



# Leveraging Quantum Technologies in Transport - A Strategic Literature Review

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**Abstract.** The rapid evolution of quantum technologies presents transformative opportunities for various industries, including the transport sector. As global supply chains grow increasingly complex and data-driven logistics become central to operational efficiency, quantum computing and quantum communication are emerging as potential enablers of next-generation transport systems. This research explores the intersection of quantum innovation and transportation, with a focus on enhancing efficiency, security, and decision-making processes in logistics and mobility. The study adopts a qualitative methodology grounded in an extensive literature review of scholarly publications, industry reports, and policy papers from the past decade. Sources were selected based on their relevance to quantum applications in transportation, including routing optimization, traffic flow prediction, secure communications, and fleet management. The review framework categorizes insights according to technological readiness, practical implementation, and strategic value in the transport sector. Findings from the literature suggest that quantum computing holds significant promise for solving large-scale optimization problems, such as dynamic route planning and freight allocation, which are currently limited by classical computational methods. Additionally, quantum key distribution (QKD) is highlighted as a secure communication solution for protecting sensitive data in autonomous and connected transport systems. Although real-world applications remain limited, pilot studies and simulations indicate measurable improvements in processing speed and security protocols. This research underscores the potential of quantum technologies to redefine competitive advantage in the transport sector. By integrating quantum solutions into existing digital infrastructure, companies may achieve faster, more secure, and more sustainable transport operations. The findings also call for interdisciplinary collaboration and proactive policy support to bridge the gap between theoretical potential and practical deployment.

## 1. Introduction

The rapid growth of global transportation and logistics systems has led to increasingly complex operational challenges that demand advanced optimization strategies.

Among the most pressing problems are dynamic route planning and freight allocation, both of which involve large-scale combinatorial decision-making under time-sensitive and uncertain conditions. Traditional, classical computing methods, while effective for small to moderately sized datasets, struggle to provide real-time, high-quality solutions as problem scales grow



exponentially. This computational bottleneck impairs efficiency, inflates operational costs, and limits the adaptability of modern transport infrastructures.

Quantum computing has emerged as a disruptive technology capable of addressing these limitations through fundamentally new paradigms of information processing. By leveraging quantum phenomena such as superposition or entanglement, quantum computers can exploit quantum interference to increase the probability of good solutions in certain classes of problems. This parallelism offers significant advantages in solving combinatorial optimization problems, which are common in logistics, scheduling, and route planning. The field advanced rapidly with the introduction of the BB84 quantum key distribution protocol by Bennett and Brassard in 1984, which demonstrated how quantum mechanics could be used to achieve provably secure communication [1]. Subsequent experimental work carried out in 1989 and later published by Bennett et al. demonstrated the practical feasibility of the BB84 protocol over short distances [2]. In the 1990s and 2000s, quantum communication systems progressed from laboratory setups to fiber-based and satellite-based demonstrations, including long-distance QKD networks in Europe, China, and North America. Notably, China's Micius satellite, launched in 2016, marked the first successful quantum communication between space and Earth, representing a pivotal milestone in achieving global-scale quantum-secure networks [3]. Quantum communication has evolved from a theoretical curiosity into a practical field with far-reaching implications for secure data exchange, particularly in areas such as financial services, government communications, and intelligent transportation systems. Its foundations were laid with the development of Bell's theorem in 1964, which introduced the concept of non-local correlations and quantum entanglement [4]. This was followed by the no-cloning theorem, which established that unknown quantum states cannot be perfectly copied, a critical principle for secure communication [5].

This historical trajectory underlines how quantum communication has transitioned from theory to application, setting the stage for its integration into mission-critical infrastructure, such as secure vehicle-to-infrastructure communication, logistics tracking, and transportation data integrity systems.

As shown in Figure 1, the historical timeline of quantum communication represents how early conceptual insights matured into one of the most transformative technological fields today.

In this paper was applied a qualitative methodology grounded in an extensive literature review of scholarly publications, industry reports, and policy papers from the past decade.



**Figure 1.** Timeline of quantum communication



Sources were selected based on their relevance to quantum applications in transportation, including routing optimization, traffic flow prediction, secure communications, and fleet management. The review framework categorizes insights according to technological readiness, practical implementation, and strategic value in the transport sector context.

## **2. Literature review**

Quantum computing holds significant promise for solving large-scale optimization problems, such as dynamic route planning and freight allocation, which are currently limited by classical computational methods. The paper of [6] explores the integration of quantum computing and blockchain technology to develop a quantum blockchain network architecture tailored for transportation services. By merging quantum principles such as superposition and entanglement with the security and decentralization of blockchain, the proposed framework aims to address key challenges in the transportation sector, including data security, transaction speed, and scalability.

Quantum algorithms, particularly quantum-inspired solutions, are being applied to transportation challenges like shortest-path and traffic flow problems. For example, companies like D-Wave have piloted real-world applications such as dynamically optimizing bus routes to reduce congestion and improve scheduling efficiency [7].

Quantum computing frameworks are being developed to handle complex logistics tasks, such as the Capacitated Vehicle Routing Problem. These methods have shown improvements in circuit performance on real quantum devices, making them suitable for future freight and delivery optimization at scale [8].

Scientometric reviews of Quantum Enhanced Intelligent Transportation Systems (QEITS) highlight quantum algorithms as critical for tasks like smart vehicle routing, energy-efficient scheduling for electric vehicles, and adaptive traffic signal control. Using data from Web of Science and Scopus, it maps publication trends, co-citation networks, and emerging topics to guide future research and innovation in QEITS [9]. Transport companies are exploring how to leverage quantum cryptographic protocols to enhance the security and efficiency of communication systems in transport operations. These include secure data exchange, smart contracts for automated services, and resilient logistics networks.

In Figure 2 are represented several trends in quantum communication sector. Recent advances in quantum algorithms, such as the Quantum Approximate Optimization Algorithm and quantum annealing, have demonstrated promising results in applications like the Capacitated Vehicle Routing Problem, real-time traffic optimization, and supply chain management. Moreover, hybrid quantum-classical approaches, implemented on near-term quantum devices, are already showing performance benefits over classical heuristics in select benchmark scenarios. These innovations are driving a paradigm shift in how transportation systems may be optimized in the coming decades.

The rise of Quantum Enhanced Intelligent Transportation Systems shows a trend toward using quantum technologies—including communication—for secure, efficient management of vehicle connectivity, traffic flow, and electric vehicle coordination. Enterprises, especially telecom and transport tech providers, are preparing for the post-quantum era by developing quantum-resistant secure communication networks for optical data transport. This includes cryptographic agility and disaggregated encryption control.

### 3. Methodology

The methodology of this paper consists of a comparative statistical analysis of quantum communication research published in two major scientific databases: Web of Science Collection and IEEE Xplore in order to identify if the exponential growth of quantum communication as a research field reflects the increasing development and interest of society and economic sectors on quantum communication applications.

The quantum communication scientific literature statistics is analysed in terms of its implications for research trends, interdisciplinary connections and historical context.

The differences between Web of Science and IEEE Xplore databases highlight the diverse academic and industrial contributions of quantum technologies.

By the end of 2024, in the Web of Science Collection were registered approximately 52.434 articles on the topic of “quantum communication”, most of them being on Optics topic (19090), Engineering Electrical Electronic (13787) and Applied Physics (11618). In IEEE Xplore database were published 33,296 scientific documents (articles) related to quantum communication between 1948 – end of 2024, with the oldest being a journal paper on quantized signals published in 1948 by Bell Telephone Laboratories (today Nokia Bell Labs). This paper is a precursor in the field of signal quantization. While not directly related to modern quantum mechanics, the article reflects early interest in quantization, providing a conceptual bridge to modern quantum communication. We can also observe the evolution of the field. The timeline reflects how the field transitioned from theoretical foundations to practical implementations. Quantum communication, as we previously stated, it began with Stephen Wiesner’s proposal of quantum money (1983) [10] and the development of the BB84 protocol (1984) [1].

The reported number of published scientific literature in two of the main scientific database was 52,434 articles in the Web of Science and 33,296 documents in IEEE Xplore, highlighting the exponential growth of quantum communication as a research field. Quantum communication has



**Figure 2.** Trends in quantum communication

grown substantially, especially in the last few decades, reflecting the increasing feasibility of experimental quantum communication systems (e.g., quantum key distribution, satellite-based quantum networks) and the rising interest from governments and industries due to potential applications in cybersecurity, secure communication, and computing.

The oldest publication in IEEE Xplore, a 1948 journal paper on quantized signals by Nokia Bell Labs, underscores the historical roots of quantum communication in the broader study of quantization [11]. This paper likely laid foundational ideas that evolved into quantum information theory. The Web of Science Categories reveal the interdisciplinary nature of quantum communication, with the highest number of articles in Optics, followed by Engineering Electrical Electronic, and Applied Physics.



**Figure 3.** Visualization of Web of Science Core Collection topics related to quantum communication and the number of published papers. Source: author’s study

The dominance of optics in Figure 3 suggest the central role of photons in quantum communication. Technologies like quantum key distribution (QKD) and quantum networks rely heavily on optical fibers and free-space optical systems. This trend underscores the importance of advances in laser technology, single-photon sources, and detectors in enabling quantum communication. The strong representation in electrical and electronic engineering highlights the integration of quantum systems with classical communication infrastructure. This suggests ongoing efforts to develop scalable and robust hardware for quantum communication, such as quantum repeaters, modulators, and integrated photonic circuits, while the significant number of articles in applied physics reflects the foundational experimental and theoretical work driving the field. The difference in publication numbers between the Web of Science (52,434) and IEEE Xplore (33,296) can be attributed to database scope and publication focus. Web of Science includes a broader range of journals across multiple disciplines, many of them theoretically approached, while IEEE Xplore focuses on engineering, computing, and technology-related publications. IEEE Xplore documents may lean more toward practical and applied aspects of quantum communication, such as hardware development and implementation strategies.

The statistics on quantum communication publications reflect an interdisciplinary, and rapidly growing field with significant implications for technology, economics, and society. The rise in publications corresponds with national quantum initiatives (e.g., China's quantum satellite Micius, the EU Quantum Flagship, and the US National Quantum Initiative), underscoring the strategic importance of the field. However, sheer volume does not always indicate impactful



research. Metrics like citation counts, journal impact factors, and practical implementations provide a more nuanced view of the field's progress.

In order to envision and comprehend the diverse applications of quantum communication scientific approach, in the figure 3 above, extracted from Web of Science Core Collection, are represented 25 topics related to quantum communication where authors have published between the number of published papers 1975-2024. The dominance of optics, engineering, and applied physics highlights the foundational and applied nature of the research.

#### **4. Conclusion**

This paper has examined the evolution and scope of quantum communication research through a comparative statistical analysis of publications indexed in the Web of Science Core Collection and IEEE Xplore. The findings underscore the exponential growth of the field, with over 52000 articles indexed in the Web of Science and more than 33000 documents in IEEE Xplore by the end of 2024. This growth reflects the increasing relevance of quantum communication across academic, industrial, and governmental sectors.

The analysis reveals that quantum communication is a distinctly interdisciplinary domain, advancing rapidly through applied research in optics, electrical and electronic engineering, and computer science. The dominance of optics followed by engineering and applied physics emphasizes the central role of photonic technologies in enabling quantum networks, quantum key distribution, and secure communication infrastructures.

Quantum communication is positioned as a strategic area of innovation, with implications for cybersecurity, national defense, and future quantum internet infrastructure. While the volume of publications offers one metric of growth, future studies should integrate citation analyses, impact factors and translational outcomes to assess the true influence and maturity of the field. The integration of quantum software for logistics and supply chain optimization could revolutionize global trade and transport coordination. Similarly, economic modeling of quantum transport systems is needed to forecast investment impacts, cost-efficiency thresholds, and infrastructure scalability. These models would bridge quantum research with practical deployment scenarios in industry and urban planning.

Moreover, the ethical, legal, and social implications of quantum communication systems require deeper examination. Issues such as quantum-enabled surveillance, data sovereignty, and the geopolitical imbalance of quantum technology access must be critically addressed through interdisciplinary frameworks that integrate ethics, law, and public policy.

In conclusion, the bibliometric patterns and historical evolution analyzed in this study affirm that quantum communication is a critical enabler of next-generation technologies. To guide its responsible and equitable growth, the research community must now look beyond foundational physics and explore cross-cutting domains such as software integration, economic impact, and ethical governance.

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