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RESEARCH ARTICLE

Analysis of Quantum Computing's Applicability in Data Analysis: Utilizing a Hybrid MCDM Approach With Quantum Spherical Fuzzy Sets

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ABSTRACT Quantum computing offers transformative processing capabilities, particularly in data analysis. However, its adoption in developing countries like Vietnam faces significant barriers, such as financial constraints, infrastructural limitations, and skill shortages. This study aims to determine and analyze these barriers' impact weights and evaluate and rank potential solutions for overcoming the most critical barriers. This study proposes a multi-faceted approach integrating Multi-Criteria Decision Making (MCDM) methods, including the Delphi Method (DELPHI), Decision Making Trial And Evaluation Laboratory (DEMATEL), Combined Compromise Solution (COCOSO), Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), and the Multiplicative form of Multi-objective Optimization based on Ratio Analysis method (MULTIMOORA), alongside the Quantum Spherical Fuzzy (QSF) set analysis. This combination, especially integrating QSF DELPHI and QSF COCOSO models, represents a significant methodological contribution. Results indicate that Vietnam's primary barriers to quantum computing are limited infrastructure, high costs, and a lack of skilled workforce. Correspondingly, the most highly rated solution strategies are cost reduction initiatives, investment in infrastructure, and training and education programs, which should be prioritized and considered to remove potential barriers. These findings highlight the need to prioritize addressing issues in facilities, human resources, and financial resources. This research bridges theoretical insights with actionable recommendations, providing a comprehensive roadmap for mitigating barriers and promoting the integration of quantum computing into Vietnam's data analysis landscape.

INDEX TERMS Quantum, quantum spherical fuzzy sets, MCDM, data analysis, quantum theory.

I. INTRODUCTION

A. RESEARCH BACKGROUND

Quantum computing represents a paradigm shift in computing technology, offering unprecedented potential for solving complex real-world problems [1]. Unlike classical computers, which operate using binary bits (0 s and 1 s), quantum computing leverages quantum bits, or qubits, which can exist in multiple states simultaneously due to the principles of quantum entanglement and superposition [2]. This enables quantum computers to perform trillions of logic operations per second, far surpassing the capabilities of traditional computers [3]. For example, Google's Sycamore quantum computer solved a mathematical problem in just 200 seconds, a task that would take the world's most powerful supercomputer 10,000 years to complete. Similarly, China's Jiuzhang quantum computer achieved the same feat in less than one second, compared to nearly five years for a supercomputer [4]. This remarkable speed and efficiency demonstrate the transformative potential of quantum computing across various industries.

Quantum computing holds immense promise for revolutionizing various professions, including data analysis [5]. As an essential process, data analysis involves gathering, processing, and synthesizing information to derive insights and recommendations. In an era dominated by digital

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advancements like the Internet of Things (IoT), artificial intelligence (AI), blockchain, and big data, the significance of data analysis is paramount. Data's exponential growth and complexity necessitate advanced computational capabilities for precise analysis. Quantum computing, with its inherent computational advantages over traditional systems, presents a groundbreaking solution for enhancing the efficiency and accuracy of data analysis in this digital age [6].

While the potential of applying quantum computing to data analysis is significant, it encounters numerous barriers, particularly in developing nations like Vietnam. Despite its digital transformation, Vietnam aspires to integrate cuttingedge technologies into its production and business sectors to propel national development [7], [8]. Interest in quantum computing technology is growing, and initial research investments are being made. However, the country still faces substantial challenges in fully harnessing this technology.

These challenges include limited investment in quantum technology, inadequate physical infrastructure, technical shortages, and a lack of professional expertise and public awareness regarding new technologies. The barriers specific to Vietnam stem from financial constraints, infrastructural limitations, and a shortage of skilled personnel. Addressing these issues is crucial for Vietnam to leverage the benefits of quantum computing in data analysis and to support its broader digital transformation goals. Hence, identifying and prioritizing solutions to overcome these barriers is essential for integrating quantum computing into Vietnam's data analysis landscape and fostering technological advancement in the region [1], [9], [10], [11], [12]. Accordingly, the research objectives are outlined as follows:

(i) Identify barriers to applying quantum computing to data analysis in Vietnam

(ii) Determine the influence weights of barriers and find out the mutual impact of the relationship

(iii) Propose and rank solution strategies in addressing barriers

From the above objectives, below are the questions that the research will answer:

(i) What are the primary obstacles hindering the integration of quantum computing into data analysis practices in Vietnam?

(ii) What is the magnitude of influence these identified barriers exert, and how are they interconnected?

(iii) Which solution strategy holds the most promise in alleviating these barriers and facilitating the adoption of quantum computing for data analysis in Vietnam?

To address the research questions and objectives, these issues are considered within the decision-making process, integral to various aspects of human life, and increasingly complex with numerous alternatives and intricate issues. Multi-Criteria Decision-Making (MCDM) and MultiAttribute Group Decision-Making (MAGDM) methods are widely employed to navigate such complexities across various domains. Several decision-making methods have been introduced in the literature, including fuzzy logic models and their variations, to manage uncertainty in decision-making processes [13], [14], [15], [16], [17], [18]. Given the intricate nature of natural systems, decisionmakers frequently encounter uncertainties while making decisions based on incomplete, ambiguous, and inaccurate information. The theory of Fuzzy Sets (FSs) proposed by Zadeh [19] enables a gradual assessment of the membership relationship between an element and a set, elucidated through a membership function. Triangular fuzzy numbers are widely utilized among the various fuzzy numbers. While triangular fuzzy numbers measure membership degree, they fail to assess the degree of non-membership and the level of uncertainty [14], [18], [20]. Spherical Fuzzy Sets (SFSs), introduced by Gündoğdu and Kahraman [21], offer a comprehensive framework that considers an object's degree of membership $x_{\tilde{P}_s}(s)$, non-membership $y_{\tilde{P}_S}(s)$, and degree of hesitation $z_{\tilde{P}_s}(s)$ to handle uncertainty, with constraint $0 \leq x^2_{\tilde{P}_s}(s) + y^2_{\tilde{P}_s}(s) + z^2_{\tilde{P}_s}(s) \leq 1$ [22], [23], [24]. Thus, the main superiority of SFSs overcomes the limitations of triangular fuzzy sets by incorporating the level of nonmembership and hesitation, leading to a more comprehensive and accurate reflection of membership within the set [16], [25], [26]. Despite these advancements, defining the appropriate membership degrees in SFSs still needs to be addressed in decision-making [27].

Lately, quantum mechanics offers a new perspective on decision-making processes by incorporating the principles of quantum theory, including amplitude and phase angle [27]. The quantum model of mass function integrates different angles to analyze the probabilities of various conditions, enabling a more precise examination of uncertainty in complex information sets. Further efficiencies can be achieved when addressing probabilities in decision-making contexts using quantum theory concepts such as amplitude and phase angle [27], [28]. This leads to the Quantum spherical fuzzy sets (QSFS) concept. The advantages of the proposed QSFS model include improved accuracy, enhanced understanding of uncertainty, broad applicability, integration of multiple parameters, and solid theoretical grounding [29]. Utilizing QSFS with the golden cut enables a more accurate representation of complex decision-making problems. By incorporating amplitude and phase angles, the methodology captures nuanced degrees of membership, non-membership, and hesitancy, leading to more precise results. It also provides a comprehensive characterization and analysis of uncertainty in decision-making, with the phase angle playing a crucial role in understanding the relationships and relative importance of different components within the QSFS [30], [31]. Again, the concept of phase angles has widespread application in various disciplines, such as physics, engineering, and mathematics. By incorporating phase angles within the framework of QSFS, the methodology extends its applicability to diverse domains, allowing for the analysis and synchronization of signals, waveforms, and oscillations [30]. Another point of view is the methodology that considers the simultaneous evaluation of membership, non-membership, and hesitancy degrees in decision-making.

This comprehensive approach provides a holistic understanding of uncertain information, enabling decisionmakers to simultaneously make informed choices based on multiple parameters. So, the methodology is built upon established theoretical foundations, including quantum mechanics, fuzzy sets, and the golden cut [32]. By integrating these theories, the methodology benefits from the robustness and rigor of existing academic frameworks, enhancing its credibility and reliability. Therefore, a threestage MCDM approach combining DELPHI, DEMATEL, and COCOSO methods integrated with QSF numbers is proposed to simulate the topic of quantum computing's applicability in data analysis compared to TOPSIS and MULTIMOORA. Initially, the DELPHI method validates the significance and relevance of identified risks. Subsequently, validated risks undergo weighting for influence and cause-and-effect relationship analysis using the QSF DEMATEL method. Compared to other weight calculation methods like Simple Additive Weightage (SAW) and AHP, DEMATEL offers the advantage of identifying cause-and-effect relationships between factors. It distinguishes between causal and effect factors while also determining the weight of each factor, providing a comprehensive overview of the factors being evaluated [33], [34], [35].

Finally, proposed strategies are ranked for efficacy and practicality using the QSF COCOSO method. The COCOSO method is used and demonstrates its superiority over other ranking methods by allowing sensitive analysis to be performed, thereby checking the accuracy and consistency of ranking results [36], [37], [38]. Furthermore, a comparative analysis is conducted using QSF TOPSIS and QSF MULTIMOORA methods. QSF TOPSIS has been used in previous studies for ranking, while MULTIMOORA has an algorithm quite similar to COCOSO, so these two methods were used to conduct comparative analysis. Expert weights are incorporated across all phases to enhance data accuracy. This study employs the MCDM method to address the multifaceted problem of barriers affecting the application of quantum computing to data analysis in Vietnam. Given the numerous interrelated factors, the study integrates MCDM methods, specifically DELPHI, DEMATEL, and COCOSO, to sequentially identify, validate, calculate weights, determine relationships among factors, and rank solution strategies. To enhance the accuracy of the research outcomes, QSF sets are combined with MCDM methods. QSF sets have been demonstrated to offer significant improvements over traditional fuzzy sets, thereby enhancing the precision and quality of the research results.

B. RESEARCH CONTRIBUTIONS

The main contributions of the paper are as follows:

(i) An analysis prioritizing barriers to quantum computing implementation in data analysis, particularly in Vietnam, was conducted. The addition of expert weights is carried out to reflect the assessments more accurately, thereby improving the accuracy of the calculation results. Based on its findings, this study aims to provide practical business insights. However, there is a scarcity of literature on this topic, necessitating further analysis to identify critical strategies for quantum computing applications in data analysis. Such efforts promise to significantly enhance enterprise performance and highlight quantum computing's transformative potential in various industries through increased speed and efficiency.

(ii) Causality analysis was performed among these barriers. Existing literature primarily focuses on the determinants of quantum computing and data analysis indicators separately, with few studies exploring their causal relationships. Despite this gap, barriers affecting quantum computing in Vietnam's data analysis can mutually influence each other. For example, increased investment in quantum technology could mitigate technical shortages, while heightened public awareness of new technologies might improve infrastructure and professional expertise in data analytics. The DEMATEL method is optimal for evaluating these determinants as it identifies causal relationships among the barriers.

(iii) Traditional fuzzy decision-making models are commonly proposed to analyze barriers and prioritize strategies within enterprises. However, the complexity of modern decision-making processes presents challenges in achieving accurate solutions. Hence, there is a critical need for a new, comprehensive decision-making model. The proposed model integrates Spherical Fuzzy Sets (SFSs) with quantum logic to incorporate probabilities of various scenarios. Currently, literature integrating Spherical Fuzzy Numbers with Quantum theory is limited, constraining exploration in decision-making studies. Another advantage of the proposed model is its use of the golden ratio for degree calculations, aiding in identifying more effective strategies to enhance company performance.

(iv) Using SFSs expands the scope of parameters considered in the examination process, broadening the analysis domain. This enhancement positively impacts the effectiveness of the proposed model, employing COCOSO and MULTIMOORA ranking methods. Additionally, utilizing the TOPSIS method for ranking potential strategies offers distinct advantages by considering distances to both positive and negative ideal solutions, facilitating more precise rankings. In contrast, other decision-making techniques typically rank alternatives based solely on their proximity to optimal positive results. Considering these factors, the proposed model is expected to excel in addressing complex decision-making structures.

The subsequent sections of this research comprise four parts. Section II will conduct a literature review and introduce the research model. Section III will elaborate on the concepts and computational formulas relevant to each method. Section IV will showcase the case study and analyze the findings. Lastly, section V will summarize the research outcomes and provide conclusions.

II. LITERATURE REVIEW

A. LITERATURE REVIEW ON ESTABLISHED METHODS

In recent years, researchers have increasingly integrated QSF sets with MCDM methods to address various research topics. **Table 1** below provides a summary of ten studies employing this combined model. The literature primarily focuses on finance, sustainability, and mergers, using established decision-making techniques like DEMATEL, M-SWARA, TOPSIS, and others. In contrast, the proposed method integrates these techniques with quantum spherical fuzzy logic, offering broader applicability across diverse industries and complex decision contexts. For example, Ai et al. [39] utilized QSF in conjunction with the Multi Stepwise Weight Assessment Ratio Analysis (M-SWARA) and Elimination and Choice Translating Reality (ELECTRE) methods to investigate the components of the fintech ecosystem for distributed energy investments.

Similarly, Al-Binali et al. [40] employed QSF DEMATEL and QSF M-SWARA methods to analyze Islamic and Conventional Bank mergers and enhance resilience. More recent models incorporating QSF with ENTROPY weighting method (ENTROPY), Additive Ratio Assessment (ARAS), and TOPSIS methods were proposed by Eti et al. [41] to identify top investment priorities for driving innovation. Rahadian et al. [42] utilized M-SWARA and TOPSIS methods in combination with QSF to identify the most appropriate investor risk profile for derivative instruments. In the fields related to energy, environment, and sustainable development, Aksoy et al. [43] and Hacioglu et al. [28] employed the QSF model with DEMATEL and TOPSIS methods to respectively evaluate electricity production capacity in emerging markets and rank sustainable industry alternatives. Dinçer et al. [44] used a one-stage model with QSF DEMATEL to explore organizations' challenges in prioritizing sustainability reporting aligned with Sustainable Development Goals (SDGs). Du et al. [27] proposed a new model combining QSF with the Simplified Group Best Worth Method (SGBWM) and Preference Ranking Organization Method For Enrichment Evaluations and Prospect Theory (PROMETHEE-PT) to analyze carbon emission reduction contributions of electricity enterprises in urban green development. In the energy sector, Kou et al. [45] proposed a model using M-SWARA, DEMATEL, ELECTRE, and TOPSIS methods combined with QSF for renewable energy project selection. Additionally, Yüksel and Dinçer [46] employed the same four methods to conduct a sustainability analysis of digital transformation and circular industrialization. While existing methods in the literature are well-established for their respective domains, the proposed method innovatively combines traditional decision-making frameworks with advanced quantum and fuzzy logic approaches.

Though established methods in the literature are robust within their specific domains, the proposed approach innovatively integrates traditional decision-making frameworks with advanced quantum and fuzzy logic methodologies. This innovation enables a more nuanced analysis of barriers and strategies in applying quantum computing to data analysis. The proposed method aims to enhance decision-making effectiveness by considering both deterministic and probabilistic factors through QSF integration. This comprehensive approach is anticipated to yield more precise and effective strategies than conventional methods in the literature.

Previous research has commonly integrated QSF sets with MCDM methods such as M-SWARA, DEMATEL, SGBWM, and ENTROPY for factor weighting. MCDM techniques like ELECTRE, TOPSIS, PROMETHEE-PT, and ARAS have also been employed for alternative ranking. However, these studies typically lack validation of input variables through expert assessments before weighting and often do not incorporate experts' qualifications and experience in their analyses. Moreover, specific MCDM methods such as COCOSO, MULTIMOORA, VIseKriterijumska Optimizacija IKompromisno Resenje (VIKOR), and SAW have not been extensively explored.

Addressing these research gaps, this study proposes a model integrating QSF with three primary MCDM methods—DELPHI, DEMATEL, and COCOSO—alongside comparative analysis using TOPSIS and MULTIMOORA. The aim is to identify barriers to applying quantum computing to data analysis and propose solution strategies. Specifically, the QSF DELPHI method validates the identified barriers in the literature review. Validated barriers undergo weighting, and causal relationships are determined using the QSF DEMATEL method. Strategies are subsequently ranked using the QSF COCOSO method. The ranking results are compared using the same dataset, derived from QSF TOPSIS and QSF MULTIMOORA methods. Additionally, the study calculates expert weights based on education and experience, proposing an aggregate formula to account for variations in weightage. This approach aims to provide a comprehensive framework that integrates expert insights and advanced methodologies to address the complexities of quantum computing applications in data analysis, particularly in developing country contexts like Vietnam.

B. LITERATURE REVIEW ON BARRIERS

Previous studies have explored the barriers to implementing quantum computing technology across various domains. Awan et al. [9] investigated challenges specific to the software industry, shedding light on critical obstacles hindering the practical application of quantum computing. Imre et al. [11] examined barriers concerning communication and human resource aspects in the context of quantum computing adoption. Similarly, Cuomo et al. [47] highlighted barriers

TABLE 1. Literature review on established methods.

No	Authors	Key Point	Quantum Spherical Fuzzy	Validate factors	Calculate Factor Weight	Ranking Alternative
1	Ai et al. [39]	"Exploring the elements of fintech ecosystems for decentralized energy investments."	υ		M-SWARA	ELECTRE
2	Al-Binali et al. [40]	"Examining mergers between Islamic and conventional banks to strengthen resilience"	υ		DEMATEL M-SWARA	
3	Aksoy et al. [43]	"Assessing electricity production capacities in emerging markets."	υ		DEMATEL	TOPSIS
4	Hacioglu et al. [28]	"Prioritizing sustainable industry alternatives in emerging markets"	υ		DEMATEL	TOPSIS
5	Yüksel and Dinçer [46]	"Analyzing sustainability in the context of digital transformation and circular industrialization."	υ		DEMATEL M-SWARA	TOPSIS ELECTRE
6	Dinçer et al. [44]	"Addressing challenges in prioritizing sustainability reporting aligned with SDGs."	υ		DEMATEL	
7	Du et al. [27]	"Analyzing contributions to carbon emission reduction in urban green development by electricity enterprises."	υ		SGBWM	PROMETHEE-PT
8	Eti et al. [41]	"Identifying key investment priorities to foster innovation."	υ		ENTROPY	ARAS TOPSIS
9	Kou et al. [45]	"Selecting renewable energy projects"	υ		M-SWARA DEMATEL	ELECTRE TOPSIS
10	Rahadian et al. [42]	"Determining optimal investor risk profiles for derivative instruments."	υ		M-SWARA	TOPSIS
11	***This Research***	***"Identify barriers in applying quantum computing to data analysis and propose solutions strategies."***	$\boldsymbol{\upsilon}$	***DELPHI***	***DEMATEL***	***COCOSO TOPSIS MULTIMOORA***

from public awareness perspectives. In a broader context, Fanelli [48] identified barriers to adopting new technologies within rural small and medium enterprises (SMEs), thereby encompassing additional challenges relevant to the application of quantum computing in Vietnam-a developing country with a significant SME presence. To initiate this analysis, an extensive search was conducted across reputable library databases, including Science Direct, Scopus, and Web of Science. Various keywords and search strings such as "quantum computing barriers," "applied quantum computing in Vietnam," and "barriers in applying quantum computing for data analysis" were employed to retrieve relevant scholarly papers. This study has identified 17 potential barriers to applying quantum computing in data analysis within Vietnam, as outlined in **Table 2**.

Several barriers related to physical facilities and technical infrastructure have been identified by researchers in the context of applying quantum computing in Vietnam. Infrastructure Accessibility (BAR4) has been highlighted by Almudever et al. [52], indicating that access to quantum computing resources and expertise may be limited outside major cities in Vietnam, potentially hindering widespread adoption. Awan et al. [9] also identified Infrastructure Stability (BAR11) and Limited Infrastructure (BAR12) as significant barriers. Infrastructure Stability refers to power supply, internet connectivity, and infrastructure stability challenges, which may impact the reliability and performance of quantum computing systems in Vietnam. Limited Infrastructure suggests that Vietnam may lack the quantum computing infrastructure to support advanced data analytics applications. Integration Complexity (BAR9) was noted by Benedetti et al. [55] as another notable barrier, highlighting the challenges associated with integrating quantum computing technologies with existing data analytics systems and workflows. Similarly, Gill et al. [2] mentioned Standards and Interoperability (BAR15) as a barrier, emphasizing the lack of standardized protocols and interoperability frameworks for quantum computing and data analytics tools, hindering adoption and collaboration. Additionally, Bova et al. [1] identified Data Security Concerns (BAR8) as a barrier, emphasizing the new security risks and vulnerabilities intro-

TABLE 2. List of potential barriers.

Code	Barriers	References
BAR1	Educational Gap	[11], [49]
BAR2	Public Awareness	[47]
BAR3	Ethical and Societal Implications	[50], [51]
BAR4	Infrastructure Accessibility	[52], [53]
BAR5	Lack of Skilled Workforce	[9], [11]
BAR6	Government Support and Policies	[48]
BAR7	Regulatory Challenges	[48]
BAR8	Data Security Concerns	[1], [54]
BAR9	Integration Complexity	[55]
BAR10	High Costs	[9], [48]
BAR11	Infrastructure Stability	[9]
BAR12	Limited Infrastructure	[9], [12]
BAR13	Cultural Acceptance	[47]
BAR14	Limited Research and Development	[9], [56]
BAR15	Standards and Interoperability	[2], [57]
BAR16	Risk Aversion	[58]
BAR17	Energy Consumption	[59]

duced by quantum computing, which may pose significant challenges for organizations in Vietnam if not addressed adequately. In addition to technical constraints, barriers associated with human factors are also of significant concern. With new technologies like quantum computing, addressing the Educational Gap (BAR1) and the subsequent Lack of Skilled Workforce (BAR5) becomes imperative. Imre [11] highlights the Educational Gap as indicative of the education system's failure to adequately equip Vietnamese students with the necessary quantum computing and data analytics knowledge and skills. This deficiency may lead to a shortage of qualified professionals capable of driving innovation in this field, thereby hindering the implementation and utilization of quantum computing solutions for data analysis tasks [11], [49]. Furthermore, societal and cultural factors play a significant role in accepting and adopting new technologies. Issues such as Public Awareness (BAR2), Cultural Acceptance (BAR13), Risk Aversion (BAR16), and Ethical and Societal Implications (BAR3) pose substantial challenges. Cuomo et al. [47] highlight issues related to Public Awareness, citing limited awareness among businesses and organizations in Vietnam about the potential benefits and applications of quantum computing in data analytics. Organizations may overlook opportunities to leverage quantum computing for data analysis without understanding its capabilities. Additionally, as noted by Kara et al. [24], Cultural Acceptance suggests that resistance to change and cultural biases may impede the acceptance and adoption of quantum computing solutions within organizations. Moreover, Risk Aversion, emphasized by Orús et al. [58], presents a significant obstacle, with Vietnamese businesses and organizations reluctant to adopt n, unproven technologies like quantum computing. Fear of failure or uncertainty about returns on investment may discourage organizations from embracing quantum computing initiatives. Finally, concerns regarding Ethical and Societal Implications, as Perrier [50] and Saurabh et al. [51], underscore the need to consider ethical and societal ramifications of using quantum computing technology in data analytics. Privacy, data sovereignty, and potential societal impacts may influence the adoption and implementation of quantum computing solutions in Vietnam. Furthermore, Fanelli [48] identifies two additional barriers concerning governmental and legal aspects relevant to the adoption of new technologies: Government Support and Policies (BAR6) and Regulatory Challenges (BAR7), respectively. The absence of governmental backing, financial support, and coherent policies to foster quantum computing research and development could impede advancements in Vietnam. Similarly, from a legal standpoint, vague or insufficient regulatory frameworks governing quantum computing in Vietnam introduce uncertainty and may discourage organizations from pursuing innovative initiatives. Without clear regulatory guidelines, businesses may hesitate to invest in quantum computing projects due to concerns about regulatory compliance. Finally, cost-related issues, investment capital constraints, and resource limitations pose significant barriers to adopting quantum computing. Awan et al. [9] and Fanelli [48] both highlighted the barrier named High Costs (BAR10). The substantial financial investment required for developing, procuring, and maintaining quantum computing technology presents a formidable challenge for organizations in Vietnam. Limited financial resources may deter investment in quantum computing initiatives, hindering widespread adoption. Moreover, the lack of sufficient Research and Development (R&D) (BAR14) investment for expensive technologies like quantum computing, particularly in a developing country like Vietnam, is noteworthy. As highlighted by Ajagekar and You [56], inadequate investment in quantum computing R&D in Vietnam, compared to other countries, slows down progress in the field. This scarcity of funding and support stifles innovation and impedes the advancement of quantum computing technologies. Furthermore, as highlighted by Ajagekar and You [59], Energy Consumption (BAR17) poses another significant challenge. Quantum computing systems require substantial amounts of energy to operate, which may pose difficulties in Vietnam, where energy resources are limited or expensive. High energy consumption may render quantum computing solutions economically unfeasible for some organizations.

C. PROPOSED SOLUTION STRATEGIES

Based on the identified barriers and extensive research on solutions implemented across various domains and countries, the research team has formulated ten strategic solutions to overcome obstacles to the early adoption of quantum computing for data analysis in Vietnam. The strategies outlined in **Table 3** represent a comprehensive approach to addressing the multifaceted challenges of integrating quantum computing technology.

TABLE 3. List of proposed strategies.

Code	Strategies	References
STG1	Curriculum Enhancement	[10], [60]
STG2	Investment in Infrastructure	[61]
STG3	Cost Reduction Initiatives	[2]
STG4	Enhanced Data Security Measures	[62]
STG5	Increase Research and Development Funding	[1]
STG6	Simplify Integration Processes	[63]
STG7	Accessibility Improvement	[64]
STG8	Regulatory Framework Development	[65]
STG9	Establish Standards and Protocols	[2], [66]
STG10	Training and Education Programs	[10], [60]

STG1 - Curriculum Enhancement: Revamping educational curricula to incorporate quantum computing and data analytics courses ensures that students receive comprehensive training. By integrating relevant coursework, educational institutions can prepare students to meet the demands of the evolving technological landscape [10], [60].

STG2 - Investment in Infrastructure: This strategy involves allocating resources to develop and enhance quantum computing infrastructure nationwide. By investing in infrastructure, Vietnam can create a supportive environment for advanced data analytics applications, enabling organizations to leverage quantum computing technology effectively [61].

STG3 - Cost Reduction Initiatives: Implementing measures to reduce the costs associated with quantum computing technology is essential for broader adoption. By lowering barriers to entry, organizations can more readily invest in quantum computing solutions for data analysis purposes [2].

STG4 - Enhanced Data Security Measures: Implementing comprehensive data security measures is essential for addressing the unique risks associated with quantum computing technologies. By prioritizing data security, organizations can mitigate potential threats and safeguard sensitive information [62].

STG5 - Increase Research and Development Funding: Increasing investment in quantum computing research and development accelerates progress in the field. By providing adequate funding, Vietnam can foster innovation and drive advancements in quantum computing technology [1].

STG6 - Simplify Integration Processes: Developing tools and frameworks to simplify the integration of quantum computing technologies with existing data analytics systems streamlines the adoption process. By reducing complexity, organizations can more efficiently incorporate quantum computing solutions into their workflows [63].

STG7 - Accessibility Improvement: Expanding access to quantum computing resources and expertise beyond major cities promotes equitable adoption across Vietnam. By improving accessibility, organizations in remote areas can also benefit from quantum computing technology [64].

STG8 - Regulatory Framework Development: Developing clear and robust regulatory frameworks for quantum computing is essential for providing guidance and ensuring compliance. By establishing regulatory standards, Vietnam can create a conducive environment for developing and adopting quantum computing technologies [65].

STG9 - Establish Standards and Protocols: Working towards establishing standardized protocols and interoperability frameworks for quantum computing and data analytics tools facilitates adoption and collaboration. By establishing clear standards, Vietnam can promote compatibility and interoperability among different systems and platforms [2], [66].

STG10 - Training and Education Programs: Establishing training and education programs is crucial for addressing the shortage of skilled quantum computing and data analytics professionals. By providing relevant training opportunities, Vietnam can develop a workforce with the necessary expertise to drive innovation in this field [10], [60].

III. METHODOLOGY

A. RESEARCH PROCESS

This study employs the MCDM method and Quantum Spherical Fuzzy numbers to analyze the barriers to applying quantum computing in Vietnam. MCDM techniques such as DELPHI, DEMATEL, and COCOSO are utilized, along with comparative and sensitivity analysis methods, to validate the ranking results of proposed strategies. The research process is illustrated in Figure 1 below:

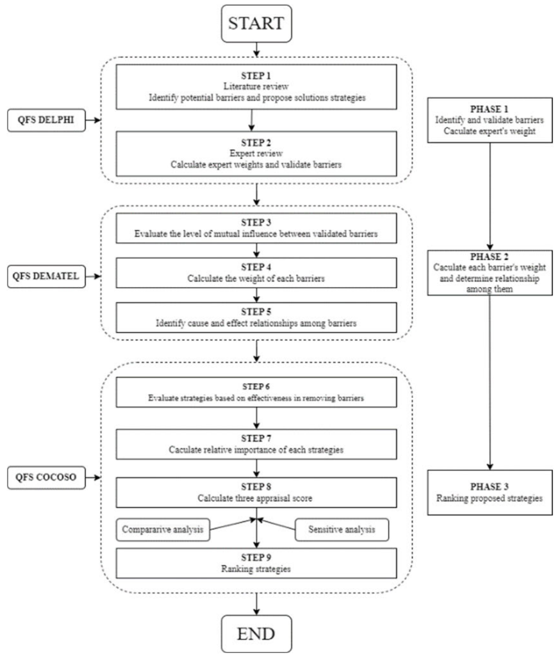

FIGURE 1. Research framework.

The research comprises three phases. Initially, potential barriers are identified and validated through a literature review process. Expert evaluations on the relevance and importance of these barriers are weighted based on their education and experience levels. The DELPHI method combined with Quantum Fuzzy Spherical (QSF DELPHI) is employed to validate accepted barriers in subsequent phases. In phase two, experts assess the mutual influence levels of the identified factors. QSF DEMATEL calculates weights and uncovers internal cause-and-effect relationships among the factors. Finally, in the third phase, experts evaluate potential strategies for their effectiveness in mitigating and overcoming barriers. The QSF COCOSO method is used to analyze the data, and the results are compared with those obtained using the QSF MULTIMOORA and QSF TOPSIS methods. Notably, expert assessments are recorded in linguistic form and then converted to QSF numbers using the scale presented in sections III-C-III-E.

B. QUANTUM SPHERICAL FUZZY (QSF)

As the complexity of decision-making problems increases, traditional methods have proven inadequate. Researchers have explored novel applications to address this challenge, including leveraging quantum mechanics for more effective problem-solving. In this context, probability is expressed through amplitude and phase angle components, allowing for the identification of probabilities under various conditions. This approach significantly enhances the management of uncertainties in decision-making processes [46]. Equations (1)-(3) elucidate the fundamental principles of this theory. In these equations, the collective exhaustive event set is denoted by δ, the amplitude result is presented as $|Q(|s\rangle)| = \psi^2$, $|\psi|^2$ represents the degree of belief, while the phase angle is denoted by ϱ [45].

$$Q(|s\rangle) = \psi e^{j\varrho} \tag{1}$$
$$|\delta\rangle = \{|s_1\rangle, |s_2\rangle, \ldots, |s_n\rangle\} \tag{2}$$
$$\sum_{|u\rangle \subseteq |\delta\rangle} |Q(|s\rangle)| = 1 \tag{3}$$

Gündoğdu and Kahraman introduced spherical fuzzy sets (SFSs) in 2019, which integrate with the quantum mechanics framework to reduce uncertainty and improve decisionmaking precision. Equations (4) and (5) explain how spherical fuzzy sets ($\tilde{P}_s$) combine membership, nonmembership, and hesitancy degrees in decision-making. The parameters x, y, z represent membership, non-membership, and hesitation, respectively [21].

$$\tilde{P}_s = \left\{\left\langle s, \left(x_{\tilde{P}_s}(s), y_{\tilde{P}_s}(s), z_{\tilde{P}_s}(s) | s \in U\right\}\right. \tag{4}$$
$$0 \le x^2_{\tilde{P}_s}(s) + y^2_{\tilde{P}_s}(s) + z^2_{\tilde{P}_s}(s) \le 1, \quad \forall_s \in U \tag{5}$$

Equations (6)-(8) elucidate the intricacies of integrating SFSs with quantum theory to form Quantum Spherical Fuzzy (QSF) sets. In these equations, membership, nonmembership, and hesitant degrees of the QSF set are denoted respectively by $\delta_{x_{\tilde{P}_s}}$, $\delta_{y_{\tilde{P}_s}}$, and $\delta_{z_{\tilde{P}}}$. Additionally, δ_x, δ_y, and δ_z Demonstrate the amplitudes of quantum membership, non-membership, and hesitancy degrees, and a, b, and c represent the set of ϱ phase angles.

$$\left|\delta_{\tilde{P}_s}\right\rangle = \left\{\left\langle s, \left(\delta_{x_{\tilde{P}_s}}(s), \delta_{y_{\tilde{P}_s}}(s), \delta_{z_{\tilde{P}_s}}(s) \,\middle|\, s \in 2^{|\delta_{\tilde{P}_S}}\right\rangle\right\} \tag{6}$$
$$\delta = \left[\delta_x \cdot e^{j2\pi \cdot a}, \delta_y \cdot e^{j2\pi \cdot b}, \delta_z \cdot e^{j2\pi \cdot c}\right] \tag{7}$$
$$\psi^2 = |\delta_x(|s_i\rangle)| \tag{8}$$

The efficient calculation of degrees is critical to ensuring evaluation accuracy. Thus, the golden ratio (GR) is used for this purpose [67]. Equations (9) - (10) elucidate the essential details. Here, l and g denote the large and small quantities along the straight line. There is a lack of consensus on membership and other scales among SFSs. To address this issue, the proposed model uses the golden ratio. This ratio uses extreme and mean ratios along a straight line to create coefficients between preceding and succeeding numbers. As a result, this classification is thought to be more meaningful, which improves the proposed model's originality and accuracy [40], [46].

$$GR = \frac{l}{g} \tag{9}$$
$$GR = \frac{1+\sqrt{5}}{2} \tag{10}$$

Non-membership degrees (δ_y) and hesitancy degrees (δ_z) are calculated using Equations (11)-(12)

$$\delta_y = \frac{\delta_x}{GR} \tag{11}$$
$$\delta_z = 1 - \delta_x - \delta_y \tag{12}$$

The phase angles (a, b, c) corresponding to the membership, non-membership, and hesitancy degrees of the QSF set are provided in Equations (13)-(15).

$$a = |\delta_x(|s_i\rangle)| \tag{13}$$
$$b = \frac{a}{GR} \tag{14}$$
$$c = 1 - a - b \tag{15}$$

Equations (16)-(20) present five basic operations of QSF number. In these equations, $\tilde{P}_s = \left(\delta_{x_{\tilde{P}}}.e^{j2\pi.a_{\tilde{P}}}, \delta_{y_{\tilde{P}}}.e^{j2\pi.b_{\tilde{P}}}, \delta_{z_{\tilde{P}}}.e^{j2\pi.c_{\tilde{P}}}\right)$ and $\tilde{Q}_s = \left(\delta_{x_{\tilde{Q}}}.e^{j2\pi.a_{\tilde{Q}}}, \delta_{y_{\tilde{Q}}}.e^{j2\pi.b_{\tilde{Q}}}, \delta_{z_{\tilde{Q}}}.e^{j2\pi.c_{\tilde{Q}}}\right)$ is two QSF numbers [27], [40], [46].

$$\lambda * \tilde{P}_s = \left\{\left(1-\left(1-\delta^2_{x_{\tilde{P}}}\right)^{\lambda}\right)^{\frac{1}{2}} e^{j2\pi\left(1-\left(1-\left(\frac{a_{\tilde{P}}}{2\pi}\right)^2\right)^{\lambda}\right)^{\frac{1}{2}}}, \delta^{\lambda}_{y_{\tilde{P}}} e^{j2\pi.\left(\frac{b_{\tilde{P}}}{2\pi}\right)^{\lambda}}, \left(\left(1-\delta^2_{z_{\tilde{P}}}\right)^{\lambda} - \left(1-\delta^2_{x_{\tilde{P}}}-\delta^2_{z_{\tilde{P}}}\right)^{\lambda}\right)^{\frac{1}{2}} e^{j2\pi.\left(\left(1-\left(\frac{c_{\tilde{P}}}{2\pi}\right)^2\right)^{\lambda} - \left(1-\left(\frac{a_{\tilde{P}}}{2\pi}\right)^2-\left(\frac{c_{\tilde{P}}}{2\pi}\right)^2\right)^{\lambda}\right)^{\frac{1}{2}}}\right\}, \lambda > 0 \tag{16}$$

$$\left(\tilde{P}_s\right)^{\lambda} = \left\{\delta^{\lambda}_{x_{\tilde{A}}} e^{j2\pi.\left(\frac{a_{\tilde{P}}}{2\pi}\right)^{\lambda}}, \left(1-\left(1-\delta^2_{y_{\tilde{P}}}\right)^{\lambda}\right)^{\frac{1}{2}} e^{j2\pi\left(1-\left(1-\left(\frac{b_{\tilde{P}}}{2\pi}\right)^2\right)^{\lambda}\right)^{\frac{1}{2}}}, \left(\left(1-\delta^2_{y_{\tilde{P}}}\right)^{\lambda} - \left(1-\delta^2_{y_{\tilde{P}}}-\delta^2_{z_{\tilde{P}}}\right)^{\lambda}\right)^{\frac{1}{2}} e^{j2\pi.\left(\left(1-\left(\frac{b_{\tilde{P}}}{2\pi}\right)^2\right)^{\lambda} - \left(1-\left(\frac{b_{\tilde{P}}}{2\pi}\right)^2-\left(\frac{c_{\tilde{P}}}{2\pi}\right)^2\right)^{\lambda}\right)^{\frac{1}{2}}}\right\}, \lambda > 0 \tag{17}$$

$$\tilde{P}_s \oplus \tilde{Q}_s = \left\{\left(\delta^2_{x_{\tilde{P}}} + \delta^2_{x_{\tilde{Q}}} - \delta^2_{x_{\tilde{P}}}\delta^2_{x_{\tilde{Q}}}\right)^{\frac{1}{2}} e^{j2\pi\left(\left(\frac{a_{\tilde{P}}}{2\pi}\right)^2 + \left(\frac{a_{\tilde{Q}}}{2\pi}\right)^2 - \left(\frac{a_{\tilde{P}}}{2\pi}\right)^2\left(\frac{a_{\tilde{Q}}}{2\pi}\right)^2\right)^{\frac{1}{2}}}, \delta_{y_{\tilde{P}}}\delta_{y_{\tilde{Q}}} e^{j2\pi\left(\frac{b_{\tilde{P}}}{2\pi}\right)\left(\frac{b_{\tilde{Q}}}{2\pi}\right)},\right.$$

$$\left(\left(1-\delta^2_{x_{\tilde{Q}}}\right)\delta^2_{z_{\tilde{P}}}+\left(1-\delta^2_{x_{\tilde{P}}}\right)\delta^2_{z_{\tilde{Q}}}-\delta^2_{z_{\tilde{P}}}\delta^2_{z_{\tilde{Q}}}\right)^{\frac{1}{2}} e^{j2\pi\left(\left(1-\left(\frac{a_{\tilde{Q}}}{2\pi}\right)^2\right)\left(\frac{c_{\tilde{P}}}{2\pi}\right)^2+\left(1-\left(\frac{a_{\tilde{P}}}{2\pi}\right)^2\right)\left(\frac{c_{\tilde{Q}}}{2\pi}\right)^2-\left(\frac{c_{\tilde{P}}}{2\pi}\right)^2\left(\frac{c_{\tilde{Q}}}{2\pi}\right)^2\right)^{\frac{1}{2}}}\Bigg\} \tag{18}$$

$$\tilde{P}_s\otimes\tilde{Q}_s = \Bigg\{\delta_{x_{\tilde{P}}}\delta_{x_{\tilde{Q}}}e^{j2\pi\left(\frac{a_{\tilde{P}}}{2\pi}\right)\left(\frac{a_{\tilde{Q}}}{2\pi}\right)},\ \left(\delta^2_{y_{\tilde{P}}}+\delta^2_{y_{\tilde{Q}}}-\delta^2_{y_{\tilde{P}}}\delta^2_{y_{\tilde{Q}}}\right)^{\frac{1}{2}} e^{j2\pi\left(\left(\frac{b_{\tilde{P}}}{2\pi}\right)^2+\left(\frac{b_{\tilde{Q}}}{2\pi}\right)^2-\left(\frac{b_{\tilde{P}}}{2\pi}\right)^2\left(\frac{b_{\tilde{Q}}}{2\pi}\right)^2\right)^{\frac{1}{2}}},$$
$$\left(\left(1-\delta^2_{y_{\tilde{Q}}}\right)\delta^2_{z_{\tilde{P}}}+\left(1-\delta^2_{y_{\tilde{P}}}\right)\delta^2_{z_{\tilde{Q}}}-\delta^2_{z_{\tilde{P}}}\delta^2_{z_{\tilde{Q}}}\right)^{\frac{1}{2}} e^{j2\pi\left(\left(1-\left(\frac{b_{\tilde{Q}}}{2\pi}\right)^2\right)\left(\frac{c_{\tilde{P}}}{2\pi}\right)^2+\left(1-\left(\frac{b_{\tilde{P}}}{2\pi}\right)^2\right)\left(\frac{c_{\tilde{Q}}}{2\pi}\right)^2-\left(\frac{c_{\tilde{P}}}{2\pi}\right)^2\left(\frac{c_{\tilde{Q}}}{2\pi}\right)^2\right)^{\frac{1}{2}}}\Bigg\} \tag{19}$$

Equation (20) is applied to defuzzy QSF number into crip value:

$$\mathrm{DEF}\left(\delta_{\tilde{P}}\right)=\delta_{x_{\tilde{P}}}+\delta_{z_{\tilde{P}}}\left(\frac{\delta_{x_{\tilde{P}}}}{\delta_{x_{\tilde{P}}}+\delta_{y_{\tilde{P}}}}\right)+\left(\frac{a_{\tilde{P}}}{2\pi}\right)+\left(\frac{b_{\tilde{P}}}{2\pi}\right)\left(\frac{\left(\frac{a_{\tilde{P}}}{2\pi}\right)}{\left(\frac{a_{\tilde{P}}}{2\pi}\right)+\left(\frac{c_{\tilde{P}}}{2\pi}\right)}\right) \tag{20}$$

Equation (21) is applied to the aggregated k QSF number. $(\delta_1, \delta_2, \ldots \delta_i, \ldots \delta_k)$ into δ.

$$\delta = \Bigg\{\left[1-\prod_{i=1}^{k}\left(1-\delta_{x_i}{}^2\right)^{\frac{1}{k}}\right]^{\frac{1}{2}} e^{2\pi\cdot\left[1-\prod_{i=1}^{k}\left(1-\left(\frac{a_i}{2\pi}\right)^2\right)^{\frac{1}{k}}\right]^{\frac{1}{2}}},$$
$$\prod_{i=1}^{k}\left(\delta_{y_i}\right)^{\frac{1}{k}} e^{2\pi\cdot\prod_{i=1}^{k}\left(\frac{b_i}{2\pi}\right)^{\frac{1}{k}}},\ \left[\prod_{i=1}^{k}\left(1-\delta_{x_i}{}^2\right)^{\frac{1}{k}}-\prod_{i=1}^{k}\left(1-\delta_{x_i}{}^2-\delta_{z_i}{}^2\right)^{\frac{1}{k}}\right]^{\frac{1}{2}} e^{2\pi\cdot\left[\prod_{i=1}^{k}\left(1-\left(\frac{a_i}{2\pi}\right)^2\right)^{\frac{1}{k}}-\prod_{i=1}^{k}\left(1-\left(\frac{a_i}{2\pi}\right)^2-\left(\frac{c_i}{2\pi}\right)^2\right)^{\frac{1}{k}}\right]^{\frac{1}{2}}}\Bigg\} \tag{21}$$

By considering each number's weight, Kou et al. [45] introduced the spherical weighted arithmetic mean (SWAM) formula to aggregate fuzzy spherical values. Similarly, this principle can be extended to QSF numbers, naming quantum fuzzy spherical weighted arithmetic (QSFWAM). With $\omega = (\omega_1, \omega_2, \ldots, \omega_k)$: $\omega_i \in [1, 0]$, $\sum_{i=1}^{k}\omega_i = 1$ being the weight of k QSF numbers, Equation (22) is used to aggregate k numbers into number δ.

$$QFSWAM_{\omega}\left(\delta_1, \delta_2, \ldots, \delta_k\right) = \Bigg\{\left[1-\prod_{i=1}^{k}\left(1-\delta_{x_i}{}^2\right)^{\omega_i}\right]^{\frac{1}{2}} e^{2\pi\cdot\left[1-\prod_{i=1}^{k}\left(1-\left(\frac{a_i}{2\pi}\right)^2\right)^{\omega_i}\right]^{\frac{1}{2}}},$$
$$\prod_{i=1}^{k}\left(\delta_{y_i}\right)^{\omega_i} e^{2\pi\cdot\prod_{i=1}^{k}\left(\frac{b_i}{2\pi}\right)^{\omega_i}},\ \left[\prod_{i=1}^{k}\left(1-\delta_{x_i}{}^2\right)^{\omega_i}-\prod_{i=1}^{k}\left(1-\delta_{x_i}{}^2-\delta_{z_i}{}^2\right)^{\omega_i}\right]^{\frac{1}{2}} e^{2\pi\cdot\left[\prod_{i=1}^{k}\left(1-\left(\frac{a_i}{2\pi}\right)^2\right)^{\omega_i}-\prod_{i=1}^{k}\left(1-\left(\frac{a_i}{2\pi}\right)^2-\left(\frac{c_i}{2\pi}\right)^2\right)^{\omega_i}\right]^{\frac{1}{2}}}\Bigg\} \tag{22}$$

Illustrative Example: With $\tilde{P}_s = \left(0.6e^{j2\pi 0.6}, 0.46904e^{j2\pi 0.37}, 0.64807e^{j2\pi 0.03}\right)$, $\tilde{Q}_s = (0.5ej^{2\pi 0.5}, 0.3873e^{i2\pi 0.31}, 0.7746e^{i2\pi 0.19})$, $\lambda = 3$, applying Equations (16)-(20), we obtain the following results:

$$2^*\left(0.6e^{i2\pi 0.6}, 0.46904e^{i2\pi 0.37}, 0.64807e^{j2\pi 0.03}\right)$$
$$=\left(0, 85899e^{i2\pi 0, 16465};0,10319e^{j2\pi 0,0002};0,4295e^{j2\pi 0, 16464}\right)$$
$$\left(0.6e^{i2\pi 0.6}, 0.46904e^{i2\pi 0.37}, 0.64807e^{i2\pi 0.03}\right)^3$$
$$=\left(0, 216e^{j2\pi 0,00087};0,72488e^{i2\pi 0,10182}; 0,65414e^{j2\pi 0,00824}\right)$$
$$\left(0.6e^{j2\pi 0.6},0.46904e^{i2\pi 0.37}, 0.64807e^{j2\pi 0.03}\right)\oplus\left(0.5ej^{2\pi 0.5}, 0.3873e^{j2\pi 0.31}, 0.7746e^{j2\pi 0.19}\right)$$
$$=\left(0,72111e^{j2\pi 0,12407};0,18166e^{j2\pi 0,00291};0,66858e^{j2\pi 0,03047}\right)$$
$$\left(0.6e^{j2\pi 0.6}, 0.46904e^{i2\pi 0.37}, 0.64807e^{j2\pi 0.03}\right)\otimes\left(0.5ej^{2\pi 0.5}, 0.3873e^{i2\pi 0.31}, 0.7746e^{j2\pi 0.19}\right)$$
$$=\left(0, 3e^{j2\pi 0,0076}; 0, 58052e^{i2\pi 0,07677}; 0, 75697e^{j2\pi 0,03056}\right)$$
$$\mathrm{DEF}\left(0.6e^{j2\pi 0.6}, 0.46904e^{i2\pi 0.37}, 0.64807e^{j2\pi 0.03}\right)$$
$$= 1, 11531$$

C. QSF DELPHI

Consider a scenario where k experts offer evaluations on n factors. Each expert assesses the importance of these factors using a linguistic scale, which is subsequently converted into QSF numbers through QSF sets. Moreover, experts are assigned weights based on their education and years of experience. After calculating the expert weights, these weights are applied to the corresponding expert's evaluation table. The weighted evaluation tables are then consolidated and used in subsequent phases. Consequently, experts with higher weights have a greater influence on the results.

The calculation process follows the outlined steps below [68], [69]:

Step 1: Calculate the weight of the expert.

Each expert's education level and years of experience will be transformed into QSF numbers based on **Table 4**. Subsequently, these results will be summed according to Equation (18) and then de-fuzzified using Equation (20) [24].

TABLE 4. Expert weighted rating scale.

Education	Experience	QSF
Doctor	Over 20 years	$(0.6e^{j2\pi 0.6}, 0.46904e^{j2\pi 0.37}, 0.64807e^{j2\pi 0.03})$
Master	10 – 20 years	$(0.54772e^{j2\pi 0.55}, 0.43589e^{j2\pi 0.34}, 0.71414e^{j2\pi 0.11})$
Bachelor	5 – 10 years	$(0.5ej^{2\pi 0.5}, 0.3873e^{j2\pi 0.31}, 0.7746e^{j2\pi 0.19})$
Under Bachelor	Under 5 years	$(0.44721e^{j2\pi 0.45}, 0.36056e^{j2\pi 0.28}, 0.81854e^{j2\pi 0.27})$

The result will be k values corresponding to k experts, respectively EXV: exv $v_i = \{exv_1, e\,xv_2, ..e\,xv_k\}$. From there, the weight of k expert EXW: exw $w_i = \{exw_1, e\,xw_2, ..e\,xw_k\}$ is calculated according to Equation (23) below:

$$e^{exw_i} = \frac{exv_i}{\sum_{i=1}^{k} exv_i} \tag{23}$$

Step 2: Summary of experts' assessments

Expert assessments are recorded in linguistic form and converted to QSF numbers according to **Table 5** [46]:

TABLE 5. QSF delphi linguistic important scale.

Important level	Code	QSF
Very low	VL	$(0.4e^{j2\pi 0.4}, 0.31623e^{j2\pi 0.25}, 0.86023e^{j2\pi 0.35})$
Low	L	$(0.44721e^{j2\pi 0.45}, 0.36056e^{j2\pi 0.28}, 0.81854e^{j2\pi 0.27})$
Medium	M	$(0.5ej^{2\pi 0.5}, 0.3873e^{j2\pi 0.31}, 0.7746e^{j2\pi 0.19})$
High	H	$(0.54772e^{j2\pi 0.55}, 0.43589e^{j2\pi 0.34}, 0.71414e^{j2\pi 0.11})$
Very high	VH	$(0.6e^{j2\pi 0.6}, 0.46904e^{j2\pi 0.37}, 0.64807e^{j2\pi 0.03})$

The evaluation of n factors by k experts, along with the corresponding weights of experts exw will be aggregated into nV_i values by applying Equation (22)

Step 3: Calculate the threshold value and validate the factor

With nV_i values corresponding to n factors, threshold value ϖ is calculated using Equation (24) below:

$$\varpi = \frac{\sum_{i=1}^{n} V_i}{n} \tag{24}$$

If the value $V_i \geq \varpi$ then factor i is accepted; otherwise, factor i will be rejected. Only the accepted factors will proceed to the subsequent phases.

D. QSF DEMATEL

Suppose k experts are engaged in assessing the interaction of n factors. The scale for evaluating the level of impact between factors is provided in **Table 6**, both in linguistic form and the corresponding QSF number [33], [46].

TABLE 6. QSF linguistic influence scale.

Influence level	Code	QSF
Equal Influence	EI	$(0.4e^{j2\pi 0.4}, 0.31623e^{j2\pi 0.25}, 0.86023e^{j2\pi 0.35})$
Low Influence	L	$(0.44721e^{j2\pi 0.45}, 0.36056e^{j2\pi 0.28}, 0.81854e^{j2\pi 0.27})$
Medium Influence	M	$(0.5ej^{2\pi 0.5}, 0.3873e^{j2\pi 0.31}, 0.7746e^{j2\pi 0.19})$
Very Influence	VI	$(0.54772e^{j2\pi 0.55}, 0.43589e^{j2\pi 0.34}, 0.71414e^{j2\pi 0.11})$
Absolutely Influence	AI	$(0.6e^{j2\pi 0.6}, 0.46904e^{j2\pi 0.37}, 0.64807e^{j2\pi 0.03})$

The expert's assessment is initially recorded in linguistic form and then converted to a QSF number for calculation. The calculation process using the DEMATEL method is presented below:

Step 1 (Establishing the Direct Relationship Matrix $\otimes F$): The assessment of k experts on the mutual impact of n factors (i affects j) along with the corresponding weights of k experts: $\{exw_1, e\,xw_2, ..e\,xw_k\}$ is compiled into matrix $\otimes\ F = [\otimes f_{ij}]_{nxn}$ using QSFWAM Equation. The diagonal elements in the matrix are 0, i.e., $\otimes f_{ij} = 0$ (when i = j) and $\otimes f_{ij}$ in the form QSF number: $\otimes f_{ij} = \left(\delta_{x_{fij}} \cdot e^{j2\pi \cdot a_{fij}}, \delta_{y_{fij}} \cdot e^{j2\pi \cdot b_{fij}}, \delta_{z_{fij}} \cdot e^{j2\pi \cdot c_{fij}}\right)$ where $i = 1, 2, \ldots n, j = 1, 2, \ldots n$.

Step 2 (Defuzzy Matrix $\otimes F$ Into Matrix $\otimes H$): The values of matrix $\otimes F$ are defuzzy using Equation (20) to form a new matrix $\otimes H$ consisting of crips values: $\otimes\ H = [\otimes\, h_{ij}]_{nxn}$ and $\otimes\, h_{ij}$ is crips score.

Step 3 (Normalize Matrix $\otimes H$ to Matrix $\otimes H^*$): Equation (25)-(26) is used to normalize matrix $\otimes H$ to the matrix. $\otimes H^* = \left[\otimes\, h^*_{ij}\right]_{nxn}$

$$\otimes\, h^*_{ij} = \tau.h_{ij} \tag{25}$$

where

$$\tau = Min\left\{\frac{1}{\sum_{i=1}^{n} h_{ij}}, \frac{1}{\sum_{j=1}^{n} h_{ij}}\right\} \tag{26}$$

Step 4 (Calculate the Total Influence Matrix $\otimes 0$): The normalized direct relationship matrix $\otimes H^*$ is computed into a comprehensive influence matrix. This integration encompasses direct and indirect influence relationships, aggregating them across a spectrum from minimal impact to maximal influence, spanning from the power of one to the power of infinity. The procedure is presented below:

$$\otimes 0 = [\otimes\, o_{ij}]_{nxn} \tag{27}$$

$$\otimes O = \otimes H^* + \otimes H^{*2} + \cdots + \otimes H^{*\infty}$$
$$= \otimes H^*\left(I + \otimes H^* + \otimes H^{*2} + \cdots + \otimes H^{*\infty-1}\right)$$

$$= \otimes H^{*}\left(I - \otimes H^{*\infty}\right)\left(I - \otimes H^{*}\right)^{-1}$$
$$= \otimes H^{*}\left(I - \otimes H^{*}\right)^{-1} \quad (28)$$

where $\otimes H^{*\infty} = [0]_{nxn}$ and I is the identity matrix

Step 5 (Determine the Relationship Between Factors and Calculate the Weights): The value $\otimes r$ is computed by summing each column of the total influence matrix $\otimes O$, representing the degree of impact of other factors. Similarly, $\otimes c$ is calculated by summing each row of matrix $\otimes O$, denoting the degree of influence from other factors. This process is detailed below in Equations (25) to (28).

$$\otimes r = [\otimes r_i]_{nx1} = (\otimes r_1, \otimes r_2, \ldots, \otimes r_i, \ldots, \otimes r_n) \quad (29)$$
$$[\otimes r_i]_{nx1} = \left[\sum\nolimits_{j=1}^{n} \otimes o_{ij}\right]_{nx1} \quad (30)$$
$$\otimes c = [\otimes c_i]_{1xn} = \left(\otimes c_1, \otimes c_2, \ldots, \otimes c_j, \ldots, \otimes c_n\right)^{TRAN} \quad (31)$$
$$\left[\otimes c_j\right]_{1xn} = \left[\sum\nolimits_{i=1}^{n} \otimes o_{ij}\right]_{1xn} = [\otimes c_i]_{nx1}^{TRAN} \quad (32)$$

Note: "TRAN" is the transpose of the matrix

The index of the strength of influences imparted and received is $\otimes r_i + \otimes c_i$. The net influence is denoted by $\otimes r_i - \otimes c_i$. A higher $\otimes r_i + \otimes c_i$ suggests that factor i exerts a more significant influence on the evaluation system. Factor i significantly influences others if $\otimes r_i - \otimes c_i > 0$ (is positive). Factor i is influenced by other factors if $\otimes r_i - \otimes c_i < 0$ (is negative).

The overall effect of the indicator on the assessment system is denoted by $\otimes r_i + \otimes c_i$. Hence, Equation (33) will be utilized to establish the impact weight of an indicator.

$$w_i = \frac{(\otimes r_i + \otimes c_i)}{\sum_{i=1}^{n} (\otimes r_i + \otimes c_i)} \quad (33)$$

E. QSF COCOSO

Assume k experts are assessing the effectiveness of m strategies in addressing n factors. Experts' opinions are initially recorded in linguistic form and converted to QSF numbers for computation. Table 7 presents the linguistic scale and corresponding QSF numbers for [70].

Details of the calculation steps using the COCOSO method are presented in detail below:

Step 1 (Build a Comprehensive Assessment Matrix): The assessment of k experts on the effectiveness of m strategies (i) in resolving n factors (j) along with the corresponding weights of k experts: $\left\{e_{w_1}, e\, xw_2, ..e\, xw_k\right\}$ is aggregated into matrix $\otimes T = \left[\otimes t_{ij}\right]_{mxn}$ using QSFWAM Equation, where $\otimes t_{ij}$ in the form of a QSF number.

Step 2 (Defuzzy Matrix $\otimes T$ Into the Matrix $\otimes G$): The values of matrix $\otimes T$ are defuzzy using Equation (20) to form a new matrix $\otimes G$ consisting of crips values: $\otimes G = \left[\otimes g_{ij}\right]_{nxn}$ and $\otimes g_{ij}$ is crips score.

Step 3 (Normalize Matrix $\otimes G$ to Matrix $\otimes G^*$): Equation (34) is used to normalize matrix $\otimes G$ to the matrix.

$$\otimes G^* = \left[\otimes g_{ij}^*\right]_{mxn}$$

TABLE 7. QSF linguistic evaluation scale.

Evaluation Level	Code	QSF
Very Poor	VP	$(0.4e^{j2\pi 0.4}, 0.31623e^{j2\pi 0.25}, 0.86023e^{j2\pi 0.35})$
Poor	P	$(0.44721e^{j2\pi 0.45}, 0.36056e^{j2\pi 0.28}, 0.81854e^{j2\pi 0.27})$
Fair	F	$(0.5e^{j2\pi 0.5}, 0.3873e^{j2\pi 0.31}, 0.7746e^{j2\pi 0.19})$
Good	G	$(0.54772e^{j2\pi 0.55}, 0.43589e^{j2\pi 0.34}, 0.71414e^{j2\pi 0.11})$
Very Good	VG	$(0.6e^{j2\pi 0.6}, 0.46904e^{j2\pi 0.37}, 0.64807e^{j2\pi 0.03})$

$$\otimes g_{ij}^* = \frac{g_{ij}}{Max\left(g_{ij}\right)} \quad (34)$$

Step 4 (Calculate the Relative Importance of the Strategies): The relative importance of the given strategies (i) is computed using the Weighted Sum Method (WS_i) and Weighted Product Method (WP_i) through Equations (35) and (36) with $w_j = \{w_1, w_2, \ldots w_n\}$ is the weight of n factors, respectively:

$$WS_i = \sum_{j=1}^{n}\left(g_{ij}^* w_j\right) \quad (35)$$
$$WP_i = \prod_{j=1}^{n}\left(g_{ij}^*\right)^{w_j} \quad (36)$$

Step 5 (Calculate Three Appraisal Score $\mathbb{R}_{ia}, \mathbb{R}_{ib}, \mathbb{R}_{ic}$):

$$\mathbb{R}_{ia} = \frac{WS_i + WP_i}{\sum_{i=1}^{m}(WS_i + WP_i)} \quad (37)$$
$$\mathbb{R}_{ib} = \frac{1}{2}\left(\frac{WS_i}{Min_i\,(WS_i)} + \frac{WP_i}{Min_i\,(WP_i)}\right) \quad (38)$$
$$\mathbb{R}_{ic} = \frac{\eta\,(WS_i) + (1-\eta)\,(WP_i)}{\eta Max_i\,(WS_i) + (1-\eta) Max_i\,(WP_i)}, 0 \le \eta \le 1 \quad (39)$$

Note: Typically, η is set to a value of 0.5. However, in this study, η will be varied from 0.1 to 0.9 to conduct sensitivity analysis.

Step 6 (Ranking): The final ranking of the alternatives is determined by arranging the $\mathbb{R}_i$ values in descending order.

$$\mathbb{R}_i = \sqrt[3]{\mathbb{R}_{ia}\mathbb{R}_{ib}\mathbb{R}_{ic}} + \frac{1}{3}\left(\mathbb{R}_{ia} + \mathbb{R}_{ib} + \mathbb{R}_{ic}\right) \quad (40)$$

IV. CASE STUDY

A. PRACTICAL PROBLEM IN VIETNAM

Quantum Computing is undergoing extensive research and application across various fields, particularly in data analysis, owing to its advantages over traditional computational methods [71]. While classical computers rely on bits that can only be 0 or 1, quantum computers leverage qubits, which can

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exist simultaneously in multiple states [11]. This theoretical capability enables qubits to perform calculations much faster than digital bits, facilitating highspeed data analysis, pattern detection in large datasets, and the execution of complex calculations within seconds [2]. Consequently, quantum computing holds the potential to revolutionize the data analysis industry. However, due to its technological complexity, conceptual novelty, and high costs, practical application poses numerous barriers, particularly in developing countries like Vietnam. This research aims to identify barriers to applying quantum computing to data analysis in Vietnam and propose solutions. **Figure 2** illustrates the Hierarchy of barriers to applying quantum computing for data analysis in Vietnam and the proposed strategies.

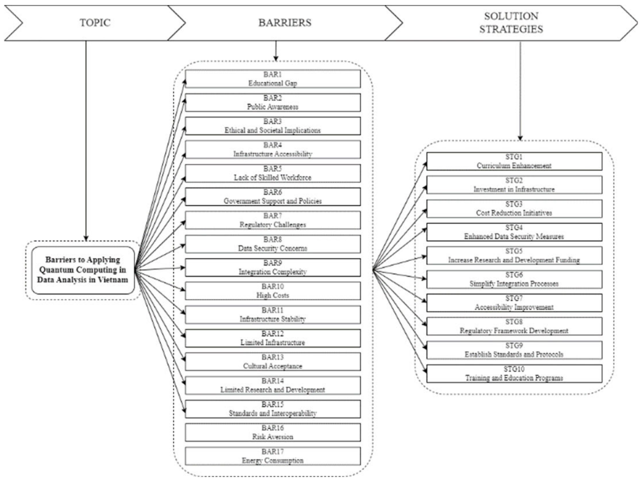

FIGURE 2. Hierarchy of barriers and strategies.

A case study in Vietnam involved a team of experts: researchers, lecturers, and professionals directly engaged in data analysis, information technology, and quantum research. Data collection occurred online via JotForm in March 2024, and subsequent analysis was conducted using VBA code-Microsoft Excel 2019 software. The results of expert weighting are presented in section IV-B.

B. EXPERTS' WEIGHTS

In MCDM studies, the sample size typically refers to the number of decision-makers or experts involved in the assessment and decision-making process rather than a statistical sampling concept [35]. The number of experts chosen depends on the complexity of the decision problem and the need for diverse perspectives to ensure comprehensive evaluation and reliable results. The number of experts or decision-makers involved in academic literature and practical applications of MCDM methods can vary widely. Generally, studies aim to include enough experts to capture a broad range of viewpoints and ensure robustness in decision outcomes. Commonly, this number ranges from 5 to 30 experts, with larger samples sometimes used for more complex or contentious decision problems [22], [25], [72], [73]. In this study, thirty experts were carefully selected based on predefined criteria outlined in the preceding sections. These criteria ensured that each expert possesses extensive experience and qualifications relevant to quantum computing and data analysis [25], [73]. Specifically, all experts have at least ten years of professional experience, with most holding advanced degrees such as master's or doctoral qualifications. This rigorous selection process aimed to ensure high expertise and credibility in evaluating barriers, assessing their interactions, and proposing practical strategies.

The selected experts were tasked with evaluating the relevance and significance of identified barriers to quantum computing adoption in Vietnam. Using QSF theory, their assessments were quantified into numerical representations that consider both the degree of membership and the level of uncertainty or vagueness associated with each barrier. This approach allows for a nuanced evaluation of barriers, considering expert judgments on the severity and complexity of each issue.

Expert weighting was determined based on differences in qualifications and experience among the panel of experts. This process ensures that assessments from experts with more extensive experience and qualifications carry greater weight in the analysis. The weights were calculated using a predefined formula (Equation 23), incorporating factors such as educational background, professional experience, and expertise in relevant domains.

Table 8 provides detailed information on the characteristics of the 30 selected experts, including their educational qualifications (Doctorate - Doc; Master's - MA; Bachelor's - BAC) and the calculated expert weights. These weights represent the relative influence of each expert's assessment in the overall analysis, providing transparency and accountability in the decision-making process.

C. QSF DELPHI RESULTS

Thirty experts will assess the relevance and significance of ten proposed barriers identified through a literature review. Expert assessments will be recorded in linguistic form, corresponding to the levels of the linguistic scale presented in **Table 5**, and then converted to QSF numbers for calculation using the DELPHI method. For each proposed barrier, the assessments of the thirty experts will be aggregated according to Equation (22) using the expert weights calculated previously. The results of the combined evaluation of the 30 experts for 17 proposed barriers, considering expert weights, are presented in **Table 9**.

The computed threshold value, which stands at 0.97148, rejects two proposed barriers: BAR3 - Ethical and Societal Implications and BAR17 - Energy Consumption. The rejection of BAR3 - Ethical and Societal Implications suggests that experts do not consider ethical considerations substantial obstacles to the practical implementation of quantum computing technology in the Vietnamese context.

This decision could stem from various factors, such as the perception that ethical frameworks are sufficiently robust or

TABLE 8. Experts profile and weights.

Expert	Education	Experience	Evaluation value QSF	Weights
1	MA	Over 20 years	(0,74297$e^{j2\pi 0,12927}$; 0,20445$e^{j2\pi 0,00319}$; 0,63734$e^{j2\pi 0,01806}$)	0,03329
2	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
3	DOC	From 10 - 20 years	(0,74297$e^{j2\pi 0,12927}$; 0,20445$e^{j2\pi 0,00319}$; 0,63734$e^{j2\pi 0,01806}$)	0,03329
4	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
5	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
6	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
7	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
8	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
9	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
10	MA	Over 20 years	(0,74297$e^{j2\pi 0,12927}$; 0,20445$e^{j2\pi 0,00319}$; 0,63734$e^{j2\pi 0,01806}$)	0,03329
11	MA	Over 20 years	(0,74297$e^{j2\pi 0,12927}$; 0,20445$e^{j2\pi 0,00319}$; 0,63734$e^{j2\pi 0,01806}$)	0,03329
12	MA	Over 20 years	(0,74297$e^{j2\pi 0,12927}$; 0,20445$e^{j2\pi 0,00319}$; 0,63734$e^{j2\pi 0,01806}$)	0,03329
13	MA	Over 20 years	(0,74297$e^{j2\pi 0,12927}$; 0,20445$e^{j2\pi 0,00319}$; 0,63734$e^{j2\pi 0,01806}$)	0,03329
14	MA	Over 20 years	(0,74297$e^{j2\pi 0,12927}$; 0,20445$e^{j2\pi 0,00319}$; 0,63734$e^{j2\pi 0,01806}$)	0,03329
15	DOC	From 10 - 20 years	(0,74297$e^{j2\pi 0,12927}$; 0,20445$e^{j2\pi 0,00319}$; 0,63734$e^{j2\pi 0,01806}$)	0,03329
16	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
17	DOC	From 10 - 20 years	(0,74297$e^{j2\pi 0,12927}$; 0,20445$e^{j2\pi 0,00319}$; 0,63734$e^{j2\pi 0,01806}$)	0,03329
18	DOC	From 10 - 20 years	(0,74297$e^{j2\pi 0,12927}$; 0,20445$e^{j2\pi 0,00319}$; 0,63734$e^{j2\pi 0,01806}$)	0,03329
19	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
20	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
21	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
22	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
23	DOC	From 10 - 20 years	(0,74297$e^{j2\pi 0,12927}$; 0,20445$e^{j2\pi 0,00319}$; 0,63734$e^{j2\pi 0,01806}$)	0,03329
24	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
25	DOC	From 10 - 20 years	(0,74297$e^{j2\pi 0,12927}$; 0,20445$e^{j2\pi 0,00319}$; 0,63734$e^{j2\pi 0,01806}$)	0,03329
26	BAC	From 10 - 20 years	(0,6892$e^{j2\pi 0,1181}$; 0,16882$e^{j2\pi 0,00267}$; 0,70463$e^{j2\pi 0,03481}$)	0,03357
27	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
28	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336
29	DOC	From 10 - 20 years	(0,74297$e^{j2\pi 0,12927}$; 0,20445$e^{j2\pi 0,00319}$; 0,63734$e^{j2\pi 0,01806}$)	0,03329
30	MA	From 10 - 20 years	(0,71414$e^{j2\pi 0,12356}$; 0,19$e^{j2\pi 0,00293}$; 0,67372$e^{j2\pi 0,02466}$)	0,03336

TABLE 9. QSF delphi results.

BAR3	(0,50156$e^{j2\pi 0,07979}$; 0,39131$e^{j2\pi 0,06181}$; 0,77157$e^{j2\pi 0,03359}$)	0,9546	*Rejected*
BAR4	(0,54743$e^{j2\pi 0,08718}$; 0,42856$e^{j2\pi 0,06766}$; 0,71879$e^{j2\pi 0,02029}$)	0,97321	Accepted
BAR5	(0,55224$e^{j2\pi 0,08796}$; 0,433$e^{j2\pi 0,06839}$; 0,71242$e^{j2\pi 0,01902}$)	0,97451	Accepted
BAR6	(0,55513$e^{j2\pi 0,08846}$; 0,43644$e^{j2\pi 0,06888}$; 0,70806$e^{j2\pi 0,01792}$)	0,97473	Accepted
BAR7	(0,55079$e^{j2\pi 0,08771}$; 0,4313$e^{j2\pi 0,06812}$; 0,71457$e^{j2\pi 0,01955}$)	0,97437	Accepted
BAR8	(0,55554$e^{j2\pi 0,08849}$; 0,43577$e^{j2\pi 0,06883}$; 0,70814$e^{j2\pi 0,01822}$)	0,97556	Accepted
BAR9	(0,55038$e^{j2\pi 0,08769}$; 0,43197$e^{j2\pi 0,0682}$; 0,71448$e^{j2\pi 0,01926}$)	0,97354	Accepted
BAR10	(0,5547$e^{j2\pi 0,08844}$; 0,43709$e^{j2\pi 0,06898}$; 0,708$e^{j2\pi 0,01762}$)	0,97391	Accepted
BAR11	(0,56164$e^{j2\pi 0,08951}$; 0,44204$e^{j2\pi 0,06976}$; 0,69939$e^{j2\pi 0,01618}$)	0,97665	Accepted
BAR12	(0,54891$e^{j2\pi 0,08743}$; 0,43027$e^{j2\pi 0,06793}$; 0,71663$e^{j2\pi 0,01978}$)	0,97337	Accepted
BAR13	(0,54803$e^{j2\pi 0,08738}$; 0,43154$e^{j2\pi 0,06813}$; 0,71654$e^{j2\pi 0,01923}$)	0,9717	Accepted
BAR14	(0,55741$e^{j2\pi 0,08876}$; 0,43685$e^{j2\pi 0,06894}$; 0,70601$e^{j2\pi 0,01796}$)	0,97647	Accepted
BAR15	(0,54891$e^{j2\pi 0,08743}$; 0,43026$e^{j2\pi 0,0679}$; 0,71663$e^{j2\pi 0,01978}$)	0,97337	Accepted
BAR16	(0,54742$e^{j2\pi 0,08718}$; 0,42855$e^{j2\pi 0,06763}$; 0,7188$e^{j2\pi 0,0203}$)	0,9732	Accepted
BAR17	(0,49056$e^{j2\pi 0,07795}$; 0,3811$e^{j2\pi 0,06013}$; 0,78366$e^{j2\pi 0,03639}$)	0,95052	*Rejected*
	Threshold	0,97148	

that ethical concerns are outweighed by potential benefits [6], [51]. Similarly, the rejection of BAR17 - Energy Consumption indicates that experts do not view energy consumption as a significant barrier to adopting quantum computing technology in Vietnam. This may be due to advancements in energy-efficient computing technologies or the belief that

TABLE 10. Aggregated experts' opinions.

	BAR1	BAR2	BAR4	BAR5	BAR6	BAR7	BAR8
BAR1	0	$(0,51798e^{j2\pi0,08216}; 0,40083e^{j2\pi0,06326}; 0,75567e^{j2\pi0,03228})$	$(0,52369e^{j2\pi0,08296}; 0,40148e^{j2\pi0,06341}; 0,75137e^{j2\pi0,03133})$	$(0,50238e^{j2\pi0,0796}; 0,38643e^{j2\pi0,06098}; 0,77349e^{j2\pi0,03633})$	$(0,51358e^{j2\pi0,08152}; 0,39585e^{j2\pi0,06247}; 0,76127e^{j2\pi0,03224})$	$(0,52237e^{j2\pi0,08309}; 0,40655e^{j2\pi0,06416}; 0,74956e^{j2\pi0,02771})$	$(0,51204e^{j2\pi0,08143}; 0,39943e^{j2\pi0,06304}; 0,76044e^{j2\pi0,03173})$
BAR2	$(0,49224e^{j2\pi0,07841}; 0,3868e^{j2\pi0,06104}; 0,7798e^{j2\pi0,03523})$	0	$(0,4962e^{j2\pi0,07869}; 0,38265e^{j2\pi0,06039}; 0,77934e^{j2\pi0,03672})$	$(0,4981e^{j2\pi0,0792}; 0,38781e^{j2\pi0,0612}; 0,77557e^{j2\pi0,03404})$	$(0,52956e^{j2\pi0,08401}; 0,40849e^{j2\pi0,06447}; 0,74344e^{j2\pi0,02759})$	$(0,51029e^{j2\pi0,08108}; 0,39639e^{j2\pi0,06256}; 0,76321e^{j2\pi0,03155})$	$(0,51505e^{j2\pi0,08178}; 0,39901e^{j2\pi0,06299}; 0,75863e^{j2\pi0,03193})$
BAR4	$(0,56072e^{j2\pi0,08916}; 0,43733e^{j2\pi0,06904}; 0,70309e^{j2\pi0,01915})$	$(0,52344e^{j2\pi0,08305}; 0,40422e^{j2\pi0,06379}; 0,75008e^{j2\pi0,02976})$	0	$(0,53903e^{j2\pi0,08537}; 0,41308e^{j2\pi0,06521}; 0,73404e^{j2\pi0,02844})$	$(0,55453e^{j2\pi0,088}; 0,42863e^{j2\pi0,06767}; 0,71328e^{j2\pi0,0226})$	$(0,56826e^{j2\pi0,09024}; 0,44028e^{j2\pi0,06951}; 0,69515e^{j2\pi0,01813})$	$(0,54698e^{j2\pi0,08689}; 0,42447e^{j2\pi0,06699}; 0,72155e^{j2\pi0,02343})$
BAR5	$(0,5345e^{j2\pi0,08465}; 0,40971e^{j2\pi0,06466}; 0,73922e^{j2\pi0,03004})$	$(0,54075e^{j2\pi0,08591}; 0,42019e^{j2\pi0,06631}; 0,72872e^{j2\pi0,02553})$	$(0,51032e^{j2\pi0,08076}; 0,38983e^{j2\pi0,06152}; 0,76655e^{j2\pi0,0355})$	0	$(0,54517e^{j2\pi0,08661}; 0,42364ej^{2\pi0,0668}6; 0,7234e^{j2\pi0,02363})$	$(0,55135e^{j2\pi0,08779}; 0,43181e^{j2\pi0,06815}; 0,71383e^{j2\pi0,02035})$	$(0,56007e^{j2\pi0,08885}; 0,43225e^{j2\pi0,06824}; 0,70673e^{j2\pi0,02221})$
BAR6	$(0,52966e^{j2\pi0,08397}; 0,40825e^{j2\pi0,06445}; 0,7435e^{j2\pi0,02964})$	$(0,50961e^{j2\pi0,08082}; 0,39322e^{j2\pi0,06211}; 0,76529e^{j2\pi0,03398})$	$(0,51523e^{j2\pi0,08164}; 0,39529e^{j2\pi0,06241}; 0,76045e^{j2\pi0,03307})$	$(0,51189e^{j2\pi0,08112}; 0,39439e^{j2\pi0,06226}; 0,76317e^{j2\pi0,03383})$	0	$(0,5128e^{j2\pi0,08149}; 0,39784e^{j2\pi0,06278}; 0,76077ej^{2\pi0,03207})$	$(0,53679e^{j2\pi0,0851}; 0,41396e^{j2\pi0,06533}; 0,73518e^{j2\pi0,0288})$
BAR7	$(0,52223e^{j2\pi0,08263}; 0,39925e^{j2\pi0,06303}; 0,75357e^{j2\pi0,03329})$	$(0,51184e^{j2\pi0,08136}; 0,39776e^{j2\pi0,06283}; 0,76145e^{j2\pi0,03122})$	$(0,49842e^{j2\pi0,07902}; 0,38397e^{j2\pi0,06065}; 0,77727e^{j2\pi0,03674})$	$(0,52455e^{j2\pi0,08326}; 0,40598e^{j2\pi0,06407}; 0,74835e^{j2\pi0,02905})$	$(0,52781e^{j2\pi0,08382}; 0,40983e^{j2\pi0,06468}; 0,74394e^{j2\pi0,02853})$	0	$(0,51146e^{j2\pi0,08107}; 0,39279e^{j2\pi0,06201}; 0,76428e^{j2\pi0,03351})$
BAR8	$(0,51144e^{j2\pi0,08107}; 0,39277e^{j2\pi0,06201}; 0,7643e^{j2\pi0,03351})$	$(0,52385e^{j2\pi0,08313}; 0,4063e^{j2\pi0,06412}; 0,74866e^{j2\pi0,0303})$	$(0,50609e^{j2\pi0,08016}; 0,38813e^{j2\pi0,06125}; 0,77022e^{j2\pi0,03577})$	$(0,48287e^{j2\pi0,07659}; 0,37332e^{j2\pi0,05894}; 0,79213e^{j2\pi0,03983})$	$(0,52992e^{j2\pi0,08397}; 0,4068e^{j2\pi0,06422}; 0,74411e^{j2\pi0,02965})$	$(0,50675e^{j2\pi0,0803}; 0,38955e^{j2\pi0,0615}; 0,76907e^{j2\pi0,03473})$	0
BAR9	$(0,53024e^{j2\pi0,08403}; 0,40828e^{j2\pi0,06443}; 0,74307ej^{2\pi0,03})$	$(0,53023e^{j2\pi0,08423}; 0,41136e^{j2\pi0,06494}; 0,74138e^{j2\pi0,02682})$	$(0,49721e^{j2\pi0,07893}; 0,38626e^{j2\pi0,06096}; 0,77691e^{j2\pi0,0363})$	$(0,52768e^{j2\pi0,08391}; 0,41094e^{j2\pi0,06485}; 0,74342e^{j2\pi0,0268})$	$(0,51969e^{j2\pi0,08266}; 0,40607e^{j2\pi0,06414}; 0,75168e^{j2\pi0,02918})$	$(0,55698e^{j2\pi0,08848}; 0,43268e^{j2\pi0,06831}; 0,70892e^{j2\pi0,02144})$	$(0,52875e^{j2\pi0,08402}; 0,41081e^{j2\pi0,06486}; 0,74274e^{j2\pi0,02759})$
BAR10	$(0,54589e^{j2\pi0,08647}; 0,41882e^{j2\pi0,0661}; 0,72567e^{j2\pi0,02758})$	$(0,52728e^{j2\pi0,08366}; 0,40807e^{j2\pi0,0644}; 0,74529e^{j2\pi0,02962})$	$(0,51767e^{j2\pi0,08211}; 0,3994e^{j2\pi0,06303}; 0,75663e^{j2\pi0,03194})$	$(0,54633e^{j2\pi0,08682}; 0,42377e^{j2\pi0,0669}; 0,72245e^{j2\pi0,02273})$	$(0,53835e^{j2\pi0,08556}; 0,41891e^{j2\pi0,06613}; 0,73123e^{j2\pi0,02508})$	$(0,54942e^{j2\pi0,08722}; 0,42553e^{j2\pi0,06716}; 0,71907e^{j2\pi0,02368})$	$(0,53664e^{j2\pi0,08516}; 0,41463e^{j2\pi0,06546}; 0,73491e^{j2\pi0,02689})$
BAR11	$(0,5261e^{j2\pi0,08343}; 0,40569e^{j2\pi0,06408}; 0,74742e^{j2\pi0,03013})$	$(0,51166e^{j2\pi0,08131}; 0,39655e^{j2\pi0,06258}; 0,76221e^{j2\pi0,03087})$	$(0,51861e^{j2\pi0,0823}; 0,40033e^{j2\pi0,06318}; 0,75549e^{j2\pi0,03111})$	$(0,51239e^{j2\pi0,08127}; 0,3955e^{j2\pi0,06242}; 0,76226e^{j2\pi0,03271})$	$(0,51956e^{j2\pi0,08241}; 0,39999e^{j2\pi0,06312}; 0,75502e^{j2\pi0,03179})$	$(0,5197e^{j2\pi0,08238}; 0,39977e^{j2\pi0,06314}; 0,75504e^{j2\pi0,03162})$	$(0,51507e^{j2\pi0,08179}; 0,39903e^{j2\pi0,06297}; 0,7586e^{j2\pi0,03192})$
BAR12	$(0,55087e^{j2\pi0,08747}; 0,4272e^{j2\pi0,06742}; 0,71697e^{j2\pi0,02326})$	$(0,52957e^{j2\pi0,084}; 0,4085e^{j2\pi0,06447}; 0,74343e^{j2\pi0,02982})$	$(0,53379e^{j2\pi0,08469}; 0,41266e^{j2\pi0,06512}; 0,73809e^{j2\pi0,02802})$	$(0,53475e^{j2\pi0,08499}; 0,41559e^{j2\pi0,06559}; 0,73575e^{j2\pi0,02545})$	$(0,50879e^{j2\pi0,08049}; 0,3885e^{j2\pi0,06133}; 0,76824e^{j2\pi0,03578})$	$(0,53836e^{j2\pi0,08523}; 0,4134e^{j2\pi0,06527}; 0,73434e^{j2\pi0,02972})$	$(0,54086e^{j2\pi0,08589}; 0,41995e^{j2\pi0,0663}; 0,72877e^{j2\pi0,02531})$
BAR13	$(0,50719e^{j2\pi0,08052}; 0,39187e^{j2\pi0,06184}; 0,76759e^{j2\pi0,03412})$	$(0,52446e^{j2\pi0,08318}; 0,40449e^{j2\pi0,06383}; 0,74921e^{j2\pi0,03065})$	$(0,49269e^{j2\pi0,07805}; 0,37883e^{j2\pi0,05978}; 0,78342e^{j2\pi0,03867})$	$(0,47498e^{j2\pi0,07554}; 0,37016e^{j2\pi0,05842}; 0,79836e^{j2\pi0,03978})$	$(0,53368e^{j2\pi0,0846}; 0,41112e^{j2\pi0,06488}; 0,73903e^{j2\pi0,02968})$	$(0,51176e^{j2\pi0,08121}; 0,39545e^{j2\pi0,06241}; 0,76271e^{j2\pi0,03239})$	$(0,52688e^{j2\pi0,08352}; 0,4051e^{j2\pi0,06393}; 0,74719e^{j2\pi0,03085})$
BAR14	$(0,52227e^{j2\pi0,083}; 0,40505e^{j2\pi0,06392}; 0,75045e^{j2\pi0,02939})$	$(0,5195e^{j2\pi0,08221}; 0,39682e^{j2\pi0,06265}; 0,75674e^{j2\pi0,03261})$	$(0,5237e^{j2\pi0,08277}; 0,39836e^{j2\pi0,06287}; 0,75302e^{j2\pi0,03407})$	$(0,54253e^{j2\pi0,08612}; 0,41948e^{j2\pi0,0662}; 0,72781e^{j2\pi0,02469})$	$(0,51372e^{j2\pi0,08152}; 0,39607e^{j2\pi0,06251}; 0,76107e^{j2\pi0,03223})$	$(0,54008e^{j2\pi0,0856}; 0,41532e^{j2\pi0,06557}; 0,732e^{j2\pi0,02789})$	$(0,537e^{j2\pi0,08521}; 0,41425e^{j2\pi0,06538}; 0,73486e^{j2\pi0,02729})$
BAR15	$(0,52988e^{j2\pi0,08409}; 0,41041e^{j2\pi0,06476}; 0,74215e^{j2\pi0,02817})$	$(0,52532e^{j2\pi0,08348}; 0,40902e^{j2\pi0,06455}; 0,74615e^{j2\pi0,02832})$	$(0,52625e^{j2\pi0,08368}; 0,41e^{j2\pi0,06476}; 0,74495e^{j2\pi0,02736})$	$(0,51868e^{j2\pi0,0823}; 0,40235e^{j2\pi0,06349}; 0,75438e^{j2\pi0,03111})$	$(0,53555e^{j2\pi0,08495}; 0,41471e^{j2\pi0,06547}; 0,73566e^{j2\pi0,02766})$	$(0,5375e^{j2\pi0,08538}; 0,41794e^{j2\pi0,06601}; 0,7324e^{j2\pi0,0261})$	$(0,53235e^{j2\pi0,08454}; 0,41302e^{j2\pi0,06517}; 0,73893e^{j2\pi0,02684})$
BAR16	$(0,50067e^{j2\pi0,07968}; 0,39184e^{j2\pi0,06184}; 0,77188e^{j2\pi0,03295})$	$(0,54427e^{j2\pi0,08656}; 0,4249e^{j2\pi0,06708}; 0,72335ej^{2\pi0,02317})$	$(0,52682e^{j2\pi0,08358}; 0,40781e^{j2\pi0,06436}; 0,74576e^{j2\pi0,02907})$	$(0,54e^{j2\pi0,08571}; 0,41897e^{j2\pi0,06611}; 0,72997e^{j2\pi0,02633})$	$(0,50924e^{j2\pi0,08098}; 0,39657e^{j2\pi0,06258}; 0,76381ej^{2\pi0,03085})$	$(0,51903e^{j2\pi0,08244}; 0,40327e^{j2\pi0,06367}; 0,75365e^{j2\pi0,02989})$	$(0,51759e^{j2\pi0,08237}; 0,40509e^{j2\pi0,06393}; 0,75366e^{j2\pi0,02934})$

	BAR9	BAR10	BAR11	BAR12	BAR13	BAR14	BAR15	BAR16
BAR1	$(0,53168e^{j2\pi0,08435}; 0,41057e^{j2\pi0,06479}; 0,74078e^{j2\pi0,02781})$	$(0,50431e^{j2\pi0,08009}; 0,38947e^{j2\pi0,06152}; 0,77071e^{j2\pi0,03345})$	$(0,50629e^{j2\pi0,08016}; 0,38849e^{j2\pi0,06131}; 0,7699e^{j2\pi0,03577})$	$(0,53505e^{j2\pi0,08468}; 0,40928e^{j2\pi0,06461}; 0,73906e^{j2\pi0,03022})$	$(0,5161e^{j2\pi0,08188}; 0,39884e^{j2\pi0,06294}; 0,758e^{j2\pi0,0326})$	$(0,50495e^{j2\pi0,0798}; 0,3844e^{j2\pi0,06072}; 0,77283e^{j2\pi0,03735})$	$(0,55441e^{j2\pi0,08808}; 0,42979e^{j2\pi0,06783}; 0,71268e^{j2\pi0,02039})$	$(0,56053e^{j2\pi0,08911}; 0,43597e^{j2\pi0,06883}; 0,70408e^{j2\pi0,01858})$
BAR2	$(0,5208e^{j2\pi0,08259}; 0,4015e^{j2\pi0,06339}; 0,75337e^{j2\pi0,03096})$	$(0,5105e^{j2\pi0,08125}; 0,39934e^{j2\pi0,06308}; 0,76152e^{j2\pi0,03052})$	$(0,50104e^{j2\pi0,07973}; 0,39146e^{j2\pi0,06178}; 0,77183e^{j2\pi0,03327})$	$(0,51157e^{j2\pi0,08107}; 0,39297e^{j2\pi0,06204}; 0,76411ej^{2\pi0,03351})$	$(0,52133e^{j2\pi0,08284}; 0,40452e^{j2\pi0,06386}; 0,75139e^{j2\pi0,02828})$	$(0,49041e^{j2\pi0,07798}; 0,38306e^{j2\pi0,0605}; 0,78279e^{j2\pi0,03654})$	$(0,53507e^{j2\pi0,08493}; 0,41531e^{j2\pi0,06553}; 0,73567e^{j2\pi0,02746})$	$(0,52055e^{j2\pi0,08269}; 0,40423e^{j2\pi0,06378}; 0,75208e^{j2\pi0,02937})$
BAR4	$(0,55274e^{j2\pi0,08786}; 0,43008e^{j2\pi0,0679}; 0,7138e^{j2\pi0,02113})$	$(0,54044e^{j2\pi0,0856}; 0,41407e^{j2\pi0,0654}; 0,73244e^{j2\pi0,02789})$	$(0,53173e^{j2\pi0,0843}; 0,40972e^{j2\pi0,06466}; 0,74121e^{j2\pi0,02965})$	$(0,5474e^{j2\pi0,08691}; 0,42381e^{j2\pi0,06688}; 0,72162e^{j2\pi0,02366})$	$(0,51496e^{j2\pi0,0817}; 0,39754e^{j2\pi0,06274}; 0,75946e^{j2\pi0,03339})$	$(0,53394e^{j2\pi0,08466}; 0,41056e^{j2\pi0,06485}; 0,73916e^{j2\pi0,02783})$	$(0,50399e^{j2\pi0,07986}; 0,38737e^{j2\pi0,06116}; 0,77197e^{j2\pi0,0359})$	$(0,50474e^{j2\pi0,07991}; 0,38758e^{j2\pi0,06116}; 0,77137e^{j2\pi0,0362})$
BAR5	$(0,55272e^{j2\pi0,08786}; 0,43007e^{j2\pi0,06787}; 0,71382e^{j2\pi0,02113})$	$(0,54477e^{j2\pi0,08648}; 0,42249e^{j2\pi0,06673}; 0,72438e^{j2\pi0,02514})$	$(0,52549e^{j2\pi0,0834}; 0,40608e^{j2\pi0,06411}; 0,74763e^{j2\pi0,02995})$	$(0,54139e^{j2\pi0,08596}; 0,42041e^{j2\pi0,06637}; 0,72812e^{j2\pi0,02595})$	$(0,53437e^{j2\pi0,08471}; 0,41037e^{j2\pi0,06479}; 0,73895e^{j2\pi0,02822})$	$(0,51353e^{j2\pi0,08151}; 0,39764e^{j2\pi0,06281}; 0,76038e^{j2\pi0,03224})$	$(0,54831e^{j2\pi0,08723}; 0,42728e^{j2\pi0,06749}; 0,71888e^{j2\pi0,02081})$	$(0,54345e^{j2\pi0,08644}; 0,42291e^{j2\pi0,06674}; 0,72513e^{j2\pi0,02198})$
BAR6	$(0,51979e^{j2\pi0,08238}; 0,39995e^{j2\pi0,06317}; 0,75489e^{j2\pi0,03162})$	$(0,49718e^{j2\pi0,07879}; 0,38229e^{j2\pi0,06038}; 0,77889e^{j2\pi0,03731})$	$(0,48367e^{j2\pi0,07691}; 0,37727e^{j2\pi0,05954}; 0,78977e^{j2\pi0,03807})$	$(0,50691e^{j2\pi0,08036}; 0,39062e^{j2\pi0,06165}; 0,76841e^{j2\pi0,03502})$	$(0,51099e^{j2\pi0,08124}; 0,39831e^{j2\pi0,06286}; 0,76174e^{j2\pi0,03255})$	$(0,5382e^{j2\pi0,08534}; 0,41494e^{j2\pi0,06554}; 0,7336e^{j2\pi0,02826})$	$(0,49312e^{j2\pi0,07803}; 0,37728e^{j2\pi0,05957}; 0,7839e^{j2\pi0,03853})$	$(0,48375e^{j2\pi0,07652}; 0,37026e^{j2\pi0,05846}; 0,79303e^{j2\pi0,04114})$
BAR7	$(0,54947e^{j2\pi0,08738}; 0,42846e^{j2\pi0,06762}; 0,71729e^{j2\pi0,02231})$	$(0,50664e^{j2\pi0,08033}; 0,38979e^{j2\pi0,06157}; 0,76901e^{j2\pi0,03487})$	$(0,51011e^{j2\pi0,08088}; 0,39306e^{j2\pi0,06203}; 0,76505e^{j2\pi0,03429})$	$(0,48795e^{j2\pi0,07727}; 0,37478e^{j2\pi0,05915}; 0,78832e^{j2\pi0,03986})$	$(0,52869e^{j2\pi0,08367}; 0,40537e^{j2\pi0,064}; 0,74576e^{j2\pi0,03188})$	$(0,52448e^{j2\pi0,08315}; 0,40407e^{j2\pi0,06382}; 0,74944e^{j2\pi0,03047})$	$(0,47719e^{j2\pi0,07577}; 0,36953e^{j2\pi0,05834}; 0,79733e^{j2\pi0,04085})$	$(0,47621e^{j2\pi0,07538}; 0,36467e^{j2\pi0,05754}; 0,80015e^{j2\pi0,04225})$
BAR8	$(0,52789e^{j2\pi0,0836}; 0,4045e^{j2\pi0,06384}; 0,7468e^{j2\pi0,03137})$	$(0,49266e^{j2\pi0,07814}; 0,38004e^{j2\pi0,06003}; 0,78285e^{j2\pi0,03742})$	$(0,50756e^{j2\pi0,08052}; 0,39247e^{j2\pi0,06196}; 0,76704e^{j2\pi0,03411})$	$(0,51716e^{j2\pi0,08183}; 0,396e^{j2\pi0,06255}; 0,75877ej^{2\pi0,03418})$	$(0,51972e^{j2\pi0,08218}; 0,39678e^{j2\pi0,06262}; 0,75661e^{j2\pi0,03436})$	$(0,52289e^{j2\pi0,0828}; 0,40117e^{j2\pi0,06337}; 0,7521e^{j2\pi0,03233})$	$(0,48058e^{j2\pi0,07626}; 0,37256e^{j2\pi0,05879}; 0,79388e^{j2\pi0,03996})$	$(0,47211e^{j2\pi0,07491}; 0,36464e^{j2\pi0,05757}; 0,80259e^{j2\pi0,04172})$
BAR9	0	$(0,52922e^{j2\pi0,08407}; 0,41065e^{j2\pi0,06486}; 0,74249e^{j2\pi0,02797})$	$(0,5156e^{j2\pi0,08179}; 0,39802e^{j2\pi0,06281}; 0,75877e^{j2\pi0,03192})$	$(0,49176e^{j2\pi0,07787}; 0,37852e^{j2\pi0,05974}; 0,78415e^{j2\pi0,03949})$	$(0,50195e^{j2\pi0,0794}; 0,3828e^{j2\pi0,06043}; 0,77557e^{j2\pi0,03706})$	$(0,52021e^{j2\pi0,08254}; 0,40147e^{j2\pi0,06341}; 0,75379e^{j2\pi0,03061})$	$(0,49358e^{j2\pi0,07823}; 0,37912e^{j2\pi0,05986}; 0,78272e^{j2\pi0,03784})$	$(0,48604e^{j2\pi0,07696}; 0,37273e^{j2\pi0,05885}; 0,79047e^{j2\pi0,03998})$
BAR10	$(0,54559e^{j2\pi0,08666}; 0,42345e^{j2\pi0,06683}; 0,7232e^{j2\pi0,02408})$	0	$(0,52691e^{j2\pi0,0835}; 0,4047e^{j2\pi0,06387}; 0,74739e^{j2\pi0,03066})$	$(0,53339e^{j2\pi0,08469}; 0,41389e^{j2\pi0,06532}; 0,73769e^{j2\pi0,02803})$	$(0,52896e^{j2\pi0,0837}; 0,40439e^{j2\pi0,06382}; 0,7461e^{j2\pi0,03204})$	$(0,52762e^{j2\pi0,08368}; 0,40725ej^{2\pi0,06432}; 0,7455e^{j2\pi0,0298})$	$(0,5439e^{j2\pi0,08641}; 0,42331e^{j2\pi0,06683}; 0,72455e^{j2\pi0,02449})$	$(0,5427e^{j2\pi0,08628}; 0,42258e^{j2\pi0,06669}; 0,72588e^{j2\pi0,02338})$
BAR11	$(0,51687e^{j2\pi0,08204}; 0,40039e^{j2\pi0,06319}; 0,75666e^{j2\pi0,03142})$	$(0,52376e^{j2\pi0,08297}; 0,40154e^{j2\pi0,06342}; 0,7513e^{j2\pi0,03131})$	0	$(0,5283e^{j2\pi0,08372}; 0,40505e^{j2\pi0,06392}; 0,74621e^{j2\pi0,02997})$	$(0,52117e^{j2\pi0,08267}; 0,40157e^{j2\pi0,0634}; 0,75307e^{j2\pi0,03147})$	$(0,51962e^{j2\pi0,08252}; 0,40188e^{j2\pi0,06348}; 0,75398e^{j2\pi0,03043})$	$(0,49506e^{j2\pi0,07851}; 0,38198e^{j2\pi0,06031}; 0,78039e^{j2\pi0,03757})$	$(0,49495e^{j2\pi0,07839}; 0,38015e^{j2\pi0,06002}; 0,78135e^{j2\pi0,0386}9)$
BAR12	$(0,50786e^{j2\pi0,08046}; 0,39025e^{j2\pi0,06159}; 0,76797e^{j2\pi0,03564})$	$(0,53738e^{j2\pi0,08537}; 0,41773e^{j2\pi0,06598}; 0,73262e^{j2\pi0,0261})$	$(0,53755e^{j2\pi0,08524}; 0,41383e^{j2\pi0,06531}; 0,7347e^{j2\pi0,02749})$	0	$(0,5484e^{j2\pi0,08691}; 0,42186e^{j2\pi0,06658}; 0,722e^{j2\pi0,02623})$	$(0,54646e^{j2\pi0,08673}; 0,42263e^{j2\pi0,06675}; 0,72302e^{j2\pi0,02475})$	$(0,53041e^{j2\pi0,08428}; 0,41263e^{j2\pi0,06518}; 0,74054e^{j2\pi0,02722})$	$(0,53836e^{j2\pi0,08556}; 0,41891e^{j2\pi0,06614}; 0,73121e^{j2\pi0,02507})$
BAR13	$(0,51195e^{j2\pi0,08103}; 0,39135e^{j2\pi0,06178}; 0,76469e^{j2\pi0,03522})$	$(0,49745e^{j2\pi0,07881}; 0,38133e^{j2\pi0,06023}; 0,77918e^{j2\pi0,03746})$	$(0,48839e^{j2\pi0,07745}; 0,37791e^{j2\pi0,05964}; 0,78655e^{j2\pi0,03906})$	$(0,52483e^{j2\pi0,08318}; 0,40326e^{j2\pi0,06366}; 0,74962e^{j2\pi0,03065})$	0	$(0,5223e^{j2\pi0,08274}; 0,40115e^{j2\pi0,06336}; 0,75252e^{j2\pi0,03199})$	$(0,48069e^{j2\pi0,07605}; 0,36813e^{j2\pi0,05812}; 0,79588e^{j2\pi0,04215})$	$(0,46967e^{j2\pi0,07446}; 0,3622e^{j2\pi0,05719}; 0,80512e^{j2\pi0,04284})$
BAR14	$(0,54065e^{j2\pi0,08586}; 0,41908e^{j2\pi0,06614}; 0,72943e^{j2\pi0,02511})$	$(0,53505e^{j2\pi0,08482}; 0,4115e^{j2\pi0,065}; 0,73782e^{j2\pi0,02896})$	$(0,54007e^{j2\pi0,08562}; 0,41576e^{j2\pi0,06561}; 0,73175e^{j2\pi0,02808})$	$(0,53138e^{j2\pi0,08433}; 0,40954e^{j2\pi0,06463}; 0,74156e^{j2\pi0,02761})$	$(0,50071e^{j2\pi0,07927}; 0,38235e^{j2\pi0,06036}; 0,77659e^{j2\pi0,03632})$	0	$(0,50449e^{j2\pi0,08023}; 0,39373e^{j2\pi0,06219}; 0,76843e^{j2\pi0,03233})$	$(0,51375e^{j2\pi0,08163}; 0,39975e^{j2\pi0,06309}; 0,75912e^{j2\pi0,03089})$
BAR15	$(0,54324e^{j2\pi0,08633}; 0,42261e^{j2\pi0,06672}; 0,72546e^{j2\pi0,02383})$	$(0,54476e^{j2\pi0,08646}; 0,42202e^{j2\pi0,06666}; 0,72466e^{j2\pi0,02493})$	$(0,53506e^{j2\pi0,08492}; 0,4153e^{j2\pi0,06556}; 0,73569e^{j2\pi0,02747})$	$(0,51915e^{j2\pi0,08247}; 0,4039e^{j2\pi0,0638}; 0,75322e^{j2\pi0,03007})$	$(0,52477e^{j2\pi0,08329}; 0,40682e^{j2\pi0,06419}; 0,74774e^{j2\pi0,02923})$	$(0,53488e^{j2\pi0,08488}; 0,41403e^{j2\pi0,06534}; 0,73653e^{j2\pi0,02707})$	0	$(0,52467e^{j2\pi0,08341}; 0,40839e^{j2\pi0,06444}; 0,74696e^{j2\pi0,02773})$
BAR16	$(0,5303e^{j2\pi0,08425}; 0,41198e^{j2\pi0,06501}; 0,74098e^{j2\pi0,02702})$	$(0,5147e^{j2\pi0,08183}; 0,40068e^{j2\pi0,06322}; 0,75798e^{j2\pi0,03003})$	$(0,53136e^{j2\pi0,08433}; 0,41142e^{j2\pi0,06498}; 0,74053e^{j2\pi0,02761})$	$(0,54347e^{j2\pi0,08625}; 0,42167e^{j2\pi0,06655}; 0,72584e^{j2\pi0,02576})$	$(0,5176e^{j2\pi0,08222}; 0,40292e^{j2\pi0,06358}; 0,75481e^{j2\pi0,03058})$	$(0,54046e^{j2\pi0,08573}; 0,41836e^{j2\pi0,06601}; 0,72999e^{j2\pi0,02653})$	$(0,5412e^{j2\pi0,08589}; 0,41866e^{j2\pi0,0661}; 0,72927e^{j2\pi0,02532})$	0

energy consumption can be managed effectively within the existing infrastructure [56], [74].

D. QSF DEMATEL RESULTS

The fifteen validated and accepted factors will undergo evaluation by experts to determine their level of interaction, utilizing the scale presented in **Table 6**. Expert assessments will be converted into QSF numbers for calculation, employing the DEMATEL method. The evaluation results of the 30 experts for the 15 barriers will be aggregated according to Equation (22) and are presented in **Table 10**.

The above results are converted into crisp values using Equation (20). These crisp values are then incorporated into the new matrix, which includes additional calculations according to Equations (25)-(28) to generate the total influence matrix. **Table 11** displays the total influence matrix depicting the relationships among the 15 barriers.

Utilizing data from the total influence matrix, values for $\otimes r_i, \otimes c_i, \otimes r_i + \otimes c_i$, and $\otimes r_i - \otimes c_i$ are computed. **Table 12** below presents the results of these values, along with the relationships between barriers and their corresponding influence weights. This comprehensive analysis offers insights into the strength of relationships among barriers and their overall influence on the application of quantum computing in data analysis within the Vietnamese context.

Table 12 indicated that BAR12 - Limited Infrastructure, BAR10 - High Costs, and BAR5 - Lack of Skilled Workforce are the top three barriers, as indicated by their highest influence weights regarding popularity value. $\otimes r_i + \otimes c_i$. According to expert assessments, BAR12 - Limited Infrastructure emerges with the highest weight, underscoring its paramount importance. As affirmed by Hasanovic et al. [10], previous research emphasizes the inherent challenges in implementing technological infrastructure. Engineering at the scientific frontier is inherently complex, and systems integration is intrinsically complex. Consequently, limitations in infrastructure equipment often impede the adoption of new technology, especially in countries like Vietnam, where economic and technical conditions may not meet the requirements of advanced technologies. As a developing nation still familiarizing itself with fundamental technologies, the infrastructure and machinery limitations pose significant barriers to mastering quantum computing technology in Vietnam [75]. Overcoming this hurdle is crucial for Vietnam to embrace and harness the potential of quantum computing effectively. The second most heavily weighted barrier, BAR10 - High Costs, underscores the formidable challenge posed by the financial implications associated with adopting new technologies, particularly one as complex as quantum computing. Investment, research, and operational costs are substantial, presenting a significant hurdle for developing countries like Vietnam [76]. Awan et al. [9] highlighted that the lack of information on short-term costs is a critical barrier to quantum computing challenges within the software industry. The ambiguity surrounding the types of costs incurred during operation further contributes to investor and operator hesitancy in embracing this technology. Indeed, beyond short-term costs, the long-term expenses associated with developing, procuring, and maintaining quantum computing technology are prohibitively high for many organizations in Vietnam [1], [11]. This financial barrier poses a considerable challenge, particularly for countries with limited budgets to research expensive technologies such as quantum computing. Overcoming this barrier requires innovative approaches to funding and resource allocation to ensure that the potential of quantum computing can be realized in Vietnam's context. The third most weighted barrier, BAR5 - Lack of Skilled Workforce, highlights the significant challenge posed by the

TABLE 11. Total influence matrix.

	BAR1	BAR2	BAR4	BAR5	BAR6	BAR7	BAR8	BAR9	BAR10	BAR11	BAR12	BAR13	BAR14	BAR15	BAR16
BAR1	9,64842	9,70678	9,67503	9,67877	9,7207	9,73237	9,72652	9,73946	9,69225	9,68045	9,71028	9,70525	9,71468	9,65769	9,64338
BAR2	9,65311	9,58031	9,61397	9,61825	9,6607	9,67155	9,66625	9,67864	9,63194	9,61979	9,64919	9,64499	9,65337	9,59713	9,58245
BAR4	9,77371	9,76517	9,66657	9,73788	9,77999	9,79192	9,78586	9,79823	9,7515	9,73913	9,76858	9,76342	9,77356	9,71437	9,69994
BAR5	9,77293	9,76505	9,73224	9,67055	9,77921	9,79087	9,78579	9,79777	9,75091	9,73845	9,76791	9,76359	9,7724	9,71487	9,70031
BAR6	9,67052	9,66221	9,63054	9,63477	9,61018	9,68765	9,68292	9,69467	9,64779	9,6352	9,66497	9,66057	9,67095	9,61208	9,59745
BAR7	9,67169	9,66339	9,63119	9,63627	9,67775	9,62295	9,68355	9,69643	9,64929	9,63746	9,66568	9,66259	9,67184	9,61257	9,59842
BAR8	9,66038	9,65284	9,62062	9,62415	9,66708	9,67793	9,60652	9,68524	9,63792	9,62643	9,65568	9,6515	9,66093	9,60181	9,58729
BAR9	9,68686	9,679	9,64602	9,65127	9,69249	9,70511	9,69891	9,64474	9,66482	9,65261	9,68083	9,67699	9,68677	9,62824	9,61369
BAR10	9,76828	9,75985	9,72737	9,73248	9,77408	9,78609	9,78028	9,7927	9,67921	9,73369	9,7628	9,7586	9,76793	9,70988	9,69539
BAR11	9,69448	9,68625	9,65449	9,65873	9,70053	9,71211	9,70635	9,71859	9,67264	9,59424	9,68972	9,68512	9,69447	9,63591	9,62164
BAR12	9,76206	9,75383	9,72166	9,72604	9,76746	9,77982	9,77415	9,78571	9,73964	9,72781	9,69017	9,75284	9,76223	9,70344	9,68919
BAR13	9,6468	9,63962	9,60688	9,61045	9,65375	9,6646	9,65964	9,67145	9,62486	9,61252	9,6425	9,57175	9,64755	9,58875	9,57398
BAR14	9,73564	9,72807	9,6961	9,70073	9,74173	9,75411	9,74845	9,76069	9,71416	9,70227	9,73106	9,72602	9,66965	9,67712	9,66303
BAR15	9,73635	9,72836	9,69621	9,70051	9,74272	9,75431	9,7487	9,76117	9,71474	9,70246	9,73103	9,72691	9,73671	9,612	9,6638
BAR16	9,7156	9,70908	9,67669	9,68142	9,72216	9,73407	9,72838	9,74108	9,69417	9,68276	9,71199	9,70692	9,71712	9,65915	9,57801

TABLE 12. QSF dematel results.

Barriers	$\otimes r_i$	$\otimes c_i$	$\otimes r_i + \otimes c_i$	$\otimes r_i - \otimes c_i$	Rank	Relations	Weight
BAR1	145,432	145,5968	291,0289	-0,1648	6	Effect	0,06673
BAR2	144,5216	145,4798	290,0015	-0,95817	13	Effect	0,0665
BAR4	146,3098	144,9956	291,3054	1,31425	5	Cause	0,06679
BAR5	146,3029	145,0623	291,3651	1,24058	3	Cause	0,06681
BAR6	144,7625	145,6905	290,453	-0,92806	10	Effect	0,0666
BAR7	144,7811	145,8655	290,6465	-1,08439	8	Effect	0,06664
BAR8	144,6163	145,7823	290,3986	-1,16595	11	Effect	0,06659
BAR9	145,0084	145,9666	290,9749	-0,95822	7	Effect	0,06672
BAR10	146,2286	145,2658	291,4945	0,96279	2	Cause	0,06684
BAR11	145,1253	145,0853	290,2105	0,04	12	Cause	0,06654
BAR12	146,1361	145,5224	291,6584	0,61366	1	Cause	0,06688
BAR13	144,4151	145,4571	289,8722	-1,04196	15	Effect	0,06647
BAR14	145,7488	145,6002	291,349	0,14867	4	Cause	0,0668
BAR15	145,756	144,725	290,481	1,03097	9	Cause	0,06661
BAR16	145,4586	144,508	289,9666	0,95063	14	Cause	0,06649

shortage of qualified human resources in mastering quantum computing technology in Vietnam. Quantum computing is a nascent field with a wealth of new knowledge that has yet to be taught or applied in Vietnam [10].

Consequently, the scarcity of quality human resources with the requisite knowledge and skills in this domain presents a formidable obstacle [10], [64]. Previous research by Awan et al. [9] corroborates this, identifying a lack of technical expertise as the primary barrier to applying quantum computing in the software industry. Thus, deficiencies in expertise, technology, and a shortage of skilled labor present long-term challenges in Vietnam's adoption and utilization of quantum computing. Addressing this barrier requires concerted efforts to enhance education and training programs, as well as initiatives to attract and retain talent in the field of quantum computing.

Table 12 reveals that BAR15 - Standards and Interoperability and BAR16 - Risk Aversion exhibit the most significant net influence ($\otimes r_i - \otimes c_i$), indicating that these two factors have the most significant impact on other factors. The absence of standards and interoperability in quantum computing and other technologies leads to barriers such as inadequate infrastructure, integration complexities, and the necessity for establishing suitable legal frameworks [2]. Similarly, risk aversion barriers contribute to a conservative perception of new technologies within the community, hindering access, reducing investment, and diminishing government support [77]. These two factors significantly influence other barriers, highlighting their critical importance in shaping the landscape of quantum computing adoption. Detailed discussions on the cause-and-effect relationships among these factors will follow.

Figure 3 depicts the relationship between barriers based on their influence weight and net influence value. Arrow lines represent interactive relationships between factors, with only relationships having influence values greater than the average prominence value ($\otimes r_i + \otimes c_i = 290.8$) shown. The horizontal axis $\otimes r_i - \otimes c_i = 0$ divides the chart into four quadrants with distinct characteristics.

The first quadrant is characterized by factors belonging to the cause group, as indicated by $\otimes \boldsymbol{r_i} - \otimes \boldsymbol{c_i} > 0$, and exhibits a strong influence, given that the $\otimes r_i + \otimes c_i$ value of each factor surpasses the average value. The barriers assessed as belonging to the cause group and exerting a strong influence include BAR12 - Limited Infrastructure, BAR10 - High Costs, BAR5 - Lack of Skilled Workforce, BAR14 - Limited Research and Development, and BAR4 Infrastructure Accessibility. First, consider BAR12 - Limited Infrastructure. Limited infrastructure represents a significant barrier and is the root cause of numerous other barriers to adopting quantum computing for data analysis in Vietnam [78]. Inadequate infrastructure poses challenges in training and research efforts related to this technology (BAR1, 14), resulting in a shortage of skilled workforce (BAR5) [79], [80]. Moreover, deficient technical infrastructure contributes to heightened risk aversion and reluctance to embrace new technology among individuals (BAR2, 13, 16) while also impeding the government's ability to establish a suitable legal framework for such technologies (BAR6, 7) [2], [9]. Additionally, the lack of synchronization with existing technologies and limitations in defining communication standards (BAR4, 6, 15) due to insufficient technical equipment and professional qualifications further compound the barriers to the application of quantum computing in Vietnam. Adequate infrastructure serves as the foundational factor for the adoption of new technology. Insufficient infrastructure hinders progress in its own right and gives rise to various other barriers, impeding the country's ability to master new technologies. High costs pose a significant barrier to the application of quantum computing in Vietnam, giving rise to various other obstacles [9], [79]. The financial burden associated with high costs constrains access, investment, and the development of necessary infrastructure for new technologies (BAR4, BAR12). Moreover, in developing countries, limited capital allocation across multiple sectors due to high costs results in constrained investment in research and education of new technologies (BAR1, 14), thereby exacerbating the shortage of qualified human resources (BAR5) [81]. The prohibitive costs also impede the widespread adoption of quantum computing in Vietnam, leading to a lack of comprehensive understanding and specific perspectives among the community and authorities. Consequently, barriers stemming from Public Awareness and Risk Aversion (BAR2, 16) and policy and legal aspects (BAR6, 7) emerge. The substantial initial investment costs, coupled with a lack of experience in managing operating expenses, contribute to numerous barriers not only on a technical level but also in terms of cognitive hurdles, rendering the application of quantum computing for data analysis in Vietnam even more challenging. BAR5 - The lack of a Skilled Workforce represents another significant barrier that engenders various challenges [11]. The absence of proficient personnel proficient in operating technology not only hampers the integration of existing technologies with new ones (BAR9) but also poses risks to information security (BAR8). The dearth of qualified human resources further impedes access to and stable technology operationBAR4, 11), thus introducing new barriers [82]. Human resources lacking in quality represent a critical bottleneck that necessitates resolution because, alongside infrastructure and investment, the human element plays a pivotal role in successfully applying new technology within a country. Indeed, proficient human resources are essential prerequisites for the practical application of technology. Similar to infrastructure limitations, the barrier of Limited Research and Development (BAR14) encompasses various challenges associated with acquiring the knowledge, skills, and understanding required to implement quantum computing in Vietnam [56], [83]. These challenges are exacerbated by issues related to infrastructure accessibility and the limited availability of resources for Vietnamese researchers. Moreover, accessing this technology abroad is also challenging due to the scarcity of countries with comprehensive infrastructure and advanced capabilities in quantum computing. In the second quadrant, BAR15 (Standards and Interoperability) and BAR16 (Risk Aversion) are categorized as "cause" factors with low influence weights. These barriers have significant net influence values and can lead to numerous other barriers. For instance, barriers related to Standards and Interoperability exacerbate challenges related to infrastructure, connectivity, and information security (BAR 4, 8, 9, 12), making them more difficult to overcome [84]. Additionally, Risk Aversion impedes community awareness and acceptance of quantum computing technology, hindering the development of skilled human resources and research and education in this field (BAR 1, 2, 5, 13, 14) [58]. The third and fourth quadrants comprise factors categorized as the "effect" group, influenced by those in the "cause" group. Specifically, BAR1 - Educational Gap and BAR9 - Integration Complexity in the fourth quadrant are weighted as influential factors that impact the adoption of quantum computing in Vietnam. These barriers stem from other obstacles, such as inadequate infrastructure, insufficient investment, and limited access to advanced technology.

E. QSF COCOSO RESULTS

Experts will evaluate the proposed strategies to assess their effectiveness in mitigating and removing barriers. Expert assessments are initially recorded in linguistic form based on the scale outlined in Table 6. Subsequently, these assessments are converted into QSF numbers, and Equation (22) is utilized to synthesize the evaluations provided by 30 experts into an aggregated matrix. The summarized opinions of the 30 experts are presented in **Table 13**.

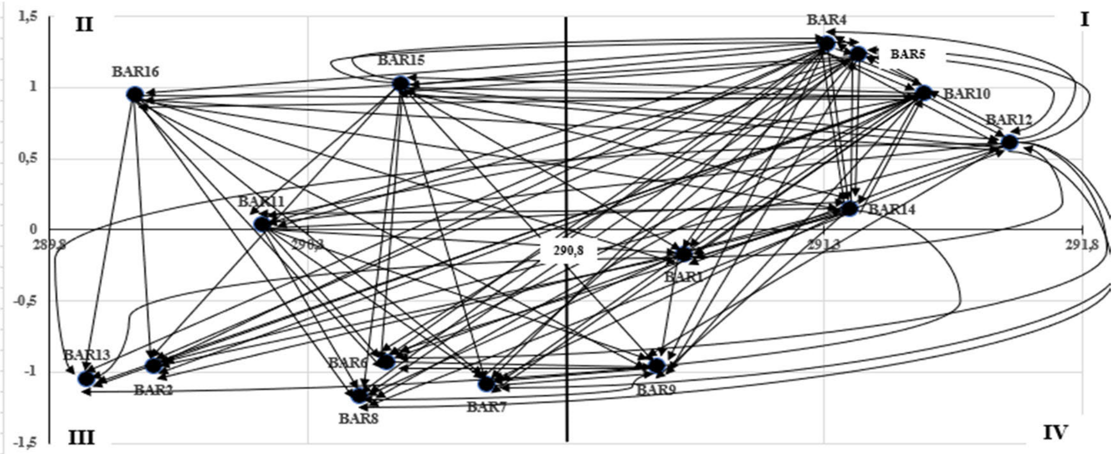

FIGURE 3. Influential network relation map of 15 barriers.

TABLE 13. Aggregated assessment matrix.

	BAR1	BAR2	BAR4	BAR5	BAR6	BAR7	BAR8
STG1	$(0,52607e^{j2\pi0,08365}; 0,40819e^{j2\pi0,06438}; 0,74608e^{j2\pi0,02699})$	$(0,51797e^{j2\pi0,08236}; 0,40289e^{j2\pi0,06351}; 0,75458e^{j2\pi0,02919})$	$(0,54851e^{j2\pi0,08727}; 0,42701e^{j2\pi0,06729}; 0,71889e^{j2\pi0,02082})$	$(0,54142e^{j2\pi0,08624}; 0,42399e^{j2\pi0,06681}; 0,72601e^{j2\pi0,02268})$	$(0,51828e^{j2\pi0,08242}; 0,40235e^{j2\pi0,0634}; 0,75465e^{j2\pi0,02954})$	$(0,50473e^{j2\pi0,08015}; 0,38999e^{j2\pi0,06146}; 0,77017e^{j2\pi0,03362})$	$(0,49521e^{j2\pi0,07861}; 0,3825e^{j2\pi0,06027}; 0,78004e^{j2\pi0,03614})$
STG2	$(0,52908e^{j2\pi0,08412}; 0,41222e^{j2\pi0,06496}; 0,74172e^{j2\pi0,02818})$	$(0,55943e^{j2\pi0,08907}; 0,43763e^{j2\pi0,06896}; 0,70392e^{j2\pi0,0177})$	$(0,52049e^{j2\pi0,08269}; 0,4031e^{j2\pi0,06355}; 0,75273e^{j2\pi0,0292})$	$(0,53386e^{j2\pi0,08481}; 0,41351e^{j2\pi0,06519}; 0,73757e^{j2\pi0,02627})$	$(0,53633e^{j2\pi0,08539}; 0,41852e^{j2\pi0,06595}; 0,73293e^{j2\pi0,0233})$	$(0,51417e^{j2\pi0,08169}; 0,39845e^{j2\pi0,06279}; 0,75952e^{j2\pi0,03108})$	$(0,54775e^{j2\pi0,08713}; 0,42712e^{j2\pi0,06731}; 0,71939e^{j2\pi0,02253})$
STG3	$(0,54565e^{j2\pi0,08669}; 0,42293e^{j2\pi0,06665}; 0,72346e^{j2\pi0,0241})$	$(0,51466e^{j2\pi0,08177}; 0,39872e^{j2\pi0,06283}; 0,75904e^{j2\pi0,03159})$	$(0,54626e^{j2\pi0,08701}; 0,42774e^{j2\pi0,0674}; 0,72016e^{j2\pi0,02129})$	$(0,56038e^{j2\pi0,08915}; 0,43701e^{j2\pi0,06887}; 0,70355e^{j2\pi0,01859})$	$(0,5385e^{j2\pi0,08572}; 0,42085e^{j2\pi0,06632}; 0,73e^{j2\pi0,02356})$	$(0,53851e^{j2\pi0,08575}; 0,42131e^{j2\pi0,06639}; 0,72973e^{j2\pi0,02379})$	$(0,51495e^{j2\pi0,08165}; 0,39561e^{j2\pi0,06234}; 0,76047e^{j2\pi0,03291})$
STG4	$(0,50977e^{j2\pi0,08097}; 0,39462e^{j2\pi0,06221}; 0,76447e^{j2\pi0,03271})$	$(0,52424e^{j2\pi0,0833}; 0,40672e^{j2\pi0,06412}; 0,74817e^{j2\pi0,02906})$	$(0,54328e^{j2\pi0,08636}; 0,42209e^{j2\pi0,06651}; 0,72573e^{j2\pi0,02384})$	$(0,54721e^{j2\pi0,08708}; 0,4271e^{j2\pi0,06733}; 0,71982e^{j2\pi0,02205})$	$(0,51821e^{j2\pi0,08245}; 0,4046e^{j2\pi0,06376}; 0,7535e^{j2\pi0,02972})$	$(0,53546e^{j2\pi0,08523}; 0,41801e^{j2\pi0,06587}; 0,73386e^{j2\pi0,02462})$	$(0,52328e^{j2\pi0,08322}; 0,4075e^{j2\pi0,06421}; 0,74842e^{j2\pi0,02851})$
STG5	$(0,51788e^{j2\pi0,08239}; 0,40313e^{j2\pi0,06353}; 0,75451e^{j2\pi0,02937})$	$(0,51286e^{j2\pi0,0815}; 0,39876e^{j2\pi0,06284}; 0,76024e^{j2\pi0,03191})$	$(0,52926e^{j2\pi0,08407}; 0,40968e^{j2\pi0,06458}; 0,743e^{j2\pi0,0278})$	$(0,52063e^{j2\pi0,08251}; 0,40072e^{j2\pi0,06315}; 0,7539e^{j2\pi0,03231})$	$(0,53309e^{j2\pi0,08454}; 0,41142e^{j2\pi0,06486}; 0,73929ej^{2\pi0,02895})$	$(0,52024e^{j2\pi0,08258}; 0,4028e^{j2\pi0,0635}; 0,75306e^{j2\pi0,03062})$	$(0,53565e^{j2\pi0,08488}; 0,41245e^{j2\pi0,06502}; 0,73686e^{j2\pi0,02916})$
STG6	$(0,52947e^{j2\pi0,08412}; 0,41097e^{j2\pi0,06476}; 0,74213e^{j2\pi0,02818})$	$(0,51924e^{j2\pi0,08266}; 0,40617e^{j2\pi0,06401}; 0,75194e^{j2\pi0,02901})$	$(0,53655e^{j2\pi0,08536}; 0,41849e^{j2\pi0,06595}; 0,73279e^{j2\pi0,02569})$	$(0,52287e^{j2\pi0,08306}; 0,40596e^{j2\pi0,064}; 0,74954e^{j2\pi0,02959})$	$(0,52692e^{j2\pi0,08365}; 0,40778e^{j2\pi0,06426}; 0,7457e^{j2\pi0,02926})$	$(0,51164e^{j2\pi0,08127}; 0,39698e^{j2\pi0,06256}; 0,76199e^{j2\pi0,03257})$	$(0,54335e^{j2\pi0,08626}; 0,42032e^{j2\pi0,06623}; 0,72671e^{j2\pi0,02556})$
STG7	$(0,51414e^{j2\pi0,08168}; 0,39842e^{j2\pi0,06278}; 0,75955e^{j2\pi0,03109})$	$(0,5334e^{j2\pi0,08465}; 0,4119e^{j2\pi0,06493}; 0,7388e^{j2\pi0,02746})$	$(0,51417e^{j2\pi0,0816}; 0,39716e^{j2\pi0,06259}; 0,76019e^{j2\pi0,03259})$	$(0,52856e^{j2\pi0,08393}; 0,41001e^{j2\pi0,06461}; 0,74331e^{j2\pi0,0291})$	$(0,53139e^{j2\pi0,08436}; 0,41089e^{j2\pi0,06477}; 0,74081e^{j2\pi0,02763})$	$(0,51063e^{j2\pi0,08094}; 0,39377e^{j2\pi0,06205}; 0,76433e^{j2\pi0,03446})$	$(0,54861e^{j2\pi0,0872}; 0,42629e^{j2\pi0,0672}; 0,71924e^{j2\pi0,02324})$
STG8	$(0,50919e^{j2\pi0,0808}; 0,39291e^{j2\pi0,06194}; 0,76574e^{j2\pi0,03367})$	$(0,52273e^{j2\pi0,0832}; 0,40794^{ej2\pi0,06428}; 0,74855e^{j2\pi0,0283})$	$(0,53547e^{j2\pi0,08509}; 0,41577e^{j2\pi0,06552}; 0,73513e^{j2\pi0,02609})$	$(0,5189e^{j2\pi0,08264}; 0,407e^{j2\pi0,06414}; 0,75173e^{j2\pi0,02882})$	$(0,51909e^{j2\pi0,0825}; 0,4032e^{j2\pi0,06354}; 0,75364e^{j2\pi0,03008})$	$(0,52238e^{j2\pi0,08311}; 0,406e^{j2\pi0,06398}; 0,74985e^{j2\pi0,02774})$	$(0,52604e^{j2\pi0,08362}; 0,40962e^{j2\pi0,06457}; 0,74531e^{j2\pi0,02908})$
STG9	$(0,51998e^{j2\pi0,08257}; 0,40237e^{j2\pi0,06341}; 0,75347e^{j2\pi0,03063})$	$(0,53951e^{j2\pi0,08569}; 0,41844e^{j2\pi0,06596}; 0,73064e^{j2\pi0,02593})$	$(0,52827e^{j2\pi0,08389}; 0,40855e^{j2\pi0,06438}; 0,74432e^{j2\pi0,02872})$	$(0,55581^{ej2\pi0,08829}; 0,43134e^{j2\pi0,068}; 0,71065e^{j2\pi0,02217})$	$(0,52285e^{j2\pi0,08308}; 0,40639e^{j2\pi0,06404}; 0,74932e^{j2\pi0,02978})$	$(0,52351e^{j2\pi0,08297}; 0,40199e^{j2\pi0,06335}; 0,75123e^{j2\pi0,03117})$	$(0,51464e^{j2\pi0,08165}; 0,39698e^{j2\pi0,06256}; 0,75997e^{j2\pi0,03292})$
STG10	$(0,54432e^{j2\pi0,08619}; 0,41744e^{j2\pi0,06581}; 0,72764e^{j2\pi0,02757})$	$(0,52548e^{j2\pi0,08354}; 0,40916e^{j2\pi0,06448}; 0,74596e^{j2\pi0,02852})$	$(0,53391e^{j2\pi0,08483}; 0,41411e^{j2\pi0,06528}; 0,73719e^{j2\pi0,02648})$	$(0,54194e^{j2\pi0,08629}; 0,42399e^{j2\pi0,06681}; 0,72562e^{j2\pi0,02316})$	$(0,5222e^{j2\pi0,08287}; 0,40358e^{j2\pi0,06362}; 0,75129e^{j2\pi0,03047})$	$(0,51092e^{j2\pi0,08119}; 0,39633e^{j2\pi0,06248}; 0,76281e^{j2\pi0,03207})$	$(0,54239e^{j2\pi0,08594}; 0,41688e^{j2\pi0,06572}; 0,7294e^{j2\pi0,02793})$

	BAR9	BAR10	BAR11	BAR12	BAR13	BAR14	BAR15	BAR16
STG1	$(0,52455e^{j2\pi0,08331}; 0,40532e^{j2\pi0,06387}; 0,74871e^{j2\pi0,02905})$	$(0,53589e^{j2\pi0,08526}; 0,41736e^{j2\pi0,06577}; 0,73391e^{j2\pi0,02484})$	$(0,50379e^{j2\pi0,08009}; 0,39132e^{j2\pi0,06169}; 0,7701e^{j2\pi0,03331})$	$(0,50859e^{j2\pi0,08072}; 0,39248e^{j2\pi0,06185}; 0,76636e^{j2\pi0,03318})$	$(0,49891e^{j2\pi0,07931}; 0,38796e^{j2\pi0,06114}; 0,77497e^{j2\pi0,03452})$	$(0,48997e^{j2\pi0,0779}; 0,38018e^{j2\pi0,05991}; 0,78447e^{j2\pi0,03597})$	$(0,51355e^{j2\pi0,08166}; 0,39884e^{j2\pi0,06285}; 0,75973e^{j2\pi0,03091})$	$(0,53538ej^{2\pi0,0851}; 0,41557e^{j2\pi0,06551}; 0,7353e^{j2\pi0,02609})$
STG2	$(0,52943e^{j2\pi0,08421}; 0,41228e^{j2\pi0,06497}; 0,74144e^{j2\pi0,02643})$	$(0,53794e^{j2\pi0,08567}; 0,42082e^{j2\pi0,06634}; 0,73043e^{j2\pi0,0231})$	$(0,56408e^{j2\pi0,08971}; 0,43982e^{j2\pi0,06933}; 0,69883e^{j2\pi0,01837})$	$(0,54777e^{j2\pi0,087}; 0,42485e^{j2\pi0,06697}; 0,72073e^{j2\pi0,02412})$	$(0,53495e^{j2\pi0,08494}; 0,41398e^{j2\pi0,06526}; 0,73651e^{j2\pi0,02727})$	$(0,54286e^{j2\pi0,08623}; 0,42091e^{j2\pi0,06633}; 0,72673e^{j2\pi0,02536})$	$(0,5232e^{j2\pi0,08313}; 0,40601e^{j2\pi0,064}; 0,74928e^{j2\pi0,03013})$	$(0,54967e^{j2\pi0,08741}; 0,42818e^{j2\pi0,06747}; 0,7173e^{j2\pi0,02232})$
STG3	$(0,54383e^{j2\pi0,08655}; 0,42439e^{j2\pi0,06688}; 0,72398e^{j2\pi0,02271})$	$(0,55348e^{j2\pi0,08809}; 0,43277e^{j2\pi0,0682}; 0,7116e^{j2\pi0,02013})$	$(0,54289e^{j2\pi0,08649}; 0,42563e^{j2\pi0,0671}; 0,72395e^{j2\pi0,02224})$	$(0,55156e^{j2\pi0,08784}; 0,43214e^{j2\pi0,0681}; 0,71346e^{j2\pi0,02064})$	$(0,54969e^{j2\pi0,08743}; 0,42879e^{j2\pi0,06757}; 0,71692e^{j2\pi0,02257})$	$(0,53743e^{j2\pi0,08543}; 0,41766e^{j2\pi0,06584}; 0,73262e^{j2\pi0,02633})$	$(0,53966e^{j2\pi0,08598}; 0,42381e^{j2\pi0,06678}; 0,72743ej^{2\pi0,02313})$	$(0,5413e^{j2\pi0,08621}; 0,42329e^{j2\pi0,06673}; 0,72651e^{j2\pi0,02246})$
STG4	$(0,54678e^{j2\pi0,08703}; 0,42728e^{j2\pi0,06733}; 0,72004e^{j2\pi0,02155})$	$(0,54772e^{j2\pi0,08701}; 0,42468e^{j2\pi0,06692}; 0,72087e^{j2\pi0,02411})$	$(0,5253e^{j2\pi0,08335}; 0,40571e^{j2\pi0,06396}; 0,74797e^{j2\pi0,02943})$	$(0,52584e^{j2\pi0,08345}; 0,40658e^{j2\pi0,06407}; 0,74712ej^{2\pi0,03016})$	$(0,50675e^{j2\pi0,08045}; 0,39251e^{j2\pi0,06188}; 0,76756e^{j2\pi0,03349})$	$(0,51482e^{j2\pi0,0819}; 0,40122e^{j2\pi0,06322}; 0,75762e^{j2\pi0,0304})$	$(0,50125e^{j2\pi0,07968}; 0,38994e^{j2\pi0,06145}; 0,77246e^{j2\pi0,03469})$	$(0,52238e^{j2\pi0,08279}; 0,40252e^{j2\pi0,06345}; 0,75173e^{j2\pi0,03199})$
STG5	$(0,51601e^{j2\pi0,08201}; 0,40126e^{j2\pi0,06323}; 0,75679e^{j2\pi0,03111})$	$(0,52559e^{j2\pi0,08354}; 0,40936e^{j2\pi0,06451}; 0,74577e^{j2\pi0,02852})$	$(0,55394e^{j2\pi0,08812}; 0,43214e^{j2\pi0,0681}; 0,71162e^{j2\pi0,02039})$	$(0,51986e^{j2\pi0,08257}; 0,40403e^{j2\pi0,06369}; 0,75267e^{j2\pi0,03062})$	$(0,5204e^{j2\pi0,08246}; 0,39945e^{j2\pi0,06295}; 0,75473e^{j2\pi0,03198})$	$(0,52942ej^{2\pi0,08399}; 0,4086e^{j2\pi0,06439}; 0,74348e^{j2\pi0,02946})$	$(0,53546e^{j2\pi0,08509}; 0,41576e^{j2\pi0,06552}; 0,73514e^{j2\pi0,02609})$	$(0,52848e^{j2\pi0,08394}; 0,40982e^{j2\pi0,06458}; 0,74348e^{j2\pi0,0291})$
STG6	$(0,51154e^{j2\pi0,08115}; 0,39509e^{j2\pi0,06228}; 0,76304e^{j2\pi0,03385})$	$(0,53354e^{j2\pi0,08483}; 0,41537e^{j2\pi0,06545}; 0,73675e^{j2\pi0,02649})$	$(0,49619e^{j2\pi0,079}; 0,38816e^{j2\pi0,06117}; 0,77662e^{j2\pi0,03467})$	$(0,52175e^{j2\pi0,08287}; 0,40464e^{j2\pi0,06376}; 0,75103e^{j2\pi0,03046})$	$(0,51859e^{j2\pi0,08247}; 0,4038e^{j2\pi0,06363}; 0,75366e^{j2\pi0,0299})$	$(0,49878e^{j2\pi0,07919}; 0,38609e^{j2\pi0,06084}; 0,77598e^{j2\pi0,03574})$	$(0,53337e^{j2\pi0,08469}; 0,41276e^{j2\pi0,06507}; 0,73834e^{j2\pi0,02785})$	$(0,52231e^{j2\pi0,08292}; 0,40464e^{j2\pi0,06376}; 0,75064e^{j2\pi0,03082})$
STG7	$(0,52279e^{j2\pi0,08295}; 0,40404e^{j2\pi0,06367}; 0,75063e^{j2\pi0,03099})$	$(0,52152e^{j2\pi0,08282}; 0,40336e^{j2\pi0,06356}; 0,75187e^{j2\pi0,03011})$	$(0,53157e^{j2\pi0,08443}; 0,4126e^{j2\pi0,06502}; 0,73972e^{j2\pi0,02821})$	$(0,54031e^{j2\pi0,08588}; 0,41924e^{j2\pi0,06607}; 0,72959e^{j2\pi0,02489})$	$(0,5402e^{j2\pi0,08603}; 0,42383e^{j2\pi0,06679}; 0,72701e^{j2\pi0,02359})$	$(0,51214e^{j2\pi0,0813}; 0,39638^{ej2\pi0,06246}; 0,76197e^{j2\pi0,03274})$	$(0,50553e^{j2\pi0,08028}; 0,39162e^{j2\pi0,06171}; 0,76881e^{j2\pi0,03443})$	$(0,51587e^{j2\pi0,08198}; 0,40061e^{j2\pi0,06315}; 0,75722e^{j2\pi0,03094})$
STG8	$(0,51437e^{j2\pi0,08174}; 0,39969e^{j2\pi0,06301}; 0,75873e^{j2\pi0,03143})$	$(0,53501e^{j2\pi0,08504}; 0,41593e^{j2\pi0,06554}; 0,73537e^{j2\pi0,02568})$	$(0,51416e^{j2\pi0,08159}; 0,39716e^{j2\pi0,06261}; 0,7602e^{j2\pi0,03259})$	$(0,54207e^{j2\pi0,08629}; 0,42421e^{j2\pi0,06685}; 0,7254e^{j2\pi0,02315})$	$(0,52814e^{j2\pi0,08392}; 0,41066e^{j2\pi0,06471}; 0,74325e^{j2\pi0,0289})$	$(0,52794e^{j2\pi0,08411}; 0,4135e^{j2\pi0,06516}; 0,74182e^{j2\pi0,0256})$	$(0,52462e^{j2\pi0,08344}; 0,4077e^{j2\pi0,06425}; 0,74737e^{j2\pi0,02774})$	$(0,53276e^{j2\pi0,08475}; 0,41448e^{j2\pi0,06534}; 0,73782e^{j2\pi0,02587})$
STG9	$(0,53461e^{j2\pi0,0848}; 0,41302e^{j2\pi0,06509}; 0,7373e^{j2\pi0,02861})$	$(0,53436e^{j2\pi0,08491}; 0,41438e^{j2\pi0,06532}; 0,73671e^{j2\pi0,02708})$	$(0,50732e^{j2\pi0,08062}; 0,3942e^{j2\pi0,06212}; 0,76631e^{j2\pi0,03253})$	$(0,51428e^{j2\pi0,08159}; 0,39735e^{j2\pi0,06262}; 0,76002e^{j2\pi0,03259})$	$(0,51907e^{j2\pi0,0825}; 0,4032e^{j2\pi0,06354}; 0,75366e^{j2\pi0,03008})$	$(0,52164e^{j2\pi0,08273}; 0,40227e^{j2\pi0,06341}; 0,75238e^{j2\pi0,03166})$	$(0,5345e^{j2\pi0,0848}; 0,41282e^{j2\pi0,06508}; 0,73748e^{j2\pi0,02861})$	$(0,53248e^{j2\pi0,0846}; 0,41313e^{j2\pi0,0651}; 0,73877e^{j2\pi0,02706})$
STG10	$(0,5215e^{j2\pi0,08284}; 0,40379e^{j2\pi0,06365}; 0,75166e^{j2\pi0,03029})$	$(0,54595e^{j2\pi0,08674}; 0,42446e^{j2\pi0,06689}; 0,72234e^{j2\pi0,02454})$	$(0,52521e^{j2\pi0,08344}; 0,40684e^{j2\pi0,06413}; 0,74742e^{j2\pi0,02775})$	$(0,5482e^{j2\pi0,087}; 0,42374e^{j2\pi0,0668}; 0,72105e^{j2\pi0,02413})$	$(0,53787ej^{2\pi0,08543}; 0,41657e^{j2\pi0,06567}; 0,73291e^{j2\pi0,02633})$	$(0,52711e^{j2\pi0,08387}; 0,40981e^{j2\pi0,06458}; 0,74446e^{j2\pi0,0262})$	$(0,54636e^{j2\pi0,0869}; 0,4261e^{j2\pi0,06715}; 0,72106e^{j2\pi0,02321})$	$(0,55994e^{j2\pi0,08914}; 0,43812e^{j2\pi0,06904}; 0,70322e^{j2\pi0,01859})$

Table 14 presents defuzzified data using Equation (20). Subsequently, each evaluation value corresponding to the barriers will be multiplied by the respective weight of that barrier determined through the DEMATEL phase. Based on these results, the values WS_i, $W\ P_i$, and $WS_i + WP_i$, along with three appraisal score $\mathbb{R}_{ia}, \mathbb{R}_{ib}, \mathbb{R}_{ic}$ (with $\eta = 0.5$) and $\mathbb{R}_i$ are calculated.

Table 14 highlights STG3 - Cost Reduction Initiatives, STG2 - Investment in Infrastructure, and STG10 - Training and Education Programs as the top-rated solution strategies. The specific ranking of strategies is as follows: STG3 > STG2 > STG10 > STG 9 > STG5 > STG7 > STG4 > STG8 > STG6 > STG1.

Addressing solutions to reduce initial investment costs (STG3) is crucial for facilitating the adoption of quantum computing in data analysis within Vietnam. The substantial initial investment required poses a significant challenge for developing countries like Vietnam, hindering their ability to adopt new technologies [48]. These costs can be effectively managed by drawing insights from past implementations and progressively developing supporting technologies to bolster local infrastructure. This approach reduces dependency

TABLE 14. QSF COCOSO results.

Strategies	WS_i	WP_i	$\mathbb{R}_{ia}$	$\mathbb{R}_{ib}$	$\mathbb{R}_{ic}$	$\mathbb{R}_i$	Rank
STG1	0,98256	0,98252	0,09953	1	0,64042	0,97944	10
STG2	0,99082	0,9908	0,10037	1,00842	0,64582	0,9877	2
STG3	0,99131	0,99129	0,10042	1,00892	0,64614	0,98819	1
STG4	0,98615	0,98612	0,09989	1,00366	0,64277	0,98302	7
STG5	0,98721	0,98719	0,1	1,00474	0,64346	0,98409	5
STG6	0,98435	0,98432	0,09971	1,00183	0,6416	0,98124	9
STG7	0,98625	0,98622	0,0999	1,00376	0,64284	0,98313	6
STG8	0,98527	0,98526	0,0998	1,00277	0,64221	0,98216	8
STG9	0,98758	0,98756	0,10004	1,00512	0,64371	0,98446	4
STG10	0,99061	0,99058	0,10034	1,0082	0,64567	0,98746	3
Min	0,98256	0,98252					
Max	0,99131	0,99129					

on complete imports from overseas, thereby offering better cost control [2]. Implementing this overarching strategy universally holds the potential to mitigate significant costrelated barriers, which are fundamental obstacles hindering

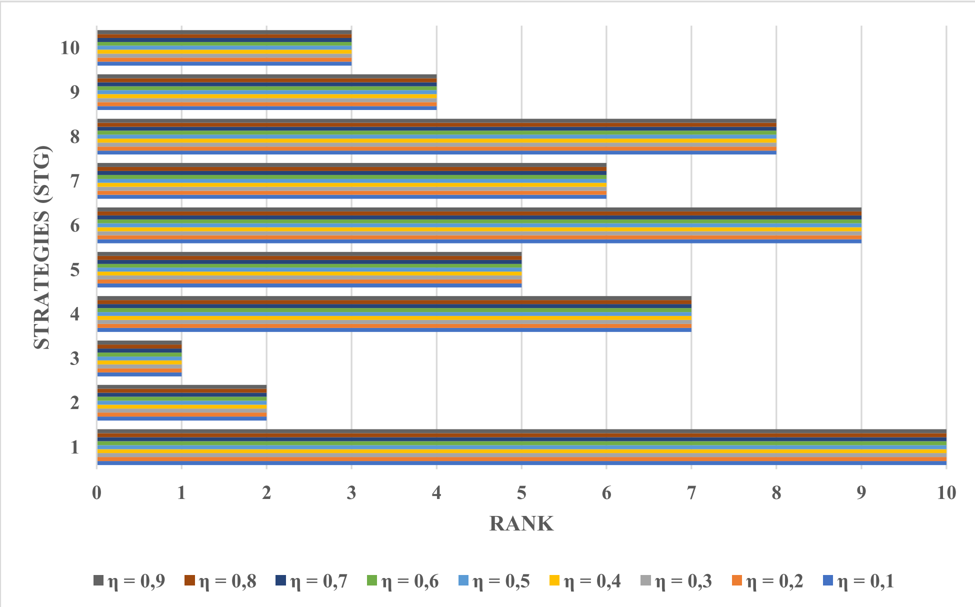

FIGURE 4. Sensitive analysis result.

Vietnam's adoption of quantum computing. By leveraging lessons learned and incrementally building local technological capacities, Vietnam can enhance its readiness to embrace quantum computing for data analysis. This proactive approach not only addresses immediate financial constraints but also lays a foundation for sustainable technological advancement in the region.

Furthermore, STG2 - Investment in Infrastructure emerges as a critical strategy aimed at overcoming the challenge of Limited Infrastructure (BAR12), which is the primary barrier obstructing progress due to constraints on essential resources, qualified human capital, public technology awareness, and interoperability with existing technologies (BAR 2, 4, 5, 9, 12, 13, 15) [61]. The establishment and enhancement of infrastructure are pivotal steps towards harnessing the full potential of quantum computing [8]. By investing strategically in infrastructure, Vietnam can gradually overcome these barriers, laying a robust foundation for integrating quantum computing capabilities. This strategic investment not only addresses immediate resource constraints but also facilitates long-term interoperability with existing technologies, fostering widespread awareness and adoption. Ranked third among the strategies is STG10 Training and Education Programs. This initiative directly tackles the challenge of developing skilled human capital and fostering community awareness of technology (BAR1, BAR5) [60]. By implementing comprehensive training and education programs, Vietnam can effectively cultivate a proficient workforce equipped to leverage quantum computing technologies. These programs not only bridge the skills gap but also enhance public awareness and acceptance of technological advancements. By nurturing a knowledgeable workforce, Vietnam can sustainably integrate quantum computing into its technological ecosystem, paving the way for future innovation and competitiveness. Briefly, investment in infrastructure and the implementation of training and education programs are integral strategies for overcoming barriers to quantum computing adoption in Vietnam.

While STG2 emphasizes investment in physical infrastructure, STG10 addresses the critical need for preparing the population through knowledge, skills, and awareness programs. Training and educational initiatives focused on quantum computing are pivotal in cultivating community understanding, dismantling cultural barriers, enhancing technology awareness, and reducing risk aversion (BAR2, 13, 16) [10]. These programs are essential for equipping individuals with the necessary expertise to harness the potential of quantum computing effectively. By fostering a knowledgeable workforce and raising awareness among the populace, Vietnam can overcome barriers associated with limited technology acceptance and adoption. Furthermore, education in quantum computing enhances technological literacy and stimulates innovation and entrepreneurship in related fields. Investing in training and educational programs represents a proactive approach to building human capital capable of integrating and advancing quantum computing within Vietnam's technological ecosystem.

Therefore, these efforts facilitate the development of more suitable government policies and regulations (BAR6, 7). Integrating the implementation of these three strategies is crucial for systematically establishing the necessary infrastructure for new technologies while simultaneously cultivating a skilled workforce capable of utilizing them proficiently. This integrated approach fosters public acceptance and adoption

TABLE 15. $\mathbb{R}_i$ under different η values.

	η	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$\mathbb{R}_i$	STG1	1,15895	0,76202	1,0304	1,16494	0,97944	0,88095	1,07543	1,13331	0,97293
	STG2	1,16872	0,76844	1,03908	1,17476	0,9877	0,88837	1,08449	1,14286	0,98113
	STG3	1,1693	0,76882	1,0396	1,17534	0,98819	0,88882	1,08503	1,14343	0,98161
	STG4	1,16319	0,7648	1,03416	1,1692	0,98302	0,88417	1,07936	1,13746	0,97648
	STG5	1,16445	0,76563	1,03528	1,17047	0,98409	0,88513	1,08053	1,13869	0,97754
	STG6	1,16107	0,76341	1,03228	1,16707	0,98124	0,88256	1,07739	1,13538	0,97471
	STG7	1,16331	0,76488	1,03427	1,16932	0,98313	0,88426	1,07947	1,13757	0,97658
	STG8	1,16216	0,76412	1,03325	1,16817	0,98216	0,88338	1,0784	1,13645	0,97562
	STG9	1,16489	0,76592	1,03568	1,17091	0,98446	0,88547	1,08094	1,13912	0,97792
	STG10	1,16845	0,76826	1,03884	1,17448	0,98746	0,88816	1,08424	1,14259	0,98089

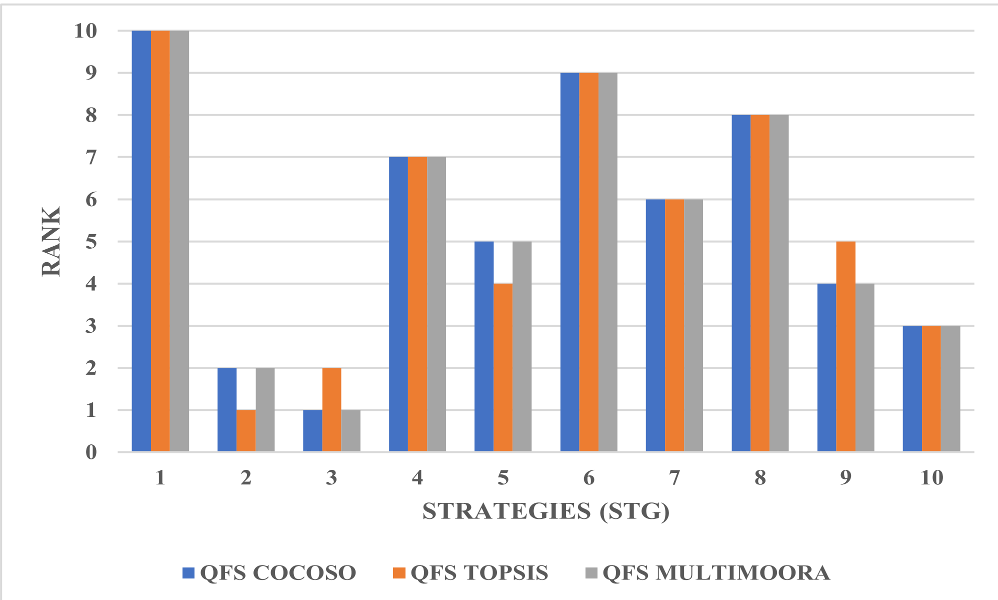

FIGURE 5. Comparative analysis results.

within a cost framework that aligns with the national context, maximizing efficiency and effectiveness.

In summary, integrating top strategies, as mentioned above, is essential for fostering technology adoption in Vietnam and ensuring both readiness and efficiency in implementation.

F. SENSITIVE ANALYSIS

To enhance the reliability of the ranking outcomes, a sensitivity analysis was conducted by adjusting parameter η across a range from 0.1 to 0.9 in increments of 0.1. This approach minimizes potential human biases that influence decision-making results [85]. By systematically varying the parameters, the analysis ensures a comprehensive examination of the robustness of the ranking outcomes, thereby bolstering the validity and credibility of the study findings. **Table 15** displays the $\mathbb{R}_i$ Results of the strategies across different η conditions.

Figure 4 presents the ranking outcomes of the ten strategies under different η conditions, ranging from 0.1 to 0.9. The consistent order observed across varying η values highlights the reliability and robustness of the ranking results, reaffirming their independence from potential human biases. This consistency strengthens the validity of the study's findings and underscores the credibility of the proposed strategies.

G. COMPARATIVE ANALYSIS

A comparative analysis assessed the precision and dependability of the ranking outcomes derived from the QSF COCOSO method. This evaluation aimed to gauge the

TABLE 16. Pearson correlation test results.

		QSF COCOSO	QSF TOPSIS	QSF MULTIMOORA
QSF COCOSO	*Pearson Correlation*	1	,976**	1,000**
	Sig. (2-tailed)		0,000	0,000
QSF TOPSIS	*Pearson Correlation*	,976**	1	,976**
	Sig. (2-tailed)	0,000		0,000
QSF MULTIMOORA	*Pearson Correlation*	1,000**	,976**	1
	Sig. (2-tailed)	0,000	0,000	

***. Correlation is significant at the 0.01 level (2-tailed).*

consistency and effectiveness of the COCOSO method in comparison to alternative approaches. By scrutinizing the similarities and disparities between the rankings obtained from different methods, the analysis provided insights into the robustness and validity of the COCOSO method in prioritizing strategies for overcoming barriers in applying quantum computing to data analysis in Vietnam [86]. The ranking outcomes derived from the QSF COCOSO method were juxtaposed with those from the QSF TOPSIS and QSF MULTIMOORA methods using the same dataset. The comparison outcomes among the three methods are presented in Figure 5:

The comparison reveals similarities in the ranking outcomes from the QSF COCOSO and QSF MULTIMOORA methods. Nonetheless, a slight disparity is observed when comparing these outcomes with those derived from the QSF TOPSIS method. Although the top 1, 2, and 4, 5 positions differ, the top 5 strategies, namely STG2, 3, 5, 9, and 10, remain consistent. This variance is attributed to the differing ranking principles employed by the TOPSIS method, which relies on the distance to the ideal solution. A Pearson correlation test was conducted to ascertain the correlation among the three sets of results. **Table 16** presents the outcomes of the Pearson correlation test between the three sets of ranking results.

The comparison results from **Table 16** reveal that the significance value (sig) between the QSF COCOSO and QSF TOPSIS methods is less than 0.05, and the correlation value is 0.976. This indicates a strong positive correlation between the ranking outcomes derived from these two methods [87]. Thus, the comparative analysis demonstrates that the ranking results obtained through the QSF COCOSO method closely resemble those obtained using the QSF MULTIMOORA method. Although a slight discrepancy is observed with the TOPSIS method, the strong positive correlation validates the reliability of the COCOSO method's outcomes.

V. CONCLUSION

This study has identified and validated 15 critical barriers to applying quantum computing in data analysis within Vietnam. These barriers, including limited infrastructure, high costs, and a lack of a skilled workforce, were identified as root causes that significantly hinder the adoption of quantum computing. Addressing these barriers is crucial for creating a conducive environment for quantum computing applications in Vietnam. The QSF DEMATEL method highlighted the interconnected nature of these barriers, emphasizing the need to prioritize infrastructure development, cost reduction initiatives, and investment in education and training programs. These strategies are pivotal in overcoming awareness, technology integration, and human resource development challenges. Theoretically, this study integrates QSF theory with MCDM methods such as DELPHI and DEMATEL to assess barrier weights and causal relationships. The QSF COCOSO method ranks proposed solutions effectively, demonstrating consistency in results across various methodologies like QSF MULTIMOORA and QSF TOPSIS. A sensitivity analysis conducted using the COCOSO method further validated the robustness and reliability of the findings. Methodological enhancements, including integrating quantum theory with spherical fuzzy sets and considering expert weights in barrier validation, contributed to the accuracy and depth of the analysis. These approaches ensure a comprehensive understanding of barriers and effective strategies for quantum computing adoption in Vietnamese data analysis contexts.

Effective policies are crucial to facilitate the adoption of quantum computing for data analysis in Vietnam. Policymakers should prioritize financial incentives to reduce initial investment barriers and foster infrastructure development tailored to support quantum technologies. Educational reforms should focus on enhancing skills in quantum computing through specialized training programs and partnerships with industry. Public awareness campaigns are essential to promote understanding and acceptance of quantum technologies. A robust regulatory framework should also be established to address privacy, security, and ethical concerns. Collaboration between government, academia, and industry fosters innovation and technology transfer. Continuous monitoring and evaluation mechanisms will ensure policy effectiveness and alignment with national goals, maximizing the benefits of quantum computing adoption across sectors.

Theoretically, this study integrates QSF theory with MCDM methods such as DELPHI and DEMATEL to assess the influence weights and causal relationships among barriers impacting the adoption of quantum computing for data analysis in Vietnam. Furthermore, solutions are proposed and ranked based on their effectiveness in mitigating identified barriers using the QSF COCOSO method, with comparisons made against other ranking methodologies like QSF MULTIMOORA and QSF TOPSIS. Additionally, sensitivity analysis is conducted using varying parameters in the COCOSO method. The results demonstrate strong consistency in ranking orders across different methods, underscoring the accuracy and reliability of the findings. Integrating Quantum theory with spherical fuzzy sets and the golden ratio offers a superior approach by interconnecting memberships in the spherical fuzzy set through the golden ratio.

Moreover, the membership level is represented more comprehensively, considering both the amplitude and phase angle components to express the degree of membership and the level of uncertainty or vagueness. Furthermore, employing the DELPHI method for barrier validation enhances the accuracy and certainty of the factors used for analysis. Additionally, considering expert weights contributes to addressing experts' varying experiences and qualifications, enhancing their responses' quality. These methodological enhancements ensure a robust and comprehensive analysis of barriers and solutions in the context of quantum computing adoption for data analysis in Vietnam.

Despite its strengths, this study is limited in scope to Vietnam, which may limit the generalizability of findings to other national contexts. Furthermore, while QSF theory was utilized, advancements in fuzzy set theories beyond spherical fuzzy sets could offer more refined analytical capabilities. Future research should expand the scope to include diverse global contexts, enabling broader applicability of findings. Exploring newer fuzzy set theories and integrating quantum theory with other advanced methodologies like neutrosophic or refined fuzzy set theory could enhance model efficiency and accuracy. Further investigation into additional MCDM methods such as VIKOR, Graph Theoretic Analysis (GTA), and Complex Proportional Assessment (COPRAS) would also contribute to developing more robust decision-making frameworks in quantum computing adoption contexts.

DATA AVAILABILITY

Data will be made available on request.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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