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A Theoretical Framework of Quantum Communication Technology Acceptance: An Application Technology Readiness and Acceptance Model

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Abstract

Quantum Communication Technology (QCT) presents a transformative approach to communication and data security by leveraging quantum mechanics. While countries such as the United States, China, and the European Union are advancing rapidly in this field, Malaysia remains in the early stages of development. However, its acceptance in Malaysia remains underexplored. This study employs the Technology Readiness and Acceptance Model (TRAM) model to examine key factors influencing QCT acceptance, including optimism, innovativeness, discomfort, insecurity, perceived usefulness, and perceived ease of use. Understanding readiness is crucial since it determines the acceptance of QCT. This study will contribute to ongoing discussions on QCT by fostering research initiatives and promoting technological advancements in Malaysia. The proposed framework from this study could be served as guideline in implementing QCT in Malaysia. This study provides input to the government and stakeholders such as industries in formulating strategies to implement QCT. This study also contributes to the body of knowledge in QCT field.

Keywords: Quantum Communication Technology; Readiness; Technology Readiness and Acceptance Model (TRAM)

1. Introduction

The persistent threat of cyberattacks remains one of the most significant challenges in modern communication systems. As technology continues to evolve, traditional cybersecurity measures, such as firewalls, antivirus software, and encryption protocols, are increasingly vulnerable to cyberattacks. Cybercriminals are continuously developing new techniques to breach security systems, making the protection of sensitive data and secure communication more difficult.

In Malaysia, the growing number of cyber incidents, including data breaches, system intrusions, and ransomware attacks, cause the urgency of improving cybersecurity. Reports indicate a rise in cyberattacks targeting critical sectors, such as government, finance, and healthcare, with significant economic and reputational impacts (Yeoh, 2023). This trend highlights the need for stronger security solutions to reduce evolving cyber threats.

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Existing technologies, such as traditional encryption methods and network security protocols, are currently in place to protect communication systems and mitigate cyber threats. However, as cyber threats become more complex, these conventional methods are increasingly ineffective in ensuring strong security. Despite the widespread use of traditional cybersecurity tools, these existing methods are no longer sufficient to fully safeguard against advanced cyber threats (Bilal, 2024). There is a pressing need for new security measures that can address emerging risks and provide stronger protection, especially in critical sectors like finance and national defense.

In response to these challenges, Quantum Communication Technology (QCT) emerges as a highly promising solution to enhance data security and communication systems. QCT leverages the principles of quantum mechanics, offering extraordinary levels of security through methods like Quantum Key Distribution (QKD). This makes it one of the secure technologies for protecting data from communication intrusion and cyber threats.

QCT utilizes quantum mechanical principles, particularly quantum entanglement and quantum key distribution, to achieve ultra-secure encryption. These mechanisms allow for the creation of cryptographic keys that are virtually unbreakable, providing a level of security far beyond what traditional technologies can offer.

Countries such as the China, United States and the European Union are at the forefront of QCT development and implementation (Kung & Fancy, 2021). These regions have recognized the transformative potential of QCT to secure communications and drive advancements in cryptography and network security. Their investments in quantum technologies are positioning them to lead to global standards.

From Systematic Literature Review (SLR), we found that, the adoption of QCT is still in its early stages in Malaysia. Although initiatives like the Malaysia Quantum Information Initiative (MYQI) are working to build a quantum ecosystem, challenges remain, including limited resources, a shortage of expertise, and insufficient awareness of QCT's potential benefits. More efforts are needed to strengthen Malaysia's quantum infrastructure and ensure its readiness for QCT adoption.

From an academic perspective, there is a significant gap in literature regarding readiness to accept QCT in Malaysia. Most existing studies focus on the theoretical aspects of quantum technologies rather than practical readiness and acceptance. Understanding the factors that influence readiness is crucial, as it directly affects the willingness of stakeholders to accept new technologies. The lack of research on readiness highlights the need for further investigation into how QCT can be integrated into Malaysia's technological landscape.

Addressing these gaps in knowledge is important for ensuring that Malaysia is ready to accept QCT. Without a clear understanding of readiness, even the most advanced technology may face resistance. This study seeks to analyze a theoretical framework of QCT acceptance using the Technology Readiness and Acceptance Model (TRAM). The study will explore factors such as optimism, innovativeness, discomfort, insecurity, perceived usefulness, and perceived ease of use. The goal is to provide a structured theoretical foundation that can guide future empirical research and assist various stakeholders including policymakers, educators, researchers, and industry players in understanding and facilitating the acceptance of QCT in Malaysia.

This paper is structured as follows: literature review, systematic literature review, theoretical framework, recommendations and conclusions.

2. Literature Review

2.1 Quantum Communication Technology (QCT)

QCT can be defined as an emerging field that leverages the principles of quantum mechanics to transform information exchange (Purohit et al., 2023). This study defines QCT as the use of quantum technology (QT) for communication purposes particularly in information and data exchange. Unlike conventional encryption, which relies on mathematical algorithms that can be broken by powerful computers, QCT provides unbreakable encryption methods through quantum key distribution (QKD) and quantum entanglement (Sarah Young et al., 2024). These properties make QCT highly secure, offering significant advantages in cybersecurity, defense, and financial transactions.

Basically, QCT utilizes unique quantum mechanical properties such as superposition and entanglement to encode and transmit data. Superposition allows quantum bits (qubits) to exist in multiple states simultaneously, while entanglement ensures that two or more qubits remain interconnected, such that the state of one instantly affects the state of the other, regardless of distance (Zhao et al., 2022). These principles enable the transmission of information in a way that is inherently secure.

In advancing its application, the development of quantum repeaters has become critical for extending communication distances, while the concept of quantum networks aims to interconnect multiple users and devices securely.

The advantages of QCT extend beyond secure communication. It enables real-time intrusion detection, provides immunity against force decryption, and opens new possibilities for highly secure government, financial, and healthcare communications (Brightwood et al., 2022). In sectors such as banking, secure transaction protocols can be enhanced through QCT, while in defense, it serves as a vital tool in protecting national security infrastructure.

However, theoretically the implementation of QCT faces notable challenges. Technology requires specialized hardware such as photon detectors and quantum repeaters, which are expensive and complex to integrate with existing classical communication infrastructure. Furthermore, environmental noise, transmission distance limitations, and the lack of international standards hinder its widespread adoption. As technology continues to evolve, addressing these challenges is critical to achieving its full potential.

Given its potential to revolutionize secure communication, QCT has gathered increasing attention from governments, researchers, and private sectors globally. Understanding the underlying mechanisms, benefits, and challenges of QCT is essential in preparing stakeholders for its gradual integration into modern communication systems.

2.2 QCT History

The history of QCT has undergone a remarkable evolution, transitioning from foundational theoretical work to sophisticated experimental systems and pilot implementations. The roots of QCT lie in the early 20th century with the birth of quantum mechanics, particularly the works of Planck, Einstein, Schrödinger, and Heisenberg, which laid the foundation for understanding quantum states, superposition, and entanglement basic to QCT applications (Quantum News, 2025).

The concept of using quantum principles for communication began to materialize in the late 20th century. Bennett and Brassard introduced the BB84 protocol, the first Quantum Key Distribution (QKD) scheme, which enabled secure communication by detecting eavesdropping attempts based on quantum measurement disturbance (Bennett et al., 1984; Bennett & Brassard, 2014). This protocol represented the first concrete step in moving quantum theory into practical secure communication systems.

In the 1990s, rapid progress followed with several experimental verifications of QKD in controlled environments. By the mid-1990s, the first practical implementation of QKD over optical fiber was conducted, which demonstrated secure key exchange over a few kilometers (Hughes et al., 1999; Paul D. Townsend, 1997). These efforts paved the way for long-distance QKD via free-space and fiber-optic channels. The early 2000s saw further improvements in single-photon sources, detectors, and quantum error correction techniques, which significantly enhanced the reliability and range of QKD systems (Gisin et al., 2002).

A major milestone in the development of QCT came with the integration of quantum repeaters, introduced theoretically in the year 1998, which addresses the issue of photon loss and decoherence in long-distance communication. Though fully operational quantum repeaters remain under development, experimental efforts have demonstrated elementary steps such as entanglement swapping and quantum memory (Sangouard et al., 2011). These components are essential to building quantum networks, which represent the backbone of the future quantum internet.

In recent years, QCT development has been increased by the merging of enabling technologies including quantum computing, integrated photonics, nanofabrication, and satellite-based systems. The launch of the Micius satellite by China in 2016 marked the first successful demonstration of space-based QKD over distances exceeding 1,200 km, proving the ability of quantum communication on a global scale (Chapman & Peters, 2022). This achievement positioned China as a leader in the field and stimulated a surge of interest from other countries and research bodies worldwide.

Governments across the globe have since recognized the strategic importance of QCT in national security, critical infrastructure protection, and digital sovereignty. Prominent initiatives include the European Union's Quantum Flagship program, launched in 2018 with a €1 billion budget to develop quantum technologies over a 10-year horizon (EUC, 2023), and the United States National Quantum Initiative Act, signed into law in 2018 to coordinate federal quantum research and foster public-private partnerships (National Quantum Initiative Act, 2021).

Similarly, countries such as Japan, Australia, India, Singapore and Canada have established dedicated quantum research centers and funding mechanisms. Japan leads with over 13,000 research papers and plans major investments in quantum encryption. India is developing 21 quantum hubs under its billion-dollar National Quantum Mission. Australia and Singapore are also active, with strong research output and government-backed initiatives (Asia and Pacific Research Center, 2023). These efforts align with global developments like Canada's $360 million National Quantum Strategy (NQS) and international collaborations, supporting the projected growth of the global quantum communication market from $0.74 billion in 2024 to $5.54 billion by 2030 (NQS, 2024).

Relatively, industry participation also has grown rapidly, with companies such as Toshiba and ID Quantique developing commercial QKD systems. Telecommunications providers, including BT in the UK and SK Telecom in South Korea, have initiated pilot quantum networks, and collaborative testbeds such as the Quantum Internet Alliance have become platforms for testing interoperability and real-world deployment (Kalbe, 2024).

Currently, research efforts are focused on overcoming practical limitations such as increasing the secure transmission distance, reducing quantum bit error rates, achieving quantum-classical network integration, and establishing standardized QKD protocols. The roadmap for the next decade includes developing entanglement-based quantum networks, quantum internet protocols, and satellite-to-ground entanglement distribution, which would enable globally distributed, secure communication systems (Singh et al., 2021).

Therefore, QCT development has advanced from theoretical propositions to real-world experimentation and international implementation. With continued investment, collaboration, and innovation, QCT is expected to become a cornerstone of global communication infrastructure, offering unprecedented security and reliability across various sectors.

2.3 QCT Initiative Worldwide & Malaysia

QCT has gained significant international attention due to its potential to revolutionize data security and information infrastructure. Several countries have emerged as global leaders in QCT research, development, and deployment, driven by national security concerns and the strategic value of quantum technologies in future digital economies.

QCT has progressed through research, legislation, and global collaboration. There are countries have already started using QCT in real-life situations. This paper presents QCT development initiative from leader countries for QCT. China have made significant strides, with China's Micius satellite proving the potential of secure quantum communication (Sidhu et al., 2021). China has positioned itself at the forefront of QCT with the successful launch of the Micius satellite, enabling satellite-based Quantum Key Distribution (QKD) over intercontinental distances. In addition, China has developed the world's longest quantum communication network, connecting major cities with over 2,000 kilometers of quantum fiber-optic infrastructure (University of Science and Technology of China, 2018).

In the West, the European Union has launched the Quantum Flagship program, investing over €1 billion in quantum research, including communication systems. One of its key initiatives is the EuroQCI aimed at developing a European secure quantum network. The European Union's Quantum Flagship program fosters cooperation through initiatives like the Quantum Internet Alliance (QIA) and Quantum Communication Infrastructure (QCI), strengthening Europe's position in QCT (EUC, 2023).

In United States (US), legislative measures like the US National Quantum Initiative Act (NQI Act) aim to advance quantum technology for economic and national security (Omaar, 2023; US Government, 2018). These global efforts show how important QCT is becoming in the race to improve cybersecurity and technological strength.

Governments play a big role in advancing QCT by creating national strategies, funding programs, and research centers. China includes QCT in its national technology plans to protect its digital systems. The US has formed groups like the Quantum Economic Development Consortium (QED-C) to encourage collaboration between researchers and companies. These efforts reflect a growing global race to achieve quantum advantage in secure communications. Moreover, 92% of quantum computing start-ups have emerged in the past decade, mainly in the US, UK, and Canada (Seskir et al., 2022).

Other than that leader countries, this study also sees other countries such as Japan, South Korea, Canada, Singapore and Australia are also making strategic investments in QCT, each emphasizing different aspects, ranging from photonic chip development to quantum network architecture. Japan and South Korea are also working on national projects to build their own quantum communication systems. These countries understand that strong government support is needed to move from research to real-world use of QCT.

International conferences play a key role in knowledge-sharing and collaboration. Events like the Quantum Communication, Measurement, and Computing (QCMC) conference and the Quantum Information Processing (QIP) conference focus on quantum cryptography and communication. Other important conferences, such as QCrypt and SPIE Quantum Communications, explore quantum optics and imaging. The European Quantum Technology Conference (EQTC) broadens discussions to include quantum computing and sensing. These gatherings help drive research, attract industry investment, and set the direction for future QCT advancements.

Thus, these global initiatives underscore the importance of cross-border collaboration and shared technological advancement. Understanding the worldwide progress of QCT provides a benchmark for assessing Malaysia's position and identifying opportunities for collaboration and growth.

As mentioned, while QCT is expanding globally, Malaysia remains in the early stages of its development. Despite comprehensive efforts in cybersecurity, Malaysia has yet to develop a policy framework for QCT, which underscores the need for strategic measures to protect critical data as the country advances in accepting quantum technologies.

The foundation for these efforts was laid with the National Cyber Security Policy (NCSP) established in 2006, which aimed to protect vital national assets against cyber threats. Over the years, Malaysia has continued to prioritize cybersecurity through various initiatives, including the National Policy on Industry 4.0 (2018), which emphasizes cybersecurity in the digitalization of industries, and the National Fourth Industrial Revolution

(4IR) Policy (2021), which highlights the modernization of the legislative framework for data protection. The Malaysia Digital Economy Blueprint (2021) and the National E-Commerce Strategic Roadmap (2021–2025) further reinforce cybersecurity's role in the digital economy. Additionally, the Malaysia Cyber Security Strategy (2020–2024) focuses on building capabilities to predict, detect, deter, and respond to cyber threats while supporting the digital economy (Huda et al., 2023).

Academic institutions in Malaysia are playing a central role in advancing QCT research. Local universities have begun exploring quantum optics, quantum key distribution, and quantum network simulation and actively participate in quantum research. These academic efforts are supported by research grants under national funding agencies such as the Malaysian Ministry of Higher Education (MOHE) and Ministry of Science, Technology and Innovation (MOSTI).

On 25 February 2025, MOSTI launched MIMOS Quantum Intelligent Centre at MIMOS Quantum Day 2025. The centre will act as a collaborative hub that turns policy into action and supports the adoption of quantum technologies across government and industry (MIMOS 2025). Malaysia has increasingly recognized the strategic importance of quantum technologies, including QCT, in strengthening national cybersecurity and driving technological advancement. While still in the early stages compared to global leaders, Malaysia has taken initial steps to position itself within the global quantum ecosystem through research funding, and academic collaboration

The Malaysia Quantum Information Initiative (MYQI) is one of the few programs promoting quantum research, yet challenges such as limited expertise, high costs, and low awareness hinder progress. The development of QCT in Malaysia faces several challenges, including limited awareness, high implementation costs, and the need for continuous improvements in cybersecurity. Although there is awareness of QCT, especially among those with information and communication technology and data security field, broader knowledge and promotion are needed to support its growth.

Beyond security, QCT also offers economic and strategic advantages. By investing in QCT, Malaysia could attract foreign investment, drive innovation, and develop expertise in an emerging industry. The integration of QCT into finance, healthcare, and telecommunications can promote technological growth and improve Malaysia's competitiveness in the digital economy. A strong QCT framework can enhance investor confidence, encourage tech startups, and create new opportunities for job creation and research collaborations.

Nonetheless, Malaysia's strategic location, strong ICT base, and active participation in ASEAN science and technology cooperation platforms present significant opportunities for regional leadership in QCT. Continued investment in research, standardization efforts, and international collaboration will be essential for bridging the readiness gap and ensuring that Malaysia is prepared to adopt and benefit from quantum-secured communication technologies soon.

Among these, economic factors are one of concern, as the cost of implementing QCT is high, necessitating significant investment from both the government and private organizations (Shahrul et al., 2024). Successful QCT implementation in Malaysia will require government support, cost-benefit analyses, specific training, and benchmarking against leading countries like the EU, China, and the US.

2.4 QCT Elements & Advantages

QCT is based on the principles of quantum mechanics to enable secure information exchange. One key component of QCT is Quantum Key Distribution (QKD). QKD allows secure key exchange by using quantum properties like the uncertainty principle to detect eavesdropping attempts, ensuring the key's security (Cavaliere et al., 2020). This method is critical for encrypting data securely, especially in the era of quantum computing.

Another essential element of QCT is quantum entanglement. This phenomenon occurs when two particles remain linked, no matter what the distance between them. It allows for instant communication and is crucial for technologies like quantum teleportation and long-distance QKD, which provide highly secure communication (Singh et al., 2020). Entanglement is not only vital for secure communication but also for advancements in quantum computing and information processing.

To address the challenges of distance and signal loss in quantum communication, quantum repeaters are used. These devices help maintain entanglement over long distances by using techniques like entanglement swapping and purification (Cavaliere et al., 2020). Quantum repeaters extend the range of quantum communication, making it possible to communicate securely over large distances.

Quantum networks form the backbone of QCT, enabling scalable and reliable communication. These networks integrate QKD systems, quantum memories, and processing units to support secure communication, distributed quantum computing, and quantum internet services (Wehner et al., 2018). The main goal of quantum networks is to create global communication channels that are both secure and efficient.

Recent progress in QCT includes the successful implementation of QKD over long distances and the launch of quantum communication satellites. These developments are important steps towards realizing practical, secure quantum networks (Sarah Young et al., 2024). As research continues, QCT is set to revolutionize communication by offering unparalleled levels of security and privacy, which are increasingly essential in today's connected world.

The key elements of QCT are QKD, quantum entanglement, quantum repeaters, and quantum networks. The elements play a vital role in ensuring secure communication. These advancements, along with global research efforts, provide a comprehensive view of QCT's potential and its future in secure communication. QCT offers significant advantages in multiple areas, including security, transmission speeds, and economic benefits, making it increasingly important in modern technology.

In terms of security, Quantum Key Distribution (QKD), a core component of QCT, enables the exchange of cryptographic keys with unconditional security. Thanks to the principles of quantum mechanics, QKD is immune to eavesdropping attempts (Liu et al., 2022). By exploiting quantum entanglement, QKD ensures that any interception of transmitted information disrupts the entangled state, providing immediate detection of potential intruders and safeguarding sensitive data (Purohit et al., 2023). These features make QCT a highly secure method for communication, protecting against conventional cryptographic attacks.

QCT also enables secure communication channels over long distances. For example, satellite-based quantum communication has been successfully demonstrated in the Quantum Experiments at Space Scale (QUESS) mission by the Chinese Academy of Sciences (CAS) (Pirandola, 2019). Such advancements have the potential to revolutionize fields like cryptography and machine learning (Vasani et al., 2024), strengthening the security of data transfer and communication on a global scale.

Regarding transmission speed, QCT enhances information processing capabilities. Quantum computers, based on quantum mechanics principles, can offer exponentially faster processing speeds for certain tasks compared to classical computers (Purohit et al., 2023). QCT plays a critical role in enabling secure and efficient transmission of quantum information between quantum processors. This opens possibilities for applications such as distributed quantum computing, secure multi-party computation, and the development of a quantum internet, significantly boosting the performance of information processing technologies.

In addition to its technological benefits, QCT offers economic advantages. As the global economy becomes more reliant on digital infrastructure, the demand for secure and efficient communication technologies is growing. Quantum communication can address the increasing cybersecurity challenges faced by governments, businesses, and individuals, helping mitigate the risks associated with data breaches, cyber-attacks, and information theft (Sarah Young et al., 2024).

By safeguarding sensitive data and ensuring the integrity of communication networks, QCT enhances the security of digital transactions and interactions, which is crucial for maintaining trust and stability in digital economies. Furthermore, investments in QCT research and development have the potential to stimulate economic growth and drive innovation in emerging industries.

2.5 Readiness and acceptance of QCT

Due to rapid technological advancements, the acceptance of new technologies is important in shaping societies and industries. QCT represents an innovation to reform communication networks by harnessing the principles of quantum mechanics. As researchers and policymakers explore the potential applications and implications of QCT, understanding the readiness landscape becomes essential for facilitating its successful integration into current infrastructures.

Readiness can be defined as the extent to which an individual or organization is prepared to undergo change resulting from the acceptance of a new technology, considering both the willingness and ability to do so (Parasuraman, 2000). This definition encompasses both the psychological and practical aspects of readiness, emphasizing not only the readiness in terms of attitude and motivation but also the capability and resources necessary to effectively implement and integrate the new technology. In this study readiness can be defined as the overall individual willingness and preparedness to accept QCT in Malaysia. Understanding readiness to accept is crucial for identifying barriers and facilitators to acceptance, informing policy decisions, and guiding strategies to promote the successful integration and utilization of new technologies. QCT has emerged as a promising field with the potential to revolutionize secure communication systems by leveraging the principles of quantum mechanics.

Status of readiness on QCT influences acceptance of this new technology. Acceptance defines users' intention and attitude toward adopting a particular technology, often influenced by perceived usefulness and perceived ease of use (Fred Davis, 1987). In this study, acceptance refers to the extent to which individuals support the use of QCT in Malaysia. It reflects their positive perception, willingness to use QCT and confidence in its potential benefits. Within the context of QCT, acceptance involves the perceived benefits of adopting quantum-secured communication and the extent to which potential users believe the technology is beneficial compared to existing systems. The TAM framework has been widely applied to investigate the acceptance of emerging technologies.

From SLR, the factors influencing readiness and acceptance remain underexplored in Malaysia. Addressing this research gap, the present study employs the TRAM framework to assess the readiness and acceptance of QCT, focusing on the academic perspective as a crucial third-party stakeholder group in the technology's national rollout.

To conclude, this part provides a foundational understanding of QCT and the theoretical models that inform its readiness and acceptance. It begins by defining QCT and outlining its core components, followed by an overview of global developments and initiatives in the field. To contextualize the study locally, the review then highlights the current landscape of QCT in Malaysia revealing the country's emerging interest in the technology and the existing gaps in research.

Then, follow with the QCT elements emphasizing key components such as quantum key distribution (QKD), quantum entanglement, repeaters, and quantum networks, all of which are essential for secure data transmission. It concludes by discussing the advantages of QCT, especially security, transmission speeds, and economic benefits.

Since Malaysia advances towards a digital economy, cybersecurity has become a critical national priority to protect sensitive data, infrastructure, and digital transactions from cyber threats. The rapid adoption of digital technologies has increased the need for robust cybersecurity measures. Without adequate protection, Malaysia risks exposure to cyberattacks that could disrupt government operations, financial systems, and public services.

3. Systematic Literature Review (SLR)

This study employed a SLR methodology to explore the existing research landscape on QCT, focusing particularly on its readiness and acceptance. The search was conducted using the keywords "Quantum Technology" and "Quantum Communication Technology" within the Scopus database to identify relevant scholarly articles. The SLR process followed the standard protocol of identification, screening, eligibility assessment, and selection for inclusion or exclusion, as outlined by (Ramos, 2020). The results indicate a significant gap in research dedicated to QCT in Malaysia, as summarized in Table 1.

Table 1: Systematic Literature Review

Process	QCT articles
Identification	Records identified through the database Scopus on 9 January 2025 (Keyword: "Quantum Technology") n = 5,121
Screening	Records title screened (Keywords: "Quantum Communication Technology") n = 167
Eligibility	Full-text articles assessed for eligibility - Relate with "QCT management" n= 2

In the identification stage, a preliminary search using the keyword "Quantum Technology" revealed a total of 5,121 global publications. To narrow the scope, the screening process was conducted using the keyword "Quantum Communication Technology," which, as of 9 January 2025, yielded only 167 documents globally published between 2014 and 2025. According to Taylor et al. (2012), a review period spanning one to one-and-a-half decades is optimal for capturing critical technological developments and trends. Therefore, this study concentrates on literature published in the last ten years to maintain relevance and align with current technological advancements in QCT.

Further screening was made by filtering publications specific to Malaysia. The keyword "Quantum Technology" returned only 12 articles, while "Quantum Communication Technology" yielded merely one publication. Hence, these articles primarily focused on theoretical aspects, with no empirical studies addressing the management, readiness, or practical implementation of the technology. This finding highlights a knowledge gap in the Malaysian context regarding QCT readiness and acceptance. However, there is limitation of references in general understanding of QCT.

Table 2: Articles related to previous studies on QT and QCT management

Author/ year	**Topic**	**Research context**	**Model**	**Findings**
Purohit et al., (2023)	Building a quantum-ready ecosystem.	They highlight progress in quantum technologies and stress collaboration between government, industry, and academic to create a quantum-ready ecosystem for real-world use.	• Quantum Technology Readiness Levels (QTRLs) • Quantum Commercial Readiness Levels (QCRLs) • Innovation models • Key Performance Indicators	QKD communication sits midway (telecom trials limited by costs). The paper urges policies, funding, talent development, and ethics to commercialize the technology by 2025-2030.
Martin et al., (2021)	Quantum technologies in the telecommunications industry	Explore how quantum technologies could transform telecommunications, focusing on opportunities like secure networks and greater capacity.	The paper employs a sectoral analysis framework, categorizing quantum applications by telecom infrastructure layers.	Quantum tech like QKD is ready for real use in telecom city's short networks (metro/access), even with setup challenges.
Sarah Young et al., (2024)	Societal implications of quantum technologies through techno criticism of quantum key distribution.	It reviews critiques from four government agencies to highlight non-technical contributions of social sciences and humanities to quantum network development.	Thematic analysis was used to examine four position statements, identifying both technical and social challenges.	Highlight five social concerns: economics, hype vs. reality, risk management, policy, and communication. This study encourages non-technical scholars to engage early to help shape effective quantum futures.
Seskir et al., (2022)	The landscape of the quantum start-up ecosystem	Examine the global start-up during the second quantum revolution, analyzing 441 companies across 42 countries to highlight trends in location, timing, and technology focus. .	This paper employs descriptive landscaping analysis.	This study expects further category expansions in the quantum field. Perceive regional preferences yet diversity within regions and highlight emerging non-profits institution improve the quantum field.
Vasani et al., (2024)	Embracing the quantum frontier: Investigating quantum communication, cryptography, applications, and future directions	It reviews quantum communication and cryptography, explaining how quantum computers threaten classical encryption while exploring key principles, protocols, applications, and future directions for secure quantum adoption.	The paper structures its analysis around foundational quantum mechanics.	QKD provides security by detecting eavesdroppers. Future directions emphasize quantum-secured identity management and even face challenges like classical integration, high costs, and global standard's needs.

Cavaliere et al., (2020)	Secure Quantum Communication Technologies and Systems: From labs to markets	Outline a roadmap from quantum communication prototypes to market, focusing on secure data via QKD and integration challenges in Europe's Quantum Flagship.	This study employs comparative roadmap framework.	QKD faces risks, authentication gaps, and high cost. This study recommends SDN networks, pilots, and standards for market rollout.

Among the six QCT-specific studies reviewed in table 2, a global perspective on the development of technology across sectors and countries was observed. The first two articles are retrieved from Scopus database. While others from google scholars are related to the study of QCT. Purohit et al. (2023) investigated the foundations of a "quantum-ready" ecosystem, emphasizing the role of policy frameworks and stakeholder engagement in the UK. Martin et al., (2021) explore how quantum technologies could transform telecommunications, focusing on opportunities like secure networks and greater capacity.

Young et al. (2024) examined how government agencies in the UK, US, France, and Germany are preparing for the deployment of quantum key distribution (QKD). Next, Seskir et al. (2022), examine the global start-up during the second quantum revolution. Vasani et al. (2024) discussed India's quantum advancements and the challenges face to implement the technology, while Cavaliere et al. (2020) explored Switzerland's transition from quantum research to commercialization. These studies consistently emphasized the importance of intersectoral collaboration involving government, academia, and industry for successful QCT integration.

Despite these contributions, the reviewed literature revealed a lack of attention to behavioral factors influencing QCT acceptance, particularly in the Malaysian setting. To address this, four studies applying the TRAM model were analyzed in depth. These include works by Lin et al. (2007), Adiyarta et al. (2018), Walczuch et al. (2007), and Godoe et al. (2012), which explored readiness for technology acceptance across different domains. Although these studies offer valuable insights into individual and organizational technology adoption behavior, none focused specifically on QCT or the Malaysian context.

Given the strategy in raising awareness of this technology, this research identifies a clear need for localized studies assessing their readiness to accept QCT. Addressing this gap can inform national strategies and support the development of a quantum-ready ecosystem in Malaysia.

4. Underpinning Theory

This study adopts the Technology Readiness and Acceptance Model (TRAM), which integrates two established models: The Technology Readiness Index (TRI) and the Technology Acceptance Model (TAM). This integration offers a comprehensive understanding of both the psychological readiness and behavioral intention to accept new technology. By combining personality-based dimensions TRI's (optimism, innovativeness, discomfort and insecurity) with perception-based variables TAM's (Perceive usefulness (PU)) and perceive ease of use (PEOU)), the TRAM model effectively captures the factors influencing the readiness and acceptance of QCT.

4.1 Technology Readiness Index (TRI)

TRI was developed by Parasuraman, 2000, as a comprehensive framework, that has various theoretical perspectives to provide insights into the changing aspects between individuals and technology. By assessing dimensions such as optimism, innovativeness, discomfort, and insecurity, TRI provides insight into understanding users' readiness to embrace technological innovations.

In the quantum field, the readiness to accept this technology is crucial to understanding factors that affect the integration of QCT and the current situation of its development in Malaysia. The Technology Readiness Index (TRI) is developed to evaluate people's beliefs and some thinking on technology (Demirci, 2008). In this context, there are four fundamental principles of TRI which are the contribute factors Optimism and Innovativeness and inhibitors factors Discomfort, and Insecurities that guiding acceptance of QCT into the current landscape (refer fig 1).

Optimism within the context of TRI refers to individuals' positive attitudes and beliefs regarding the potential benefits of a new technology (Parasuraman, 2000). Optimism can be interpreted as showing optimistic feelings on the new technology to be accepted (Godoe & Johansen, 2012). In the case of QCT, people with optimism behavior may recognize its potential to enhance communication security and enable unprecedented data transmission speeds. Research institutions and universities are actively exploring digital transformation under various initiatives. However, optimism towards QCT remains uncertain due to its complex nature and limited awareness.

Innovativeness reflects individuals' willingness to try new technologies and explore their capabilities (Parasuraman, 2000). Innovativeness also can be a tendency for technology to be a pioneer in the industry (Ariani et al., 2018). Innovativeness is crucial for QCT as it drives the willingness to explore its capabilities in enhancing secure communication and data protection. By embracing new technologies like QCT, individuals and organizations can benefit from secure communication advancements.

Discomfort refers to the degree of unease or hesitation individuals may feel towards adopting a new technology (Parasuraman, 2000). Discomfort may also be interpreted as an individual's perception of insufficient control over technology, resulting in feelings of being overwhelmed by it (Demirci, 2008). In the context of quantum communication, discomfort may arise due to the perceived complexity of quantum principles including concepts such as quantum entanglement and cryptographic applications, may lead to discomfort among stakeholders in Malaysia. A lack of hands-on exposure and training opportunities further increase hesitation in incorporating QCT.

Insecurity, the final dimension of TRI, encompasses concerns related to risks and uncertainties associated with a new technology (Parasuraman, 2000). Insecurity can be defined as a lack of trust in the newly adopted technology's ability to effectively accomplish the task at hand (Berlilana et al., 2021). In the case of quantum communication, insecurity may come from concerns about the reliability of quantum systems, as well as potential security vulnerabilities. In Malaysia, uncertainties regarding its regulatory framework and implementation costs also contributes to insecurity among stakeholders.

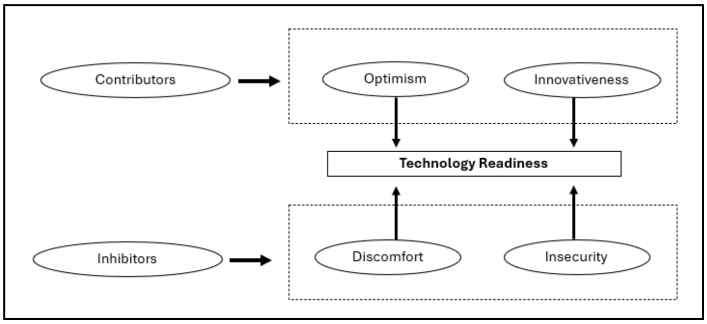

Fig 1: Technology Readiness Index (TRI) (Adiyarta et al., 2018)

4.2 Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) explains how individuals adopt new technologies based on based on their perceptions and experiences (Fred Davis, 1987). The Technology Acceptance Model (TAM), as depicted in Figure 2, outlines the process by which individuals develop an intention to use new technology based on their perceptions and experiences. The model is structured around three primary responses: cognitive, affective, and behavioral. The cognitive response consists of two fundamental beliefs: perceived usefulness (PU) and perceived ease of use (PEOU). PU refers to the extent to which users believe that technology will enhance their performance or provide benefits, while PEOU represents how effortless they perceive its use to be.

TAM further suggests that PU and PEOU influence an individual's intention to use the technology. If a system is perceived as useful and easy to use, users are more likely to develop a positive attitude and intention toward its usage. This intention then translates into actual system use, which represents the final step in technology acceptance. Thus, PEOU also indirectly impacts behavioral intention through PU, as users may perceive a system as more useful if it is easier to use.

In the context of Quantum Communication Technology (QCT), if potential users find QCT beneficial for secure communication (PU) and easy to integrate into the current system (PEOU), they are more likely to accept it. TAM suggests that these perceptions directly influence an individual's behavioral intention to adopt technology.

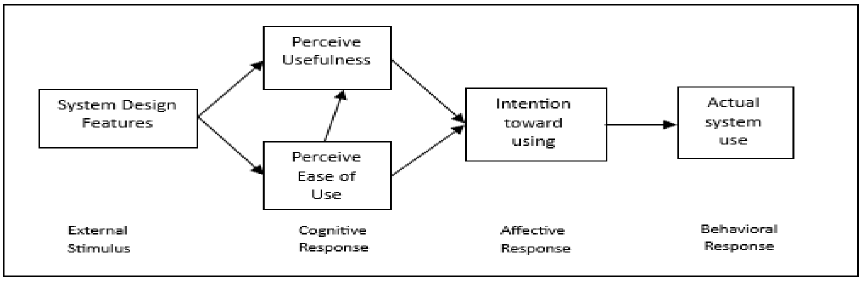

Fig 2: Technology Acceptance Model (TAM) (Fred Davis, 1987)

4.3 Technology Readiness and Acceptance (TRAM)

The Technology Readiness and Acceptance Model (TRAM) as shown in figure 3 is used in this study to examine factor that contribute to Malaysia's readiness and acceptance. TRAM integrates two key models: Technology Readiness Index (TRI) and Technology Acceptance Model (TAM) (Lin et al., 2007). Technological readiness consists of four dimensions: optimism and innovativeness, which serve as enablers of technology acceptance, and discomfort and insecurity, which act as inhibitors. These factors shape users' perceptions of technology, influencing their perceived ease of use (PEOU) and perceived usefulness (PU) the cognitive response of TAM.

Studies indicate that optimism and innovativeness positively influence technology acceptance, as individuals who see potential benefits and are open to new innovations are more likely to accept and integrate them. In contrast, discomfort and insecurity act as barriers, with concerns about complexity, security risks, and implementation challenges potentially hindering acceptance (Adiyarta et al., 2018). Additionally, perceived usefulness and ease of use are crucial factors, if individuals believe that QCT enhances communication security and is user-friendly, they are more inclined to accept it.

In the context of QCT acceptance among potential user in Malaysia, this model highlights the need to enhance optimism and innovativeness while addressing discomfort and insecurity to improve readiness. By ensuring that QCT is perceived as both useful (enhancing secure communication) and easy to use (seamless integration into current system), acceptance rates can be increased.

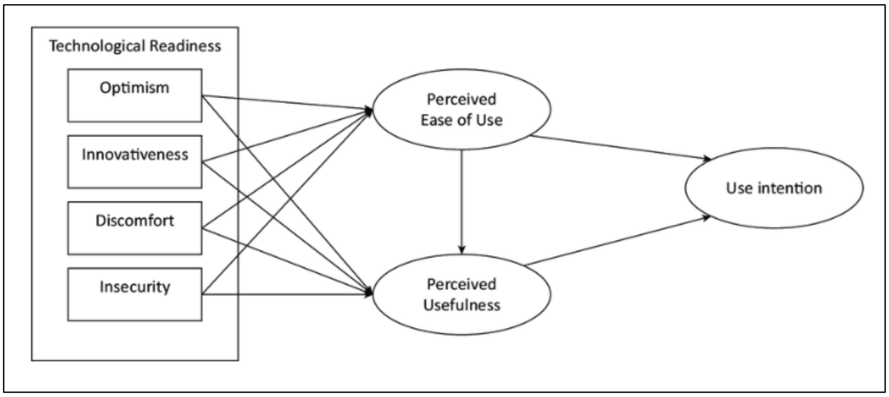

Fig 3: Technology Readiness and Acceptance Model (TRAM) (Lin et al., 2007)

To conclude, this part focuses on the theoretical underpinnings that guide this study. It discusses the Technology Readiness Index (TRI), the Technology Acceptance Model (TAM), and the integrated Technology Readiness and Acceptance Model (TRAM), the study's approach to understanding QCT readiness and acceptance. This paper suggests that the development of framework Technology Readiness and Acceptance Model (TRAM) in the context of QCT is essential.

5. Theoretical Frameworks

The framework presented in the figure 4.1 is an adaptation of the Technology Readiness and Acceptance Model (TRAM) to assess the readiness to accept Quantum Communication Technology (QCT). In this framework, readiness to accept QCT is influenced by perceived usefulness (PU) and perceived ease of use (PEOU), which are key determinants of technology acceptance. These perceptions, in turn, are shaped by four dimensions of technology readiness: optimism and innovativeness (contributors), which facilitate acceptance, and insecurity and discomfort (inhibitors), which create resistance.

The framework categorizes these four dimensions into contributors and inhibitors (Adiyarta et al., 2018). Optimism reflects a positive outlook on technology, believing that it enhances productivity and efficiency. Innovativeness represents the tendency to be an early adopter of new technologies (Walczuch et al., 2007). Both dimensions positively influence perceived usefulness (PU) and perceived ease of use (PEOU), encouraging QCT acceptance. On the other hand, insecurity refers to distrust in technology, fearing risks such as security breaches or system failures. Discomfort reflects concerns about complexity and difficulty in using QCT (Godoe & Johansen, 2012). These inhibitors negatively impact perceived usefulness and ease of use, making individuals more hesitant to accept QCT.

By integrating TRI and TAM, this framework provides a comprehensive approach to understanding QCT acceptance. If QCT is perceived as both useful and easy to use, individuals are more likely to adopt it. However, if insecurity and discomfort outweigh optimism and innovativeness, acceptance may be hindered. This framework is particularly relevant in Malaysia, where QCT is still emerging, and factors influencing readiness must be thoroughly assessed. Understanding these dimensions will help policymakers, researchers, and institutions develop strategies to increase awareness, reduce concerns, and promote QCT acceptance in academic and professional environments.

Based on this theory Figure 4 is the research framework developed for this study.

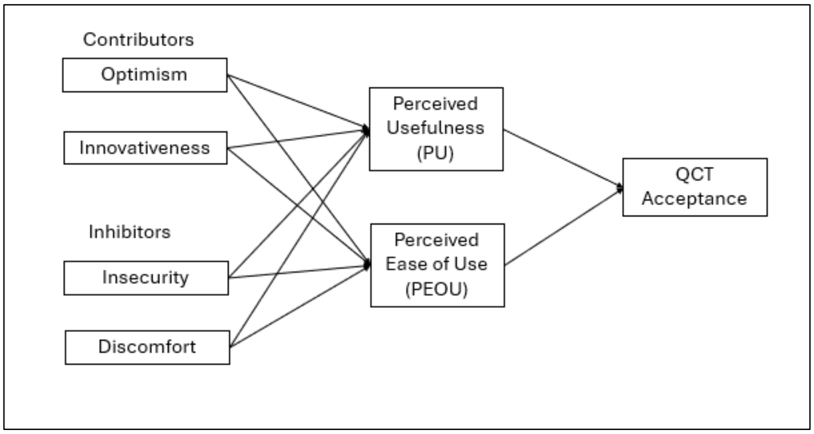

Fig 4: Theoretical framework

The literature review highlights the transformative potential of QCT in cybersecurity, the global initiatives in quantum technology, and Malaysia's current challenges in adopting the technology. The Systematic Literature Review (SLR) reveals a significant research gap in QCT readiness and acceptance within the Malaysian context, emphasizing the need for empirical investigation. By employing TRAM, this study able to identify key determinants influencing perceptions on acceptance of QCT, offering insights that will inform policy decisions and strategic initiatives for quantum technology integration in Malaysia's higher education sector.

This study investigates the factors influencing the acceptance of Quantum Communication Technology (QCT), guided by the Technology Readiness and Acceptance Model (TRAM). The study focus on how individual traits which are optimism, innovativeness, discomfort, and insecurity affect perceived usefulness and ease of use, which in turn influence QCT acceptance. Understanding these relationships is crucial in assessing readiness to accept QCT, as they play a key role in research, education, and policy development.

Optimism and innovativeness are expected to positively impact perceived usefulness and ease of use. Optimism refers to an individual's positive belief that technology enhances efficiency and improves quality of life. Thus, potential users with a high level of optimism are more likely to perceive QCT as beneficial for their work, enhancing research capabilities and facilitating secure communication.

Additionally, optimism is linked to ease of use, as individuals with a positive outlook tend to approach new technology with confidence, making them more likely to perceive QCT as user-friendly. Similarly, innovativeness, which reflects a person's willingness to accept new technology before others, is hypothesized to enhance perceived usefulness and ease of use. Individuals who are open to exploring emerging technologies may find QCT valuable, while also perceiving it as easier to integrate into current system.

However, discomfort and insecurity may hinder perceptions of QCT's usefulness and ease of use. Discomfort refers to the apprehension or lack of confidence in using advanced technologies, often stemming from unfamiliarity or perceived complexity. If individuals feel discomfort with QCT, they may perceive it as less useful in their work and more difficult to use.

Insecurity, on the other hand, is related to concerns about the risks associated with new technologies, such as data security, reliability, and ethical considerations. If individuals perceive QCT as vulnerable to cyber threats or as a technology with uncertain outcomes, they are likely to view it as less useful and harder to implement. Addressing these concerns is crucial for improving perceptions of QCT's viability.

Finally, the study proposes that perceived usefulness and perceived ease of use directly influence the acceptance of QCT. Perceived usefulness refers to the belief that QCT provides significant benefits in research, teaching, and secure communication. If individuals see clear advantages in using QCT, such as enhanced data protection and security, they will be more inclined to accept it.

Additionally, perceived ease of use plays a crucial role in acceptance, as technology that is accessible is more likely to be accepted. If potential users find QCT simple to use, they will be more willing to accept it.

Overall, this study highlights the importance of readiness in shaping QCT acceptance. By concluding optimism and innovation while addressing discomfort and insecurity, stakeholders can enhance readiness for QCT. This study is valuable for policymakers, educational institutions, and technology developers aiming to promote QCT acceptance in Malaysia's higher education sector.

6. Conclusion

This paper has outlined a theoretical framework for understanding the acceptance of Quantum Communication Technology (QCT) by applying the Technology Readiness and Acceptance Model (TRAM). Through a systematic literature review (SLR), there is significant gaps in existing research in Malaysia. This gap also result in the absence of comprehensive national policies about QCT.

The need to safeguard communication systems and improve cybersecurity is focus behind the development of QCT. As cyber threats become more sophisticated, the importance of quantum-secured communication grows. This technological advancement is crucial for industries dealing with sensitive information, including government, finance, healthcare, and telecommunications. Understanding the acceptance of QCT will assist the potential user to strategize in making decisions to protect against cybersecurity threats.

This paper suggests to developing the theoretical framework using TRAM model to assess readiness and acceptance in the context of QCT. TRI focuses on the psychological factors that influence an individual's or organization's willingness to adopt new technologies. These behavioral factors essential in shaping how likely people are to accept QCT. Individuals who have higher levels of optimism and innovative are more likely to embrace QCT, whereas those who feel discomfort or insecurity may resist acceptance.

Besides, TAM contributes to understanding how PEOU and PU impact technology acceptance. In the context of QCT, PEOU refers to how easy and accessible individuals find QCT technology, while PU relates to the extent to which QCT is seen as beneficial in addressing communication security. TAM's focus on these factors complements TRI, as it provides insight into how technological attributes influence individuals' attitudes toward adopting QCT.

By integrating TRI and TAM within the TRAM framework, this paper emphasizes the importance of addressing both psychological and perceptual barriers that could hinder the acceptance of QCT. Understanding how behavioral readiness (via TRI) and perceived ease of use and usefulness (via TAM) influences QCT acceptance enables policymakers and organizations to propose more strategies to encourage its adoption. These strategies could involve awareness campaigns, training programs, and initiatives aimed at increasing confidence in QCT by improving knowledge in its benefits.

This study lacks empirical study on QCT in Malaysia, existing QCT literature focuses predominantly on technical aspects rather than management. Therefore, this study recommends the need for more empirical research to test the applicability of this framework and explore the factors influencing QCT acceptance in Malaysia. By focusing on these factors, future research can help create a more quantum-ready ecosystem and guide the effective integration of QCT into existing communication infrastructures.

In conclusion, the application of the TRAM model, with its integration of TRI and TAM, provides a comprehensive framework for understanding the acceptance of QCT. This theoretical framework not only contributes to academic literature but also lays the foundation for future research and policy development, which is essential for ensuring the successful integration of QCT into global communication systems.

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