

# Potential of Quantum Computing in Information Systems

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**Abstract** - Quantum computing is a groundbreaking technology that could revolutionize how we process data. It promises faster computations, which could help solve complex problems in areas like optimization, data encryption, and machine learning. This paper looks at the current research on how quantum computing could affect information systems (IS), with a focus on areas like cybersecurity, AI, and business technology. While the potential is huge, the technology is still in its early stages. The paper also discusses the challenges in adopting quantum computing and points out the areas that need further research.

**Key Words:** Quantum Computing, Information Systems, Machine Learning, Cybersecurity, Optimization, Quantum Cryptography

## 1. INTRODUCTION

Quantum computing can change how we solve complex problems in information systems (IS). At its core, quantum computing relies on the principles of quantum mechanics—the science that explains how things behave at the smallest scales, like atoms and particles. Unlike traditional computers, which use bits to represent data as either a 0 or a 1, quantum computers use qubits. Qubits are special because they can represent both 0 and 1 at the same time, thanks to a property called superposition. This allows quantum computers to handle many possibilities simultaneously, making them potentially much more powerful than classical systems when solving certain types of problems. The potential of quantum computing to revolutionize fields such as optimization, machine learning, and data security has caught the attention of researchers and businesses alike. For instance, tasks that involve sifting through huge datasets, optimizing complex systems, or breaking and creating cryptographic codes could be done much more efficiently with quantum computers. This is why there's so much buzz about how quantum technology could transform industries, from healthcare and finance to IT services and cybersecurity. Quantum computers are costly to develop, and the specialized workforce needed to operate them is currently lacking. These factors mean that we're still a few years away from seeing quantum computing used widely in everyday business systems. However, there are already signs that quantum computing will play an important role in shaping the future of information systems. For example, companies like IBM, Google, and Microsoft are not just conducting

research, but also creating platforms that allow businesses to experiment with quantum algorithms through the cloud.

This paper aims to explore how quantum computing can impact different areas of information systems, particularly in machine learning, cybersecurity, and business ecosystems. We'll review existing research and examine the key challenges and opportunities that come with adopting this technology. In addition, we'll look at the socio-technical implications, focusing on how quantum computing could affect business models, IT infrastructures, and even the way companies and employees approach the future of technology. While the disruptive potential of quantum computing is clear, overcoming the obstacles to practical implementation will be crucial. This paper will not only highlight the current state of quantum computing, but also suggest important areas for future research that can help accelerate its adoption and overcome existing hurdles.

## 2. QUANTUM COMPUTING OVERVIEW

Classical computing relies on bits that can represent either 0 or 1, performing computations based on binary logic. In contrast, quantum computing uses qubits, which can exist in multiple states simultaneously through superposition, allowing quantum computers to handle complex problems much faster and solve optimization problems, simulate molecular interactions, and process large datasets exponentially quicker.

**Table -1:** Classical vs Quantum Computing Comparison

Feature	Classical Computing	Quantum Computing
Data Storage	Bits (0 or 1)	Qubits (superposition of 0 & 1)
Processing Power	Limited by classical circuits	Exponentially faster with quantum gates
Parallelism	Limited (one operation at a time)	Massive parallelism due to superposition
Key Principle	Boolean logic and binary operations	Quantum mechanics (superposition, entanglement)

## 2.1 Superposition: The Power of "Both At Once"

In regular computers, information is stored in bits, which can either be 0 or 1. But quantum computers use qubits, and here where things get interesting. A qubit can be both 0 and 1 at the same time! This is called superposition. Imagine flipping a coin. While it's in the air, it's both heads and tails at the same time. When it lands, it picks one side, but before that, it could be in both states. This ability allows quantum computers to do many calculations at once, making them super-fast for certain problems (Nielsen & Chuang, 2000) [12].

## 2.2 Entanglement: Instant Connections

Another feature of quantum computers is something called entanglement. When two qubits are entangled, changing the state of one qubit instantly changes the state of the other, even if they're far apart—like, light-years away! It's like having two dice that are connected: if you roll one and it shows a 3, the other one will automatically show a 3, no matter how far away it is. This means quantum computers can solve problems in a way that regular computers can't, because they can process information more effectively and in parallel (Bennett & Wiesner, 1992) [2].

## 2.3 Interference: Fine-Tuning the Right Answer

Quantum interference is a little like tuning a radio device. In a quantum computer, as it works through calculations, it can make some results stronger and others weaker, which helps it find the correct answer faster. Think of it like narrowing down possibilities in a huge maze: quantum computers use interference to zoom in on the solution more efficiently (Farhi et al., 2014) [4].

## 2.4 Quantum Gates Algorithms: The Instructions

Just like regular computers use logical gates (like AND, OR, NOT) to process information, quantum computers use quantum gates. These gates are used to manipulate qubits, turning them into different states, and they help quantum algorithms (instructions for the computer) perform tasks. For example, Shor's Algorithm can factor large numbers much faster than classical computers, which is a huge deal for things like encryption and cybersecurity (Shor, 1997) [15].

## 2.5 Quantum Speedup: Solving Problems Fast

The biggest promise of quantum computing is its speed. For certain problems, quantum computers could provide solutions that would take traditional computers millions of years to solve, in just a few minutes or hours. This is because quantum computers can consider many different possibilities all at once (thanks to superposition), rather than one by one like classical computers (Grover, 1996) [7].

## 2.6 Challenges: Keeping Things Stable

Quantum computing is still in the early stages, and one of the biggest challenges is something called quantum decoherence. This happens when qubits lose their special quantum state because they interact with their environment (like heat, light, or even vibrations). To make quantum computers work for real-world problems, scientists are developing techniques to protect the qubits from these outside influences. This is called quantum error correction, and it's much more complicated than what we use in classical computers (Nielsen & Chuang, 2000) [12].

## 3. LITERATURE REVIEW

This section provides an in-depth review of various aspects of information systems (IS), including machine learning, cybersecurity, business ecosystems, and IT services.

### 3.1 Quantum Computing and Information Systems

The potential for quantum computing to transform information systems lies primarily in its ability to solve complex optimization and simulation problems that classical computers struggle with. At its core, quantum computing leverages quantum bits (qubits) which, unlike classical bits, can exist in multiple states simultaneously due to superposition. This property allows quantum computers to process a vast number of possibilities in parallel. This has direct implications for solving problems related to logistics, supply chains, and financial modelling (Nielsen & Chuang, 2000) [12].

Quantum algorithms, such as Grover's search algorithm, provide significant improvements over classical algorithms in specific areas like database search and optimization (Grover, 1996) [7]. This has made quantum computing particularly attractive to the IS community, as it holds the potential to address challenges like resource allocation, scheduling, and large-scale data analysis. However, practical quantum systems that can outperform classical counterparts are still in their infancy, and current quantum computers are mostly in the experimental stage (Carrel-Billiard et al., 2021) [3].

### 3.2 Quantum Computing in Machine Learning and AI

Quantum computing also has the potential to revolutionize machine learning (ML) and artificial intelligence (AI), which are central to modern information systems. The promise of quantum-enhanced machine learning (QML) lies in its ability to speed up computations that are typically bottlenecked in classical systems. For example, quantum computers can potentially accelerate matrix operations and feature extraction processes, which are key components of training machine learning models (Biamonte et al., 2017) [1].

Researchers have shown that quantum algorithms could provide an exponential speedup for certain machine learning tasks, such as matrix inversion, which is crucial in algorithms like support vector machines (Gao et al., 2018) [5].

Quantum computers may also play a role in optimizing machine learning models through quantum annealing, a method that can find the minimum of a cost function more efficiently than classical optimization methods (Farhi et al., 2014) [4]. In areas like neural network training and clustering, quantum algorithms may outperform classical counterparts by processing large datasets in less time. This holds particular promise for industries dealing with large-scale data, such as finance, healthcare, and logistics, where processing efficiency is crucial (Gao et al., 2018) [5].

### 3.3 Quantum Computing in Cryptography and Cybersecurity

One of the most widely discussed applications of quantum computing is in the field of cybersecurity. On one hand, quantum computers have the potential to break traditional encryption schemes. For instance, Shor's algorithm allows quantum computers to factor large numbers exponentially faster than classical algorithms, which would make RSA encryption, the backbone of most secure online communications, obsolete (Shor, 1997) [15]. This has created significant concern over the future security of digital systems, as the risk of quantum computers cracking widely-used encryption protocols is a critical issue for organizations worldwide (Lutkenhaus, 2001) [10].

On the other hand, quantum computing can also enhance cybersecurity by introducing new methods for securing data, such as quantum key distribution (QKD). QKD uses the principles of quantum mechanics to ensure that communication is secure, even in the presence of eavesdroppers. Since any attempt to intercept a quantum-encrypted message changes its state, quantum encryption methods can theoretically offer unbreakable security (Bennett & Wiesner, 1992) [2]. In addition, post-quantum cryptography focuses on developing encryption methods that are resistant to quantum attacks, ensuring the long-term security of sensitive information (Gartner, 2019) [6].

### 3.4 Quantum Computing Ecosystems and Business Models

As quantum computing matures, it is expected to foster the creation of new ecosystems involving hardware manufacturers, software developers, service providers, and academic institutions. For instance, companies such as IBM, Google, and Microsoft are making significant strides in quantum computing, offering cloud-based quantum services that enable businesses to explore quantum algorithms without needing to invest in costly hardware (Müller et al., 2019) [11]. These ecosystems will be characterized by a

collaborative network where businesses, governments, and academia work together to drive technological development and innovation.

In particular, quantum computing could revolutionize the business models of industries that rely heavily on computational power. For example, industries in logistics, pharmaceuticals, and finance could benefit immensely from quantum technologies, allowing them to perform complex simulations and optimizations that were previously too computationally expensive. However, for quantum computing to be widely adopted, organizations will need to integrate quantum solutions into their existing IT infrastructures, which could involve significant restructuring of business operations (Carrel-Billiard et al., 2021) [3].

### 3.5 Challenges and Barriers to Adoption

Despite the immense potential of quantum computing, there are significant challenges that must be addressed before the technology can be widely adopted in information systems. One of the primary hurdles is the high cost associated with developing and maintaining quantum hardware. Current quantum computers are expensive to build and operate, and they require extremely precise conditions, such as very low temperatures, to function effectively (Hughes et al., 2022) [8].

Another critical challenge is the lack of skilled professionals. Quantum computing requires deep knowledge of quantum mechanics, linear algebra, and computer science, creating a gap in the workforce that is hindering the widespread adoption of quantum technologies (Hughes et al., 2022) [8]. As quantum technologies advance, there will be an increasing demand for professionals who can bridge the gap between the theoretical foundations of quantum computing and practical applications in information systems.

Lastly, the complexity of quantum algorithms makes it difficult for businesses to adopt quantum solutions without a strong understanding of both the technology and the specific business problems they aim to solve. The steep learning curve associated with quantum programming languages and quantum hardware poses another barrier to the widespread implementation of quantum computing (Carrel-Billiard et al., 2021) [3].

### 3.6 Research & Developments

Given that quantum computing is still in its nascent stages, there are several key areas where further research is needed. First, quantum-safe cryptography must be developed to ensure the security of digital systems in the post-quantum world. Research in post-quantum encryption algorithms will be critical for organizations that need to safeguard their data from quantum-enabled threats (Gartner, 2019) [6].

Second, workforce development is another priority. There is a significant gap in the current quantum workforce, and preparing IT professionals for the quantum era will be essential for the successful adoption of quantum technologies. Educational programs and certifications that focus on quantum computing will play a crucial role in addressing this issue (OECD, 2021) [13]. Lastly, researchers should investigate the societal and economic impacts of

quantum computing. While the technology promises significant benefits, it could also lead to disruption in various industries and labor markets. Understanding how quantum computing will reshape economies and societies is crucial for businesses, governments, and policymakers to prepare for these changes (Rietsche et al., 2021) [14].

#### 4. METHODOLOGY

This paper is based on a comprehensive literature review of research articles, conference papers, and industry reports published between 2015 and 2025. Research databases used to identify relevant publications. In addition to academic sources, expert opinions in the quantum computing field were incorporated to provide real-world insights into the challenges and opportunities of quantum computing in IS.

#### 5. RESULTS AND DISCUSSION

In this section, we discuss the findings from the literature review and examine the implications of quantum computing for information systems (IS). Also explore the potential impact on business ecosystems, IT organizations, service providers, and cybersecurity, focusing on both the opportunities and challenges that quantum technologies bring to these areas.

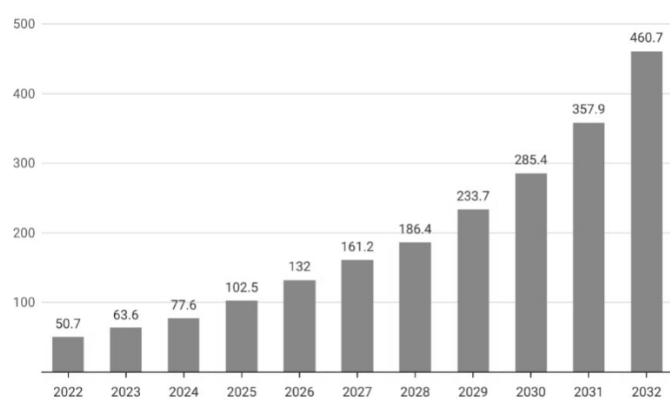


Chart -1- Quantum computing market revenue growth

##### 5.1 Implications for Business Ecosystems

Quantum computing is growing set to create entirely new business ecosystems, where collaboration between businesses, academic institutions, and governments will be critical for fostering the development and commercialization

of quantum technologies. As highlighted in previous research, organizations like IBM, Google, and Microsoft are already playing a leading role in shaping the quantum computing ecosystem by developing cloud-based platforms for quantum experimentation (Müller et al., 2019) [11].

This collaborative environment will likely evolve into a networked ecosystem, where quantum service providers, hardware manufacturers, and research institutions work together to advance quantum computing applications. The introduction of quantum computing into industries such as logistics, pharmaceuticals, and financial services will not only create new business models but will also disrupt existing ones. For instance, optimization problems that currently require massive amounts of computational power, such as supply chain optimization and financial portfolio management, could be solved much more efficiently using quantum algorithms (Carrel-Billiard et al., 2021) [3]. The ability to perform complex simulations, such as drug molecule interactions or risk assessments in finance, at unprecedented speeds will allow companies to achieve competitive advantages.

However, the transition to a quantum-enabled business ecosystem will require careful integration into existing information systems. Businesses must ensure that their IT infrastructures can accommodate quantum solutions without significant disruption to their operations. Moreover, as quantum technologies are still in the early stages, businesses will need to balance the promise of these advanced tools with the costs and uncertainties involved in adopting them (Gartner, 2019) [6]. Despite the long-term potential, quantum computing's initial adoption is likely to be a gradual process that requires businesses to invest in research, training, and infrastructure to build out a future-proof system.

##### 5.2 Impact on IT Organizations and Service Providers

IT service industries and providers will play a central role in the integrating quantum computing into existing infrastructures. Many quantum computing platforms are now available as cloud services, which allows IT organizations to test quantum algorithms and leverage quantum resources without the need to invest in expensive quantum hardware (Müller et al., 2019) [11]. The widespread availability of quantum computing through the cloud will likely reduce the barriers to entry for businesses looking to experiment with quantum solutions and could accelerate their adoption. However, as more organizations begin to use quantum computing, IT providers will face the challenge of managing these quantum resources alongside traditional computing infrastructure.

One of the most important challenges for IT organizations is ensuring compatibility between legacy systems and

emerging quantum technologies. Current data formats and systems are not designed to handle the unique nature of quantum computations. As quantum computing operates fundamentally differently from classical computing, businesses may need to adapt their data storage, processing, and management systems to work efficiently with quantum resources. For example, quantum computers rely on a new form of data representation called quantum states, which cannot be directly mapped onto classical data structures (Carrel-Billiard et al., 2021) [3]. This discrepancy between classical and quantum data structures will require substantial changes in data management practices. Additionally, IT service providers will need to develop new frameworks for managing quantum algorithms. Unlike traditional computing, where algorithms are linear and deterministic, quantum algorithms can exhibit complex behaviours due to the principles of superposition and entanglement (Nielsen & Chuang, 2000) [12]. Understanding and managing these behaviours in a way that aligns with business goals will require a new generation of quantum-savvy IT professionals. This presents another challenge: the shortage of skilled quantum computing experts, which is discussed in the next section.

### 5.3 Security and Cryptography

The potential impact of quantum computing on cybersecurity is one of the most significant areas of concern. As quantum computers become more powerful, they will be capable of breaking widely-used encryption systems, such as RSA encryption (Shor, 1997) [15]. This vulnerability is particularly concerning for businesses that rely on traditional encryption methods to secure sensitive data. The threat of quantum attacks has already sparked the development of quantum-safe cryptography, which aims to develop encryption systems as shown in Fig 1 that are resistant to the unique capabilities of quantum computers (Lutkenhaus, 2001) [10].

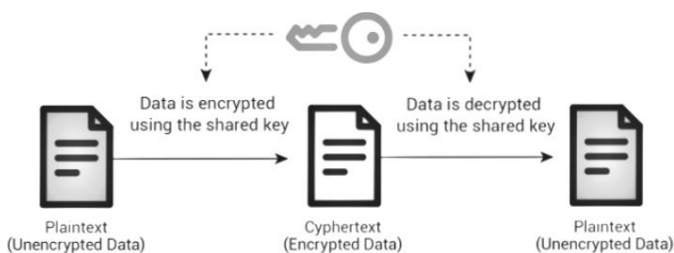


Fig 1:- encryption systems and shared key

Post-quantum cryptography is an active area of research that focuses on finding alternative encryption methods that can protect data in the era of quantum computing. Several promising algorithms, such as lattice-based cryptography and hash-based signatures, are being investigated as potential solutions (Gartner, 2019) [6]. However, transitioning to quantum-safe encryption will require a

comprehensive overhaul of current systems and standards, which could be costly and time-consuming. On the positive side, quantum computing can also enhance cybersecurity by

introducing new ways of detecting and mitigating threats. Quantum computers have the ability to simulate and analyze potential security vulnerabilities in real-time, providing businesses with advanced tools for identifying and responding to cyber threats before they occur (Gartner, 2019) [6]. Moreover, quantum key distribution (QKD) offers a way to establish ultra-secure communication channels, making it virtually impossible for eavesdroppers to intercept messages without detection (Bennett & Wiesner, 1992) [2].

The broader adoption of quantum-enhanced security protocols could drastically reduce the risks posed by cyberattacks. However, transitioning to these new technologies will require extensive research and standardization. The collaboration between quantum researchers and cybersecurity professionals will be essential in ensuring that businesses can protect their systems from the evolving threats posed by quantum computing.

### 5.4 Addressing the Skills Gap

A major challenge in the adoption of quantum computing is the skills gap in the workforce as shown in Fig 2. As quantum computing becomes more prominent in information systems, there will be an increasing demand for professionals with expertise in both quantum mechanics and computer science. The current pool of quantum computing professionals is limited, and there is a growing need for specialized education and training programs to address this shortage (Hughes et al., 2022) [8]. The gap in quantum talent is a critical issue for businesses that wish to leverage quantum computing but lack the necessary expertise. According to recent reports, IT professionals will need to be trained not only in traditional IT skills but also in the fundamentals of quantum mechanics, linear algebra, and quantum algorithms (OECD, 2021) [13].

Applications	Application architecture and development
Use case-specific libraries	Industry / domain knowledge
Performance libraries	Quantum computing system algorithms
Compilers, optimizers, simulators	Advanced math, quantum computing system expertise
Assembly language and drivers	Quantum physics, quantum computing system expertise
Quantum computing hardware	Quantum physics, chemistry, engineering

Fig 2:- Skills demand in Quantum Computing

This will require collaboration between universities, businesses, and governments to create educational programs that can equip the next generation of workers with the skills necessary for the quantum era. Moreover, as quantum technologies continue to advance, the field will need to adapt rapidly. Educational institutions and businesses will need to ensure that their quantum curricula stay up-to-date with the latest developments. This will be essential in maintaining a competitive workforce that can effectively implement quantum technologies in information systems.

### 5.5 Societal and Economic Impacts

Finally, it is important to consider the broader societal and economic impacts of quantum computing. As businesses adopt quantum technologies, certain sectors may experience significant disruption. For example, industries that rely on classical optimization methods or machine learning could see shifts in how problems are solved and what technologies are considered state-of-the-art (Rietsche et al., 2021) [14]. Quantum computing could lead to the displacement of some traditional job roles, while also creating new opportunities for workers with specialized skills. The economic implications of quantum computing are also profound. As businesses embrace quantum technologies, those that are able to leverage these tools effectively will have a competitive advantage in areas such as supply chain optimization, AI-driven analytics, and financial modeling (Carrel-Billiard et al., 2021) [3]. However, the widespread adoption of quantum computing will require careful regulation to ensure that it does not exacerbate inequalities in access to advanced technology.

Additionally, the societal impact of quantum computing could include shifts in privacy, security, and data ownership. As quantum-enabled encryption methods become widespread, individuals will need to trust that their data is secure in a quantum-enabled world. Policymakers and business leaders will need to work together to ensure that quantum computing benefits society as a whole while minimizing any negative impacts.

## 6. CONCLUSION

Quantum computing stands on the brink of revolutionizing information systems across industries. The potential applications are vast, ranging from dramatically improving machine learning algorithms to offering unprecedented capabilities in data security and optimization. However, while the promise of quantum computing is exciting, the path to widespread adoption is not without its challenges. At its core, quantum computing differs fundamentally from classical computing. By harnessing the strange properties of quantum mechanics—like superposition and entanglement—quantum computers can solve problems that were once considered too complex or time-consuming for even the most powerful classical

computers. For example, quantum algorithms can potentially solve optimization problems more efficiently, such as determining the most efficient delivery routes in supply chains or predicting stock market trends with greater accuracy. This could give businesses a significant competitive edge in areas like logistics, finance, and healthcare.

One of the most disruptive potential impacts of quantum computing is its effect on cybersecurity. The very algorithms that make quantum computers so powerful also pose a threat to current cryptographic techniques, such as RSA encryption, which protects sensitive data online. However, quantum computing also brings with it the promise of new encryption methods that are far more secure, such as quantum key distribution (QKD) and post-quantum cryptography. These innovations could protect data in ways that classical methods cannot, making them crucial for industries that rely on securing sensitive information, such as finance and healthcare. Despite its potential, quantum computing's adoption is still in its early stages. Quantum hardware is expensive, and only a few companies, such as IBM, Google, and Microsoft, have the resources to invest in developing quantum computers and building out cloud-based quantum platforms. For many businesses, adopting quantum computing may still be a few years away. The cost of developing quantum infrastructure and the need for specialized knowledge in quantum mechanics create a significant barrier for smaller companies that may lack the necessary resources. Moreover, the transition to quantum computing will require a substantial investment in human capital. There is a critical shortage of quantum computing experts and professionals with the skills needed to integrate these technologies into business applications. Educational institutions and businesses will need to work together to create training programs that equip the workforce with the necessary skills to succeed in a quantum-enabled world. Without these efforts, the skills gap could slow down the widespread adoption of quantum technologies.

Additionally, businesses and policymakers will need to consider the societal and economic impacts of quantum computing. The rise of quantum technologies will likely bring about significant disruptions in industries, as some traditional methods are replaced by more efficient quantum solutions. While this could lead to new opportunities, it could also cause job displacement in sectors reliant on outdated technologies. For example, automation and AI-driven tasks might become even more efficient with quantum computing, leading to shifts in employment across various industries. However, these changes could also create new job opportunities in fields such as quantum algorithm development and quantum-safe cybersecurity.

In conclusion, while quantum computing holds immense promise, its widespread implementation will require overcoming significant challenges. The technology is still

developing, and businesses must carefully assess how it fits into their existing infrastructure. Moreover, the workforce will need to evolve to support the growing demand for quantum expertise. With collaboration between researchers, businesses, and governments, the disruptive power of quantum computing can be harnessed for the greater good. As the technology matures, it has the potential to transform information systems, enabling businesses to solve problems that were once thought impossible, and creating new opportunities in industries across the globe.

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