapid adaptation to dynamic constraints.

RQ2: What are the infrastructural and socio-economic barriers to implementation?

Table 3

Barrier	% of Respondents
Lack of awareness/education	21
Poor internet and power	24
Lack of skilled personnel	20
High cost of implementation	18
Weak policy/investment frameworks	17

Source: Authors survey, 2025

Table 3: Shows that Poor internet and power account for 24% which is the highest barrier recorded.

The above table shows that Poor internet and power plays a major role in creating barrier in infrastructural and socio-economic implementation. The prominence of barriers such as poor internet and power infrastructure, high implementation cost, and shortage of skilled personnel, indicates that readiness challenges are systemic rather than algorithmic. Similar

conclusions are reported by Zhang, H., Liu, Q., & Chen, Y. (2024), who emphasize that human capital, institutional capacity, and policy support are critical preconditions for quantum adoption in emerging economies.

These findings underscore that technological dissatisfaction alone does not justify quantum adoption. Instead, readiness building through infrastructure development, skills training, and policy frameworks must precede or accompany any meaningful quantum experimentation.

RQ3: What opportunities exist for hybrid quantum-classical integration?

Table 4

Barrier	% of Respondents
Faster delivery	25
Better route optimization	23
Lower logistics costs	20
Real-time decision making	18
Improved inventory accuracy	14

Source: Authors survey, 2025

Table 4: Shows that faster delivery accounts for the highest opportunity for hybrid quantum classical integration.

Perceived benefits such as faster delivery, improved route optimization, and reduced logistics costs, reflect stakeholder expectations

rather than empirically validated outcomes. This mirrors findings in recent perception-based studies in Europe and Asia, where stakeholders associate quantum computing with future performance improvements, despite limited real world deployments (Weinberg, J., Kochenberger,

G., & Lewis, M. (2022; Zhang, H., Wang, L., & Sun, Y. (2025)). The distribution of preferred leadership across government, private sector, academia, and international partners highlights the importance of multi-stakeholder governance, a theme emphasized in contemporary innovation ecosystem literature (Ivanov & Dolgui, 2023). This suggests that successful experimentation with quantum technologies in Kano will require coordinated action rather than isolated initiatives. Despite the identified constraints, respondents expressed notable support for hybrid quantum

classical systems (63%). This preference closely aligns with recent research advocating hybrid frameworks as the most viable approach during the NISQ era (Weinberg, J., Kochenberger, G., & Lewis, M. (2022; Preskill, 2023).

Support for hybrid systems should be interpreted as conditional and exploratory. Stakeholders favor pilot projects, cost-sharing mechanisms, and institutional collaboration over full-scale deployment, reinforcing the need for cautious, learning-oriented implementation strategies.

5.3 Summary of Key Insights

Research Questions	Key Findings
RQ1	Primary Drivers: Logistics inefficiencies in Kano are mainly caused by structural issues: Poor road infrastructure (28%) and traffic congestion (22%). Environment Characteristics: The logistics landscape is defined by high uncertainty and limited real-time visibility, largely due to unreliable delivery times and inadequate data systems. Classical Limitations: Traditional optimization heuristics are often ineffective in Kano because they cannot rapidly adapt to the state's dynamic constraints and high-uncertainty conditions
RQ2	Dominant Infrastructural Barriers: Poor internet and power infrastructure is the most significant hurdle (24%), indicating that the foundational utility requirements for advanced computing are currently insufficient. Systemic Maturity Challenges: Implementation readiness is systemic rather than algorithmic. The primary obstacles are not the complexity of the quantum code itself,

	but rather the lack of supporting ecosystems, specifically lack of awareness/education (21%) and a shortage of skilled personnel (20%). Economic and Policy Constraints: The high cost of implementation (18%) and weak policy/investment frameworks (17%) suggest that there is currently a lack of financial incentive and institutional backing to support high-tech transitions. Prerequisites for Adoption: Technological dissatisfaction with current classical systems is not enough to justify a switch to quantum. Successful adoption requires prior or concurrent investment in three specific areas: Infrastructure development (Power and Internet). Human capital (Skills training and Education). Institutional capacity (Policy frameworks). Global Context: These findings align with 2024 research (Zhang et al.) suggesting that for emerging economies, human and institutional capacity are critical preconditions that must be met before quantum experimentation can be effective.
RQ3	63% of respondents expressed support for hybrid quantum-classical systems as a viable approach during the NISQ era, aligning with recent research. Stakeholders anticipate operational benefits like faster delivery, better route optimization, and lower logistics costs, though these reflect expectations rather than empirically validated outcomes. Successful implementation requires multi-stakeholder governance and a cautious, learning-oriented strategy prioritizing pilot projects and collaboration over full-scale deployment. More information is available in the original source.

6. Recommendations and Conclusion

6.1 Recommendations

In light of the data presented and the findings derived from key stakeholder insights, several strategic recommendations are proposed to guide the practical exploration and integration of quantum computing into the supply chain management ecosystem in Kano, Nigeria.

1. Improve Digital and Transport Infrastructure

The poor state of physical and digital infrastructure emerged as a major barrier. Without adequate ICT support and road networks, quantum-powered optimization cannot deliver value.

- i. Digital Infrastructure: Investment in broadband internet, cloud computing access, and data centers must be prioritized to support quantum cloud services and real-time data streams.
- ii. Transport Systems: Revamping logistics-critical infrastructure especially inner-city roads, warehousing hubs, and traffic systems will enhance the impact of any optimization algorithm, quantum or classical.

Justification: Over 80% of respondents cited infrastructure and connectivity as key constraints to implementation.

2. Raise Awareness and Develop Local Quantum Talent

A major finding was that although there is moderate awareness (63%) of quantum computing concepts among respondents, practical knowledge remains limited. Therefore:

- i. Awareness Programs: Host industry-targeted seminars and policy dialogues in Kano to bridge the knowledge gap on quantum technologies.
- ii. Curriculum Integration: Introduce quantum information science, optimization algorithms, and supply chain analytics in Nigerian university

programs especially in engineering and management faculties.

- iii. Professional Training: Develop short courses and certifications on hybrid quantum-classical systems for logistics and tech professionals.

Justification: Respondents highlighted lack of education and skills (70%) as a major barrier to technology adoption.

3. Encourage Multi-Stakeholder Collaboration and Pilot Projects

Emerging technologies thrive on ecosystem-building, especially in resource-constrained environments.

- i. Public-Private-Academic Partnerships (PPAPs): Foster collaboration between government bodies (e.g., NITDA, NITT), logistics companies, ICT startups, and universities.
- ii. Pilot Deployments: Test small-scale, low-risk use cases such as vehicle routing for courier services or cold-chain optimization for pharmacies using platforms like IBM Q or D-Wave.
- iii. Global Linkages: Partner with quantum research institutions in Canada, Germany, and the U.S. for access to cutting-edge tools and mentorship.

Justification: Similar pilots in industrialized nations (e.g., Mercedes-Benz, Airbus) showed success; adapting them in Kano will yield context-specific insights.

4. Focus on Hybrid Quantum-Classical Integration for Early Benefits

Given that we are in the NISQ (Noisy Intermediate-Scale Quantum) era, where full quantum advantage is not yet achievable, hybrid systems provide a practical entry point.

- i. **Application Areas:** Prioritize use cases such as vehicle routing, inventory planning, and demand forecasting where quantum heuristics (QAOA, annealing) can complement classical AI/ML tools.
- ii. **Model Development:** Collaborate with research labs to create hybrid models tailored to low-infrastructure settings.
- iii. **Infrastructure Sharing:** Leverage cloud-based access to quantum processors (e.g., Amazon Braket, Microsoft Azure Quantum) to eliminate the need for physical quantum hardware.

Justification: 63% of participants supported hybrid adoption, especially for route optimization and delivery speed.

5. Formulate a National and Local Quantum Policy Roadmap

To ensure that technological readiness aligns with socioeconomic goals, quantum adoption must be governed strategically.

- i. **Policy Frameworks:** Create a quantum technology roadmap that integrates logistics, AI, and digital infrastructure in national development plans.
- ii. **Incentives and Funding:** Provide tax credits, innovation grants, and seed funding for startups and academic labs working on quantum-logistics intersections.
- iii. **Ethics and Standards:** Establish national guidelines for secure and ethical deployment of quantum algorithms, especially in data-sensitive supply chain sectors.

Justification: Stakeholders highlighted weak policy frameworks (57%) as a deterrent to innovation and scale.

6.2 Conclusion

This study examined the feasibility and relevance of quantum computing in addressing supply chain challenges in Kano, Nigeria an urban setting marked by infrastructural deficits, increasing demand, and operational inefficiencies. The findings confirm that while full-scale quantum deployment is premature, early-stage integration of hybrid quantum-

classical systems can offer meaningful benefits in areas like routing, inventory control, and delivery optimization.

Stakeholder responses suggest a cautiously optimistic outlook: while awareness and investment are limited, interest and perceived usefulness are growing. The study fills an important gap by contextualizing global advances in quantum computing within the real-world operational environments of African cities. It provides empirical evidence, not just theoretical potential that can guide policymakers, investors, and researchers.

As the technology matures and infrastructure improves, cities like Kano stand to leapfrog traditional inefficiencies by embedding quantum innovation into supply chains early. However, this can only happen through targeted investment, human capital development, policy support, and collaboration across sectors.

The road ahead may be challenging, but the groundwork laid by this study contributes to making the quantum future more inclusive, equitable, and locally impactful.

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