Quantum Computing for Social Business Optimization: A practitioner's perspective

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Research Article

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Abstract

Currently, E-commerce is widely adopted as it is important for business management and economic growth in the new global economy, and to reach the rapid increasing population. To better manage the e-commerce, it is important to collect and evaluate the Consumer Behaviour data for decision making and optimization. The conventional computing technologies need high amount of power and time for large data analysis. Quantum computing has the potential to analyze the large amount of data more efficiently than classical computing. This paper aims to explore the core process areas that need to be consider by the practitioners for adopting quantum computing in social business. To address the objective of this study, we conducted a literature review and empirical study to explore the core process areas that need to be considered for the consideration of quantum computing in social business. The results show that limited scalability, regulatory challenges, high initial cost, limited availability of quantum resources, education and training and security are the most important process areas that need to be focused by the industry practitioners. The result of this study gives a knowledge base for research and practitioners community to develop the tools and strategies for the adoption of quantum computing in social business.

1. Introduction

Quantum computing is an emerging technology that holds great promise for revolutionizing many fields. Unlike classical computers that use binary digits, or bits, to perform calculations, quantum computers use quantum bits, or qubits, which can exist in a superposition of states[1]. This enables quantum computers to perform certain types of calculations exponentially faster than classical computers [1].

Quantum computing has the potential to revolutionize many aspects of modern business, including e-commerce [2, 3]. E-commerce businesses rely on complex algorithms to optimize pricing, personalize recommendations, and manage supply chain logistics[4, 5]. However, traditional computers are limited in their ability to perform these tasks quickly and efficiently.

Quantum computing, on the other hand, offers a new paradigm for computation that could significantly enhance e-commerce operations [4, 6]. By harnessing the power of quantum mechanics, quantum computers can perform calculations exponentially faster than classical computers. This would allow e-commerce businesses to process large amounts of data and make more accurate predictions about customer behavior and market trends [7, 8].

One of the most promising applications of quantum computing for e-commerce is in the field of optimization. E-commerce companies often need to solve complex optimization problems, such as finding the most efficient route for product delivery or determining the optimal pricing strategy [7]. Quantum computers are uniquely suited to solving these problems, as they can consider many possible solutions simultaneously and find the optimal solution in a fraction of the time it would take a classical computer [9].

Quantum computing could also be used to improve the security of e-commerce transactions. Quantum cryptography offers a new way to secure communications, using the principles of quantum mechanics to create unbreakable codes[10]. This could help protect sensitive customer data, such as credit card numbers and personal information, from cyber-attacks[6, 10].

Furthermore, quantum computing has the potential to transform the e-commerce industry, offering faster, more accurate, and more secure solutions for a wide range of business problems[5, 11]. As the technology continues to evolve and become more accessible, e-commerce businesses should consider investing in quantum computing research and development to stay ahead of the competition[11]. Overall, quantum technology represents a major opportunity for the ecommerce industry to improve security, efficiency, and customer experience[5, 12].

Despite the potential benefits of quantum computing, building and operating quantum computers remains a significant technical challenge. Many obstacles, such as the need for error correction and the difficulty of scaling up quantum systems, must be overcome before quantum computers become practical for real-world applications. Nevertheless, the promise of quantum computing has led to a significant investment in research and development by governments and private industry alike, making it an exciting and rapidly evolving field.

2. Background

2.1 Quantum technology

Quantum technology is a rapidly growing field that uses principles from quantum physics to develop new technologies and applications. This field has the potential to revolutionize many areas of science and technology, including computing, cryptography, sensing, and communication[12].

Quantum physics is the branch of physics that studies the behavior of matter and energy at the smallest scales, such as the level of individual atoms and subatomic particles[13]. At this scale, classical physics no longer applies, and the behavior of particles is described by quantum mechanics. This leads to many counterintuitive and fascinating phenomena, such as quantum entanglement, superposition, and tunneling[13].

Quantum technology is based on the idea of manipulating and controlling these quantum phenomena to perform new types of tasks that are not possible with classical physics[14]. One of the most promising areas of quantum technology is quantum computing. Classical computers store and process information using bits that can be either 0 or 1[15]. Quantum computers, on the other hand, use quantum bits or qubits, which can be in superpositions of 0 and 1 at the same time. This allows quantum computers to perform certain types of calculations exponentially faster than classical computers, which could have profound implications for areas such as drug discovery, machine learning, and cryptography[15, 16].

Another area of quantum technology is quantum communication, which is based on the principles of quantum entanglement[17]. Quantum communication offers the potential for completely secure communication channels, as any attempt to eavesdrop on the communication would be immediately detected due to the fundamental properties of quantum mechanics[17].

Other applications of quantum technology include quantum sensing, which uses quantum properties to detect extremely small changes in magnetic fields, temperature, or other physical quantities, and quantum cryptography, which uses quantum principles to generate unbreakable encryption keys[18, 19].

Despite the promise of quantum technology, there are still many challenges to overcome, such as the difficulty of building stable and scalable quantum systems, controlling and measuring qubits, and correcting errors in quantum computations. However, research in this field is advancing rapidly, and many companies and research institutions are investing heavily in the development of quantum technology.

2.2 Quantum in Social commerce

Quantum computing has the potential to revolutionize many areas of business, including social commerce. Social commerce refers to the use of social media platforms to facilitate online shopping and transactions[5, 20, 21]. Here are some potential ways in which quantum computing could be used in social commerce:

One of the main benefits of social commerce is the ability to provide personalized recommendations to users based on their browsing and purchase history[20]. Quantum computing could be used to analyze large amounts of data from social media and other sources to provide even more accurate and tailored recommendations to users[22].

Fraudulent transactions are a significant problem in social commerce, and current methods of detecting and preventing fraud can be time-consuming and imperfect[22]. Quantum computing could be used to analyze transaction data in real-time and identify fraudulent patterns more quickly and accurately[20].

Quantum computing could be used to optimize the complex supply chains that are often involved in social commerce [20, 22]. By analyzing data on inventory levels, shipping times, and other factors, quantum algorithms could help businesses reduce costs and improve efficiency. Quantum computing could be used to improve the quality and speed of customer service in social commerce[5]. For example, a quantum-powered chatbot could quickly and accurately answer customer questions and provide personalized recommendations based on the customer's purchase history[23]. Quantum computing could be used to analyze large amounts of pricing data to help businesses optimize their prices in real-time. By analyzing data on customer behavior, competition, and other factors, businesses could adjust their prices to maximize profits and stay competitive[23].

Despite the potential benefits of quantum computing in social commerce, there are still many challenges to overcome, such as the high cost and complexity of building and maintaining quantum computing systems. However, as quantum technology continues to advance and become more accessible, it is likely that we will see more businesses exploring the use of quantum computing in social commerce and other areas.

2.2 Challenges using quantum in social business

Based on the background study, we identify the following list of important challenging areas that need to be considered while using quantum in social business [5, 10, 18–23].

CH1 (Regulatory challenges)

Quantum technology is subject to various regulatory challenges, including compliance with data protection and privacy laws.

CH2 (High initial cost)

The cost of developing and implementing quantum technology is high, which may be a barrier for small and medium-sized social businesses.

CH3 (Limited availability of quantum resources)

Quantum technology requires specialized equipment and resources that may not be readily available or accessible for social businesses.

CH4 (Limited scalability)

Quantum technology is still in its early stages, and it may not be scalable enough to meet the demands of social businesses.

CH5 (Security)

Quantum technology is vulnerable to security threats, which may put sensitive data at risk.

CH6 (Regulatory challenges)

Quantum technology is subject to various regulatory challenges, including compliance with data protection and privacy laws.

CH7 (Education and training)

There is a lack of education and training on quantum technology, which may limit the ability of social businesses to adopt it.

CH8 (Ethical considerations)

Quantum technology raises ethical questions, such as how it may be used to manipulate or control individuals or groups.

CH9 (Lack of standards)

There is a lack of standards and best practices for the development and implementation of quantum technology.

CH10 (Integration with existing systems)

Integrating quantum technology with existing systems and infrastructure may be challenging and require significant resources.

CH11 (Interdisciplinary collaboration)

Quantum technology requires collaboration between various disciplines, including physics, mathematics, and computer science.

CH12 (Limited expertise)

There is a shortage of experts in quantum technology, which may limit the ability of social businesses to access the necessary expertise.

CH13 (Uncertainty)

The future of quantum technology is uncertain, and it is unclear how it will evolve or be adopted in the future.

CH14 (Limited applications)

The current applications of quantum technology are limited, which may limit its usefulness for social businesses.

CH15 (Resistance to change)

Resistance to change may prevent social businesses from adopting quantum technology and reaping its potential benefits.

CH16 (Intellectual property)

There may be intellectual property issues related to the development and implementation of quantum technology.

CH17 (Limited access to funding)

Social businesses may have limited access to funding for quantum technology projects.

CH18 (Environmental impact)

The development and implementation of quantum technology may have an environmental impact, which may be a concern for social businesses with a focus on sustainability.

3. Research Methodology

According to [24] the selection of the data collection approach is based on “available data collection resources,” “controlling mechanism of selected approach”, and “skill to operate the variable of interest”. In this expletory study, we used the questionnaire survey techniques to get the insight of industry experts. Questionnaire survey effective way to approach the targeted population working in different geographical areas.

Therefore, to address the [25] research objectives of this study, we used the questionnaire survey approach and considered the following steps:

3.1 Questionnaire development

Obtaining the perspective of real-world practitioners is crucial in evaluating literature findings, particularly in the field of quantum implications in social business. In our study, we identified of 18 challenges associated with quantum implications in social business domains, reported in study background. To verify the literature survey findings and gather additional insights, we designed a questionnaire with two parts.

The first part of the questionnaire consists of a closed-ended section that includes the list of 18 challenges identified during the literature review study. To gauge the opinions of the survey participants, we utilized a five-point Likert scale that includes options for "strongly agree, agree, neutral, disagree, and strongly disagree". The inclusion of a neutral option in the Likert scale is important to ensure unbiased data collection, as it allows respondents to select "neutral" when they lack knowledge about a certain factor.

The second part of the survey questionnaire is open-ended, which enables participants to add any success factors not listed in the closed-ended section. This approach ensures that the survey is comprehensive and provides a broader perspective on the challenges associated with the adoption of quantum technology in social business.

Pilot Assessment:

To ensure that the queries and questionnaire variables are easily understandable and clear, we conducted a pilot assessment of the questionnaire. The assessment involved two postdoctoral researchers from Nanjing University of Aeronautics and Astronautics in China and Griffith University in Australia, as well as three industrial experts from Virtual force-Pakistan, Integrio Systems in Canada, and Startup Development House in Poland. All participants were asked to complete the questionnaire and provide feedback to improve its understandability.

Based on the participants' recommendations, we added more questions regarding the bibliographic information of survey participants, such as the size and type of their organizations and the nature of their businesses. We also put all the variables in a tabular form to enhance the survey's readability. We took all of their suggestions into consideration, and the final survey instrument was used for the data collection process. Please refer to Appendix-B for a sample of the questionnaire used in the study.

Data sources

To reach the potential population for our study, we employed various methods, including ResearchGate, LinkedIn, email, and Facebook. Using the snowball technique, we circulated the questionnaire among the targeted population [26–28]. The data collection process was conducted between January 2023 and March 2023, during which we received a total of 121 responses. We reviewed all the responses manually and found 8 incomplete submissions. Therefore, we utilized the final 113 responses for further analysis.

By utilizing various platforms and the snowball technique, we aimed to increase the response rate and obtain a representative sample of the population. The use of multiple platforms and the snowball technique allowed us to reach a diverse group of participants with different backgrounds and perspectives, which improves the validity and generalizability of our study findings.

Survey data analysis

All 113 completed responses were included in the data analysis process. To analyze the data, we employed a frequency analysis approach, which is recognized as the most suitable method for analyzing descriptive data [29]. This method enabled us to compare and analyze the survey variables and compute the agreement level between survey participants based on the selected Likert scale.

The frequency analysis approach has been widely adopted in various empirical studies in software engineering[30–34], making it a reliable and commonly used method. By employing this method, we were able to identify patterns in the responses and gain insights into the challenges and success factors associated with DevSecOps projects.

3.2 Phase 2: ISM Approach

Interpretive Structure Modeling (ISM) was defined by Sage[35] as "a methodology that helps to impose order and direction on the complex relationship among factors and system that results into a holistic systematic model". ISM is an interactive learning technique that assists to structure the related factors directly or indirectly in a holistic model. The model gives a clear and conceptual picture in graphical format [35, 36]. ISM helps to fix the complication faced concerning the relationship among different factors, hence, the ISM gives the clear understanding of such types of factors relationships. Several existing studies used this approach to develop the conceptual models for the understanding of relationships between the factors (Kannan et al. [37], Sharma et al.[38], Agarwal and Vrat [39].

This approach has the chances of personal biasness considering the judgments pointed by the expert group to integrate elements/factors with each other. Consequently, the inter-personal biasness in the expert's opinions might affect the results of ISM. The ISM approach does not give weights to analyze ranking of each factor. To avoid this concern, we have adopted fuzzy AHP approach in later steps, which will prioritize the Quantum computing project management success factors based on their relationship with 10 knowledge areas of Project management. The steps adopted in ISM approach is to find the interaction in between PMBOK knowledge areas. Figure 1 presents the detailed steps adopted to perform the ISM approach; and we consider these steps of ISM from Raj and Attri [40].

Step-1

"Identify the elements which are relevant to the problem. This could be done by a survey or group problem solving technique."

Step-2

"Establish a contextual relationship between elements with respect to which pairs of elements would be examined."

Step-3

"Develop a structural self-interaction matrix (SSIM) of elements. This matrix indicates the pair-wise relationship among elements of the system. This matrix is checked for transitivity."

Step-4

"Develop a reachability matrix from the SSIM."

Step-5

"Partition the reachability matrix into different levels."

Step-6

“Convert the reachability matrix into conical form.”

Step-7

“Draw graph based on the relationship given in reachability matrix and remove transitive links.”

Step-8

“Convert the resultant graph into an ISM based model by replacing element nodes with the statements.”

Step-9

“Review the model to check for conceptual inconsistency and make the necessary modifications. MICMAC analysis to categorize the elements into various clusters.”

3.3 Phase 3: Fuzzy TOPSIS

Fuzzy Set theory

The fuzzy set theory is a useful approach for handling ambiguity, subjective, and imprecise judgments. It allows for the quantification of linguistic aspects in available data and opinions, which can be useful for individual or group decision-making[41].Mathematically, the fuzzy set theory is presented as:

Definition

Fuzzy set in is defined as:

” $\bar{A}$ = $\{x, \mu_A(x)\}$, where $x \in X$,

The membership function of $\bar{A}$ is $\mu_A(x) : X = [0,1]$; and $\mu_A(x)$ is degree of pertinence of x in $\bar{A}$.

If the value of $\mu_A(x) = 0$ then, x is not a member of fuzzy set $\bar{A}$.

If the value of $\mu_A(x) = 1$ then x is a member of fuzzy set $\bar{A}$ ”.

The fuzzy set theory is different from classical set theory in that it allows for a more flexible approach to defining membership. In the fuzzy set theory, the membership of an element x is denoted by μ_A (x), where the value of μ_A (x) lies between 0 and 1. This value indicates the degree to which x belongs to the fuzzy set. A value of 1 indicates complete membership, while a value of 0 indicates no membership. Values between 0 and 1 represent varying degrees of membership, allowing for a more nuanced understanding of concepts that may have varying degrees of relevance or uncertainty. This aspect of fuzzy set theory makes it a valuable tool for decision-making and analysis in situations where imprecision or ambiguity is present.

Fuzzy TOPSIS method

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was developed by Hwang and Yoon in 1981[42]. The aim of TOPSIS is to define the positive and negative ideal solutions for a given problem. The positive ideal solution seeks to maximize the benefit criteria while minimizing the cost criteria. In contrast, the negative ideal solution aims to maximize the cost criteria while minimizing the benefit criteria [42].

The solution is considered the best if it is close to the positive ideal solution and far from the negative ideal solution. However, in situations where the criteria involve imprecision or ambiguity, the use of TOPSIS may be limited. To address this limitation, Chen and Tsao[43] developed a fuzzy TOPSIS approach that collects the opinions of a group of experts on a specific subject matter. The group of decision-makers marks the weights of each criterion in linguistic variables, which are then converted into triangular fuzzy numbers (TNFs). The TNF approach is useful for managing the vagueness of the linguistic terms mentioned by the group of decision-makers[44–46].

The fuzzy TOPSIS algorithm is designed to address multi-criteria decision-making and is provided below. This approach provides a more nuanced and comprehensive framework for decision-making, particularly in situations where there is a high degree of ambiguity or imprecision involved.

Step-1. Suppose the problem with m alternative and n criteria can be expressed in matrix form, where A_1, A_2,….A_m are the alternatives, E_1, E_2,…,E_n is the evaluation criteria, F_{ij} is the performance rating judged by decision makers to the alternative F_i against the criterion E_j and weight is represented by W_j of each criterion E_j.

$$\begin{matrix} & E_1 & E_2 & \dots & E_n \end{matrix}$$

$$D = (F_{ij})_{m*n} = \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{pmatrix} A_{11} & A_{12} & \dots & A_{1n} \\ A_{21} & A_{22} & \dots & A_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ A_{m1} & A_{m2} & \dots & A_{mn} \end{pmatrix} \quad (1)$$

Step 2 of the fuzzy TOPSIS algorithm involves assembling the alternatives and their weighted criteria, which can be done using Eq. 1. The next step is to assign ratings to each defined criterion and alternative using Bozbura et al.'s [47] [fuzzy triangular scale, as illustrated in Table 5.

The fuzzy triangular scale provides a way to convert the linguistic terms used by decision-makers into numerical values that can be used in the decision-making process. By converting the linguistic terms into fuzzy sets represented by triangular numbers, the scale can handle the vagueness and uncertainty of the terms used by decision-makers, making it a useful tool in multi-criteria decision-making. Using the fuzzy triangular scale in conjunction with the TOPSIS algorithm allows decision-makers to make more informed decisions that take into account the imprecision and ambiguity inherent in the decision-making process.

Table 5
Triangular-fuzzy scale [47]

Linguistic terms	Triangular Fuzzy Scale
Just Equal (JE)	(1,1,1)
Equally Important (EI)	(0.5,1,1.5)
Weakly Important (WI)	(1,1.5,2)
Strongly More Important (SMI)	(1.5,2,2.5)
Very Strongly More Important (VSMI)	(2,2.5,3)
Absolutely more important (AMI)	(2.5,3,3.5)

Step-3. Determine the aggregate fuzzy rating of K decision-makers for each criterion by using equations Eq. 2 and Eq. 3.

A_{ij} =$K^{min}\left\{x_{ijk}\right\}$, b =$\frac{1}{K}\sum_{k=1}^{K} y_{ijK}$, c = $K^{max}\left\{z_{ijK}\right\}$ (2)

W_{j1} =$K^{min}\left\{x_{jK1}\right\}$, b =$\frac{1}{K}\sum_{k=1}^{K} y_{jK2}$, c = $K^{max}\left\{z_{jK3}\right\}$ (3)

Where A_{ij} = (x_{ij}, y_{ij}, z_{ij}) and i = 1,2,3,...m and j = 1,2,3...,n and weight of each criterion is calculated as

W_j= (W_{j1},W_{j2},W_{j3}).

Step-4. Calculate normalized decision matrix of 'R' using linear scale transformation. The matrix after normalization will presented as:

$R^{\sim}$= $[r_{ij}]_{m*n}$ (4)

The Eq. 5 and Eq. 6 given below are used to calculate the cost and benefit criteria of each alternative.

r_{ij}= $\left(\frac{x_{ij}}{z_j^+}, \frac{y_{ij}}{z_j^+}, \frac{z_{ij}}{z_j^+}\right)$ and z_j^+ =$\max_i z_{ij}$ (benefit criteria) (5)

r_{ij}= $\left(\frac{x_j^-}{z_{ij}}, \frac{x_j^-}{y_{ij}}, \frac{x_j^-}{x_{ij}}\right)$ and x_j^- = $\max_i l_{ij}$ (cost criteria) (6)

Step-5. To compute the weighted normalized fuzzy decision matrix V~, the weights of each criterion Wj are multiplied by the calculated values of the normalized fuzzy decision matrix. This step involves applying the weights to each criterion to give them appropriate importance in the decision-making process.

The resulting weighted normalized fuzzy decision matrix V ~ is a crucial component of the fuzzy TOPSIS algorithm, as it provides a way to compare the alternatives and determine their relative performance based on the criteria involved. By applying the weights to the normalized fuzzy decision matrix, decision-makers can make informed decisions that take into account the importance of each criterion involved in the decision-making process.

V$\cong$ $[v_{ij}]_{m*n}$, where v_{ij} is calculated by using Eq. 8 (7)

v_{ij} = A_{ij} * W_j (8)

Step-6. In this step, fuzzy positive and negative ideal solution is calculated as shown in Eq. 9 and Eq. 10.

A^+= $[v_{1,}^+ v_{j,}^+ \ldots\ldots v_m^+]$ (9)

A^-= $[v_{1,}^- v_{j,}^- \ldots\ldots v_m^-]$ (10)

Where the values of positive and negative ideal solution ranges between [0.1].

Step-7. Compute the distance of each alternative from positive and negative ideal solution.

D_i^+ =$\sum_{j=1}^{n} D_v(v_{ij}, v_j^+)$ (11)

$D_i^- = \sum_{j=1}^{n} D_v(v_{ij}, v_j^-)$ (12)

Where D represents the distance between two fuzzy numbers.

Step-8. To compute the ranks of alternatives CCi value is computed by considering fuzzy positive and negative ideal solution.

CCi = $\frac{D_i^-}{D_i^+ + D_i^-}$ (13)

Step-9. Once the weighted normalized fuzzy decision matrix V ~ has been calculated, the next step in the fuzzy TOPSIS algorithm is to define the priority-wise ranking of all alternatives based on their CCi values. The CCi value represents the closeness of each alternative to the ideal solution, and the higher the CCi value, the better the rank of that alternative. This ranking provides a way to compare the alternatives based on their overall performance, taking into account the criteria involved and their respective weights.

By defining the priority-wise ranking of the alternatives based on their CCi values, decision-makers can identify the best alternative that meets their needs and requirements. This approach provides a more nuanced and comprehensive framework for decision-making, particularly in situations where there is a high degree of ambiguity or imprecision involved.

4. Results

This section contains the results of questionnaire survey, ISM technique, and fuzzy TOPSIS analysis.

4.1 Questionnaire survey study

The aim of the empirical study was to gather the perceptions of experts working in the quantum and social business environment. To collect their opinions, we developed an online survey instrument that utilized a five-point Likert scale, ranging from "strongly agree" to "strongly disagree," with a "neutral" option.

We classified the responses into three categories: positive ("strongly agree" and "agree"), negative ("strongly disagree" and "disagree"), and "neutral." The positive category represents the opinions of those survey participants who agreed that the identified factors could negatively impact quantum and social business practices. The negative category shows the opinions of those participants who did not consider the identified factors as a challenge for quantum implementation in social business. Lastly, the neutral category represents those respondents who were unsure about the impact of identified factors on the quantum implication in social business.

We summarized the results of these categories in Table 7, providing an overview of the opinions of the survey participants. This approach provides a comprehensive understanding of the challenges associated with quantum implication in social business, taking into account the diverse perspectives of the experts involved.

Table 5
Questionnaire survey results

S.No.	Challenges	Empirical Investigations (n = 113)							
		Positive			Negative			Neutral	
		S.A	A	%	D	S.D	%	F	%
Ch1	Regulatory challenges	40	56	85	4	1	4	12	11
Ch2	High initial cost	51	42	82	5	5	9	10	9
Ch3	Limited availability of quantum resources	41	47	78	7	6	12	12	11
Ch4	Limited scalability	37	51	78	6	4	9	15	13
Ch5	Security	37	48	75	6	7	12	15	13
Ch6	Regulatory challenges	31	61	81	3	6	8	12	11
Ch7	Education and training	46	39	75	9	3	11	16	14
Ch8	Ethical considerations	30	64	83	2	6	7	11	10
Ch9	Lack of standards	39	46	75	8	7	13	13	12
Ch10	Integration with existing systems	30	51	72	10	5	13	17	15
Ch11	Interdisciplinary collaboration	39	46	75	8	7	13	13	12
Ch12	Limited expertise	42	53	84	6	2	7	10	9
Ch13	Uncertainty	49	34	73	7	6	12	17	15
Ch14	Limited applications	33	56	79	5	4	8	15	13
Ch15	Resistance to change	39	53	81	8	5	12	8	7
Ch16	Intellectual property	41	55	85	5	6	10	6	5
Ch17	Limited access to sustainable funding	43	44	77	7	4	10	15	13
Ch18	Environmental impact	35	50	75	5	8	12	15	13

4.4 Application of ISM

The ISM approach has been used to examine the interaction between the key knowledge areas of PMBOK used to map the success factors of quantum computing in social business. Various existing studies [37–39] also used the same approach to examine the relationship between the key knowledge areas of quantum computing in social business. Therefore, for the development of the contextual interaction between the knowledge areas, the development of structural-self-interaction matrix (SSIM) is critical, as given in the below section:

Structural-self-interaction matrix (SSIM)

To apply the ISM approach for examining the contextual relationship between the key knowledge areas of Quantum computing project management success factors, the perceptions of experts were considered. A group of 8 experts was established to get the opinions for processing the steps of ISM approach. The invitation was sent to the participant of first survey. Out of eight participants, seven belong to real-world software industry and one is from empirical software engineering lab where quantum computing social business is an active research area. The demographic data about the participants is provided at: https://tinyurl.com/2hwtaedp. Using the data collected form the experts' group, we developed the SSIM matrix. It can be argued that the sample size might not be strong enough and thus the study results are limited in generalization. However, it is noticed that Kannan et al. [37] used the opinions of five experts for the selection of reverse logistic providers. Similarly, Soni et al. [48] established a group of nine members to analyse the factors causing complexities in urban rail transit system. We further found that the Attri et al. [49] used the data of five experts to determine the success factors of total productive maintenance.

The following symbols are used to indicate the direction of relationship between the quantum computing in social business challenges (m and n).

1. 1. "V" indicates the relationship from m enabler to n challenge.
2. 2. "A" indicates the relationship from n enabler to m challenge.
3. 3. "X" indicates when both challenge m and n reach each other.
4. 4. "O" presents the situation when there is no relationship between enabler m and challenge n.

Considering the experts' opinions, we have developed SSIM that is presented in Table 21.

Table 21
SSIM based on experts' opinions

	KA10	KA9	KA8	KA7	KA6	KA5	KA4	KA3	KA2	KA1
KA1	O	X	O	X	X	O	A	O	A	*
KA2	O	V	V	O	O	A	V	V	*	*
KA3	V	O	V	O	O	O	V	*	*	*
KA4	X	V	X	O	O	O	*	*	*	*
KA5	V	O	V	O	O	*	*	*	*	*
KA6	A	X	O	X	*	*	*	*	*	*
KA7	A	X	O	*	*	*	*	*	*	*
KA8	X	V	*	*	*	*	*	*	*	*
KA9	X	*	*	*	*	*	*	*	*	*
KA10	*	*	*	*	*	*	*	*	*	*

The results given in Table 21 shows that there is no relationship between KA1 (Integration) and KA10 (Cost), as their relationship is presented with 'O'. Similarly, there is no relationship between KA2 and KA10 because the results show 'O' between both. Furthermore, KA1 and KA9 has 'X' type relationship, and it presents that KA1 and KA9 can reach each other. We noticed the 'V' type relationship between K2 and K9, which renders that both knowledge areas have a relationship. Moreover, we noted that both KA6 (Procurement) and KA7 (Schedule) has 'A' type of relationship with KA10, and this indicated that KA6 and KA7, assist to improve the KA10. All the other relationships between the 10 knowledge areas are given in Table 21.

Reachability matrix

For the development of reachability matrix, the values of V, A, X and O are transformed to binary digits (0, 1). Hence, to develop the reachability matrix, we follow the following protocols.

1. 1. If the value of m and n in SSIM is V, then we replace it with 1; else, the assigned value is 0.
2. 2. If the value of m and n in SSIM is A, then it is replaced with 0; else it become 1.
3. 3. If the value of m and n in SSIM is X, then it is replaced with 1; and give 1 to n and m entry.
4. 4. If the value of m and n in SSIM is O, then it is replaced with 0; and for n and m, the assigned value is also 0.

Considering the above developed protocols, the reachability matrix is developed, and the results are given in Table 22. Furthermore, the final form of reachability was developed considering the transitivity process as given in section 3.4; and 1* is used to incorporate the transitivity. This assists to fill the gap, if any, exists in the data collected from experts while developing SSIM. The incorporation of transitivity check is given in Table 22.

Table 22
Reachability matrix

	KA10	KA9	KA8	KA7	KA6	KA5	KA4	KA3	KA2	KA1
KA1	1	0	0	0	0	1	1	0	1	0
KA2	1	1	1	1	0	0	0	1	1	0
KA3	0	0	1	1	0	0	0	1	0	1
KA4	1	0	0	1	0	0	0	1	1	1
KA5	0	1	0	0	1	0	0	1	0	1
KA6	1	0	0	0	0	1	1	0	1	0
KA7	1	0	0	0	0	1	1	0	1	0
KA8	0	0	0	1	0	0	0	1	1	1
KA9	1	0	0	0	0	1	1	0	1	1
KA10	0	0	0	1	0	1	1	1	1	1

The results of driving, dependence power and ranks of all criteria, to achieve Quantum computing project management knowledge area. The dependence power shows the criteria that may help in achieving it. This dependence and driving power will help in MICMAC analysis, where we divide the criteria into four clusters i.e., autonomous, dependent, linkage and independence cluster.

Table 23
Transitivity check

	KA10	KA9	KA8	KA7	KA6	KA5	KA4	KA3	KA2	KA1	DRI	RANK
KA1	1	0	0	0	0	1	1	0	1	1*	5	1
KA2	1	1	1	1	0	1*	1*	1	1	1*	9	4
KA3	1*	0	1	1	0	1*	1*	1	1*	1	8	3
KA4	1	0	0	1	0	1*	1*	1	1	1	7	2
KA5	1*	1	1*	1*	1	1*	1*	1	1*	1	10	5
KA6	1	0	0	0	0	1	1	0	1	1*	5	1
KA7	1	0	0	0	0	1	1	0	1	1*	5	1
KA8	1*	0	0	1	0	1*	1*	1	1	1	7	2
KA9	1	0	0	1*	0	1	1	1*	1	1	7	2
KA10	1*	1*	1*	1	0	1	1	1	1	1	9	4
DEP	10	3	4	7	1	10	10	7	10	10	72	
RANK	5	2	3	4	1	5	5	4	5	5		

Development of conical matrix

To perform the MICMAC analysis, the conical matrix was developed, and the values are given in Table 24. To develop the conical matrix, the data of Tables 22 and 23 are used. To do this, firstly, we ordered all the criteria considering their level numbers (see Table 24). At second step, the values given in Table 23, were considered for each criterion. For example, the value of KA1 (Integration) across rows and columns of conical matrix (Table 24) shows the '1' relationship with KA6 (Procurement), KA7 (Schedule), KA9 (Quality) and KA10 (Cost). Besides, we noticed that KA1 has '0' relationship between KA4 (Communication), KA8 (Risk), KA2 (Human Resource Management), KA3 (Stakeholders) and KA 5 (Scope).

Table 24
Conical matrix

	KA1	KA6	KA7	KA9	KA10	KA4	KA8	KA2	KA3	KA5	DRI
KA1	1	1	1	1	1	0	0	0	0	0	5
KA6	1	1	1	1	1	0	0	0	0	0	5
KA7	1	1	1	1	1	0	0	0	0	0	5
KA9	1	1	1	1	1	1	1	0	0	0	7
KA10	1	1	1	1	1	1	1	1	1	0	9
KA4	1	1	1	1	1	1	1	0	0	0	7
KA8	1	1	1	1	1	1	1	0	0	0	7
KA2	1	1	1	1	1	1	1	1	1	0	9
KA3	1	1	1	1	1	1	1	0	1	0	8
KA5	1	1	1	1	1	1	1	1	1	1	10
DEP	10	10	10	10	10	7	7	3	4	1	

Partitioning the reachability matrix

Warfield [50] underlined that the reachability set consists of the element itself and other elements that it may assist in achieving, whereas the antecedent set consists of the element itself and other elements that may assist in achieving it" The intersection of these sets is then calculated for all of the items. The top level of the ISM hierarchy is occupied by elements for which the reachability and intersection sets are the same. The hierarchy's top-level element would not assist in the achievement of any element above its own level.

The top-level element is split from the other elements once it has been discovered. The process is then repeated to determine the items in the following level. This method is repeated until each element's level is determined. These levels aid in the construction of the diagraph and the ISM model."

Table 25 shows the reachability set, antecedent set, intersection set, and levels of ten criteria (project management knowledge domains) used in this study. The results shown in Table 25, renders that KA1 (Integration), KA6 (Procurement), KA7 (Schedule), KA9 (Quality), KA10 (Cost) stand on top level. This presents that these five knowledge areas have inter-relationship, and they depend on rest of the knowledge areas. Moreover, these five knowledge areas assist to drive each other and depend open rest of the knowledge areas, mapped in level 2, level 3 and level 4.

We noted that level-2 consists of two knowledge areas i.e., KA4 (Communication), KA8 (Risk); KA2 (Human Resource Management) and KA3 (Stakeholders) are mapped with Level-3 and lastly, KA5 (Scope) stands on level-5. To summarize, the ISM results show that all the knowledge areas depend on KA5.

Table 25
Level partitioning

	LEVEL PARTITIONS				
	ITERATION ONE				
	Reachability Set	Antecedent Set	Intersection set	Level	Knowledge areas
KA1	1,6,7,9,10	1,2,3,4,5,6,7,8,9,10	1,6,7,9,10	LEVEL 1	KA1, KA6, KA7, KA9, KA10
KA2	1,2,3,4,6,7,8,9,10	2,5,10	2,10		
KA3	1,3,4,6,7,8,9,10	2,3,5,10	3,10		
KA4	1,4,6,7,8,9,10	2,3,4,5,8,9,10	4,8,9,10		
KA5	1,2,3,4,5,6,7,8,9,10	5	5		
KA6	1,6,7,9,10	1,2,3,4,5,6,7,8,9,10	1,6,7,9,10	LEVEL1	KA1, KA6, KA7, KA9, KA10
KA7	1,6,7,9,10	1,2,3,4,5,6,7,8,9,10	1,6,7,9,10	LEVEL1	KA1, KA6, KA7, KA9, KA10
KA8	1,4,6,7,8,9,10	2,3,4,5,8,9,10	4,8,9,10		
KA9	1,4,6,7,8,9,10	1,2,3,4,5,6,7,8,9,10	1,4,6,7,8,9,10	LEVEL 2	KA4, KA8
KA10	1,2,3,4,6,7,8,9,10	1,2,3,4,5,6,7,8,9,10	1,2,3,4,6,7,8,9,10	LEVEL3	KA2, KA3
	ITERATION TWO				
KA5	5	5	5	LEVEL 4	KA5

Interpretation of ISM model

To determine and express the inter relationship between the 10 knowledge areas of quantum computing in social business; we develop the ISM interpretation model. Using the arrows, the inter-relationship between the knowledge areas is directed from one knowledge areas to other. The transitivity analysis was performed to check the vagueness in the data once the diagraph finally converted to ISM model (Fig. 11).

According to the levelling results presented in Table 25, KA1 (Integration), KA6 (Procurement), KA7 (Schedule), KA9 (Quality), KA10 (Cost) stand on level 1, this shows that these five knowledge areas have inter-relationships and depend upon rest of the areas. It is noted that KA4 (Communication), KA8 (Risk) stand on level-2 and this indicated that these both knowledge areas drive each other and just depend upon the knowledge areas of level-3 and level-4. Similarly, level-3 consists of KA2 (Human Resource Management) and KA3 (Stakeholders) and these two knowledge areas just depends on KA5. Lastly, the KA5 is mapped against level 4, and this indicated that KA5 is an independent knowledge area.

MICMAC analysis

The categorization was done using MICMAC (matrix cross-impact matrix multiplication). The MICMAC analysis aids in the examination of the system's major enablers. The MICMAC is “an analysis to analyze the driving power and dependence power of enablers,” according to Attri et al.[49]. The enablers are divided into four groups based on their ability to drive and rely on others.

Step-1 Autonomous cluster: the enabler that belongs to this cluster have weak driving and dependence power. They are mostly disconnected from the system due to weak link.

Spet-2 Linkage cluster: the enablers belong to this cluster have strong driving and dependence power and effect other enablers due to strong linkage.

Step-3 Dependent cluster: This cluster's enablers have a lot of reliance power but not much driving power.

Step-4 Independent cluster: the enablers that belong to this cluster have weak dependence power but have strong driving power, they are also known as “key challenges”.

We followed the classification method of Kannan et al.[37] and preset the MICMAC analysis results in Fig. 12. All the quantum computing in social business criteria were classified into four clusters of MICMAC analysis. The first cluster includes autonomous enablers, second cluster includes dependent enablers, and third and fourth cluster includes independent enablers.

The results of MICMAC analysis given in Fig. 12 shows that KA5 (Scope) belongs to cluster-IV (independent cluster); as this knowledge area did not depend on other areas. However, the other knowledge areas depend upon KA5. In other words, KA5 have strong driving power and weak dependence power. Moreover, it is noted that KA2 (Human Resource Management) and KA3 (Stakeholders) both belong to independent cluster which indicates that KA2 and KA3 has weak dependence power and strong driving power. This implies that, the stakeholders need to arrange or allow training session for educating the human resources according to their tasks; besides, the human resources management needs to perform efficient task to meet the stakeholder’s objectives.

According to the results, KA4 (Communication), KA8 (Risk), KA 9 (Quality) and KA10 (Cost) belong to cluster-III (linkage variables); and this indicated that they have both driving and dependence power. Cluster-II (dependent variables) contains the KA1 (Integration), KA6 (Procurement) and KA7 (Schedule), which renders that these knowledge areas have weak driving power but have strong dependence power. An interesting observation is that no knowledge area belongs to Cluster-I (autonomous), and this shows that all the knowledge areas are important for quantum computing in social business.

4.4 Application of Fuzzy TOPSIS

The findings of ISM only level the key categories of quantum computing in social business challenges. To address the uncertainties and vagueness in consideration of quantum computing in social business challenges, we applied the fuzzy TOPSIS approach. The fuzzy TOPSIS approach gives the ranks of each challenging factor that assists the practitioners in considering the highest priority challenging factors for the success and progression of quantum computing in social business. The fuzzy-TOPSIS approach has been used in studies of other engineering domains to address multi-criteria decision-making problems [44, 51–53].

To perform the fuzzy-TOPSIS approach, we requested ten experts (who participated in ISM, appendix-C) to mark each challenging factor concerning their own experience and understanding. We developed a questionnaire as presented in Appendix C. Each participant could consult other colleagues while ranking the complex factors to get a more representative response from experts. The following steps were applied to calculate the fuzzy-TOPSIS results.

Step 1& 2

To get the insights of experts regarding the effectiveness of quantum computing in social business, we used the fuzzy triangular scale, which gives linguistic values (Table 5) [37–39].

Step 3

Using Eq. 1 (section 3.4), we compute the combined decision matrix. In this paper, we study a total of 18 challenging factors that are related to the ten core criteria of quantum computing in social business challenges. Table 13 shows the combined decision matrix, which shows the collective opinion of all the experts involved in decision-making.

Table 13
Combined decision matrix

		Weight	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch 10	Ch 11	Ch 12	Ch 13	Ch 14	Ch 15	Ch 16	Ch 17
Testing	Combined decision matrix	1.0	0.5	0.5	0.5	1.5	0.5	0.5	0.5	0.5	0.5	0.5	1.5	0.5	0.5	0.5	0.5	0.5	0.5
		1.2	2.5	1.6	1.4	2.5	2.0	2.0	1.8	1.3	1.2	1.2	2.1	1.0	1.4	1.0	1.2	1.2	1.3
		2.0	3.5	3.0	3.0	3.0	3.0	3.0	3.5	2.0	2.5	2.5	3.0	1.5	2.5	1.5	2.0	2.0	2.0
Standards		1.2	1.5	0.5	1.0	1.5	0.5	0.5	1.5	1.5	0.5	0.5	1.0	0.5	1.0	0.5	1.0	1.0	0.1
		2.5	2.4	2.1	1.2	2.1	1.2	1.2	2.3	1.8	1.2	1.2	2.0	1.4	1.4	1.4	1.4	1.2	1.8
		3.5	3.5	3.0	2.5	3.0	2.0	2.5	3.0	3.0	2.5	2.0	3.0	2.5	2.0	2.5	2.0	2.0	2.0
Compliance and policy		0.5	1.5	1.5	0.5	2.2	1.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5	1.5	1.5	0.5	1.5	0.5
		1.0	2.5	2.4	2.3	3.0	2.4	2.0	1.7	2.3	2.1	2.3	2.1	2.4	2.4	2.3	1.4	2.3	1.7
		2.0	3.5	3.5	3.5	3.5	3.5	3.0	3.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	2.5	3.5	3.0
Strategy and matrices		0.5	1.5	0.5	1.0	0.5	1.5	0.5	1.5	0.1	0.5	0.1	0.5	0.5	0.5	0.1	1.0	0.1	1.5
		1.4	2.4	2.1	1.2	1.3	1.2	1.6	2.3	1.8	1.2	1.8	1.2	1.4	1.4	1.8	1.4	1.8	2.3
		2.5	3.5	3.0	2.5	3.0	3.0	2.5	3.0	3.0	2.5	2.0	2.5	2.5	2.5	3.0	2.0	3.0	3.0
Requirements		0.5	1.5	0.5	0.5	1.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
		1.0	2.5	1.3	1.4	3.0	2.0	1.0	1.8	1.3	1.2	1.3	1.2	1.0	1.0	1.3	1.2	1.3	1.8
		1.5	3.0	1.5	3.0	3.5	3.0	1.5	3.5	2.0	2.5	2.0	2.5	1.5	1.5	2.0	2.0	2.0	3.5
Training		0.5	1.5	1.5	0.5	1.5	1.5	1.5	0.5	1.5	0.5	0.5	0.5	1.5	1.5	1.5	0.5	0.5	1.5
		1.4	2.5	2.4	2.3	2.5	2.2	2.4	1.7	2.3	2.1	2.1	1.5	2.4	2.3	2.4	1.4	1.4	2.3
		2.5	3.5	3.5	3.5	3.5	3.5	3.5	3.0	3.5	3.5	3.0	3.0	3.5	3.0	3.5	2.5	2.5	3.0
Security feature and design		0.5	0.5	0.5	0.5	1.5	0.5	1.5	0.5	0.5	1.0	0.5	1.0	0.5	0.5	0.5	0.5	0.5	0.5
		1.2	1.0	1.6	1.3	2.4	1.0	1.2	1.7	1.0	1.3	1.0	1.3	1.0	1.0	1.0	1.5	1.2	1.4
		2.0	1.5	2.5	2.5	3.5	1.5	2.5	3.0	1.5	2.0	1.5	2.0	1.5	2.0	1.5	2.5	2.0	2.0
Architecture analysis		0.5	1.5	1.5	0.5	2.2	1.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5	1.5	1.5	0.5	1.5	0.5
		1.3	2.5	2.4	2.3	3.0	2.4	2.0	1.7	2.3	2.1	2.3	2.1	2.4	2.4	2.3	1.4	2.3	1.7
		3.0	3.5	3.5	3.5	3.5	3.5	3.0	3.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	2.5	3.5	3.0
Configuration management		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
		1.5	1.6	1.7	1.4	2.1	1.2	1.0	1.0	1.0	2.0	1.0	2.0	1.0	1.0	1.0	1.2	1.0	1.0
		2.5	3.5	3.0	3.5	3.0	2.5	2.5	1.5	1.5	3.0	1.5	3.0	1.5	1.5	1.5	2.5	1.5	1.5
Software Environment		0.5	1.5	0.5	1.0	0.5	1.5	0.5	1.5	0.1	0.5	0.1	0.5	0.5	0.5	0.1	1.0	0.1	1.5
		1.2	2.4	2.1	1.2	1.3	1.2	1.6	2.3	1.8	1.2	1.8	1.2	1.4	1.4	1.8	1.4	1.8	2.3
		2.5	3.5	3.0	2.5	3.0	3.0	2.5	3.0	3.0	2.5	2.0	2.5	2.5	2.5	3.0	2.0	3.0	3.0

Step 4

In this step, we calculated the normalized decision matrix, and to achieve this, we used equations 2 and 3 (section 3.4). To normalize the decision matrix, we must consider cost and beneficial criteria [54]. The cost and benefit criteria is a systematic process to measure the strengths and weaknesses of alternatives used to determine options that provide the best approach to achieving benefits while performing a specific task [54]. Hence, to complete the normalization process, we used the ‘requirements’ as a cost criterion as it includes the challenging factors related to ‘translate compliance constraints to requirements. The results of the normalized decision matrix are presented in Table 14.

Table 14
Normalized decision matrix

		Weights	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch
Secure Testing	Normalized decision matrix	1.0	0.1	0.1	0.1	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.1	0.1	0.1	0.1
		1.2	0.7	0.5	0.4	0.7	0.6	0.6	0.5	0.4	0.3	0.3	0.6	0.3	0.4	0.3	0.3
		2.0	1.0	0.9	0.9	0.9	0.9	0.9	1.0	0.6	0.7	0.7	0.9	0.4	0.7	0.4	0.6
Standards		1.2	0.4	0.1	0.3	0.4	0.1	0.1	0.4	0.4	0.1	0.1	0.3	0.1	0.3	0.1	0.3
		2.5	0.7	0.6	0.3	0.6	0.3	0.3	0.7	0.5	0.3	0.3	0.6	0.4	0.4	0.4	0.4
		3.5	1.0	0.9	0.7	0.9	0.6	0.7	0.9	0.9	0.7	0.6	0.9	0.7	0.6	0.7	0.6
Compliance and policy		0.5	0.4	0.4	0.1	0.6	0.4	0.4	0.1	0.4	0.1	0.4	0.1	0.6	0.4	0.4	0.1
		1.0	0.7	0.7	0.7	0.9	0.7	0.6	0.5	0.7	0.6	0.7	0.6	0.7	0.7	0.7	0.4
		2.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7
Strategy and matrices		0.5	0.4	0.1	0.3	0.1	0.4	0.1	0.4	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.3
		1.4	0.7	0.6	0.3	0.4	0.3	0.5	0.7	0.5	0.3	0.5	0.3	0.4	0.4	0.5	0.4
		2.5	1.0	0.9	0.7	0.9	0.9	0.7	0.9	0.9	0.7	0.6	0.7	0.7	0.7	0.9	0.6
Requirements		0.5	0.2	0.3	0.2	0.1	0.2	0.3	0.1	0.3	0.2	0.3	0.2	0.3	0.3	0.3	0.3
		1.0	0.2	0.4	0.4	0.2	0.3	0.5	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.4
		1.5	0.3	1.0	1.0	0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Training		0.5	0.4	0.4	0.1	0.4	0.4	0.4	0.1	0.4	0.1	0.1	0.1	0.4	0.4	0.4	0.1
		1.4	0.7	0.7	0.7	0.7	0.6	0.7	0.5	0.7	0.6	0.6	0.4	0.7	0.7	0.7	0.4
		2.5	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0	1.0	0.9	0.9	1.0	0.9	1.0	0.7
Security feature and design		0.5	0.1	0.1	0.1	0.4	0.1	0.4	0.1	0.1	0.3	0.1	0.3	0.1	0.1	0.1	0.1
		1.2	0.3	0.5	0.4	0.7	0.3	0.3	0.5	0.3	0.4	0.3	0.4	0.3	0.3	0.3	0.4
		2.0	0.4	0.7	0.7	1.0	0.4	0.7	0.9	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.7
Architecture analysis		0.5	0.4	0.4	0.1	0.6	0.4	0.4	0.1	0.4	0.1	0.4	0.1	0.4	0.4	0.4	0.1
		1.3	0.7	0.7	0.7	0.9	0.7	0.6	0.5	0.7	0.6	0.7	0.6	0.7	0.7	0.7	0.4
		3.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7
Configuration management		0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		1.5	0.5	0.5	0.4	0.6	0.3	0.3	0.3	0.3	0.6	0.3	0.6	0.3	0.3	0.3	0.3
		2.5	1.0	0.9	1.0	0.9	0.7	0.7	0.4	0.4	0.9	0.4	0.9	0.4	0.4	0.4	0.7
Software Environment		0.5	0.4	0.1	0.3	0.1	0.4	0.1	0.4	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.3
		1.2	0.7	0.6	0.3	0.4	0.3	0.5	0.7	0.5	0.3	0.5	0.3	0.4	0.4	0.5	0.4
		2.5	1.0	0.9	0.7	0.9	0.9	0.7	0.9	0.9	0.7	0.6	0.7	0.7	0.7	0.9	0.6

Step 5

in this step, we calculated the weighted decision matrix based on the weights assigned by the group of experts for each criterion were multiplied with their alternative (i.e., challenging factors) using Eq. 4, and the determined results are given in Table 15.

Table 15
Weighted normalized decision matrix

		WEIGHTS	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	C
Secure Testing	Weighted Normalized decision matrix	1.0	0.1	0.1	0.1	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.1	0.1	0.1	0
		1.2	0.9	0.5	0.5	0.9	0.7	0.7	0.6	0.4	0.4	0.4	0.7	0.3	0.5	0.3	0
		2.0	2.0	1.7	1.7	1.7	1.7	1.7	2.0	1.1	1.4	1.4	1.7	0.9	1.4	0.9	1
Standards		1.2	0.5	0.2	0.3	0.5	0.2	0.2	0.5	0.5	0.2	0.2	0.3	0.2	0.3	0.2	0
		2.5	1.7	1.5	0.9	1.5	0.9	0.9	1.6	1.3	0.9	0.9	1.4	1.0	1.0	1.0	1
		3.5	3.5	3.0	2.5	3.0	2.0	2.5	3.0	3.0	2.5	2.0	3.0	2.5	2.0	2.5	2
Compliance		0.5	0.2	0.2	0.1	0.3	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.3	0.2	0.2	0
and policy		1.0	0.7	0.7	0.7	0.9	0.7	0.6	0.5	0.7	0.6	0.7	0.6	0.7	0.7	0.7	0
		2.0	2.0	2.0	2.0	2.0	2.0	1.7	1.7	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1
Strategy		0.5	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0
and matrices		1.4	1.0	0.8	0.5	0.5	0.5	0.6	0.9	0.7	0.5	0.7	0.5	0.6	0.6	0.7	0
		2.5	2.5	2.1	1.8	2.1	2.1	1.8	2.1	2.1	1.8	1.4	1.8	1.8	1.8	2.1	1
Requirements		0.5	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0
		1.0	0.2	0.4	0.4	0.2	0.3	0.5	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0
		1.5	0.5	1.5	1.5	0.6	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1
Training		0.5	0.2	0.2	0.1	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0
		1.4	1.0	1.0	0.9	1.0	0.9	1.0	0.7	0.9	0.8	0.8	0.6	1.0	0.9	1.0	0
		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.1	2.5	2.5	2.1	2.1	2.5	2.1	2.5	1
Security feature		0.5	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0
and design		1.2	0.3	0.5	0.4	0.8	0.3	0.4	0.6	0.3	0.4	0.3	0.4	0.3	0.3	0.3	0
		2.0	0.9	1.4	1.4	2.0	0.9	1.4	1.7	0.9	1.1	0.9	1.1	0.9	1.1	0.9	1
Architecture analysis		0.5	0.2	0.2	0.1	0.3	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0
		1.3	0.9	0.9	0.9	1.1	0.9	0.7	0.6	0.9	0.8	0.9	0.8	0.9	0.9	0.9	0
		3.0	3.0	3.0	3.0	3.0	3.0	2.6	2.6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2
Configuration management		0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0
		1.5	0.7	0.7	0.6	0.9	0.5	0.4	0.4	0.4	0.9	0.4	0.9	0.4	0.4	0.4	0
		2.5	2.5	2.1	2.5	2.1	1.8	1.8	1.1	1.1	2.1	1.1	2.1	1.1	1.1	1.1	1
Software Environment		0.5	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0
		1.2	0.8	0.7	0.4	0.4	0.4	0.5	0.8	0.6	0.4	0.6	0.4	0.5	0.5	0.6	0
		2.5	2.5	2.1	1.8	2.1	2.1	1.8	2.1	2.1	1.8	1.4	1.8	1.8	1.8	2.1	1

Step 6

In this step, we execute equations 5 and 6 and calculate the fuzzy ideal solutions (positive and negative). The fuzzy positive and negative solutions are given in Tables 16 and 17.

Step 7: In this step, we determined the distance Di* and Di- for each Quantum computing challenging factor for criteria (Eq. 7 and Eq. 8), and the results are given in Tables 16 and 17. Whereas: ST = Secure Testing, S = Standards, C = Compliance, and policy, SM = Strategy and matrices, R = Requirements, T = Training, SF = Security feature and design, A = Architecture analysis, C = Configuration management, SE = Software Environment.

Table 16
Fuzzy positive ideal solution

	ST	S	C	SM	R	T	SF	A	C	SE	di*
Ch1	0.16	0.00	0.10	0.00	0.60	0.00	0.72	0.12	0.12	0.00	1.84
Ch2	0.29	0.37	0.11	0.23	0.07	0.02	0.38	0.14	0.23	0.23	2.08
Ch3	0.32	0.77	0.18	0.50	0.10	0.09	0.40	0.21	0.17	0.48	3.22
Ch4	0.16	0.31	0.00	0.34	0.57	0.00	0.00	0.00	0.21	0.31	1.90
Ch5	0.25	1.02	0.11	0.35	0.15	0.07	0.72	0.14	0.47	0.31	3.60
Ch6	0.25	0.79	0.24	0.46	0.00	0.02	0.41	0.33	0.49	0.45	3.44
Ch7	0.22	0.29	0.30	0.21	0.14	0.29	0.23	0.40	0.87	0.21	3.15
Ch8	0.57	0.38	0.13	0.27	0.07	0.05	0.72	0.16	0.87	0.26	3.49
Ch9	0.45	0.79	0.20	0.50	0.06	0.12	0.54	0.24	0.21	0.48	3.60
Ch10	0.45	1.02	0.13	0.64	0.07	0.24	0.72	0.16	0.87	0.64	4.94
Ch11	0.18	0.35	0.20	0.50	0.06	0.32	0.54	0.24	0.21	0.48	3.09
Ch12	0.74	0.74	0.10	0.48	0.00	0.02	0.72	0.14	0.87	0.46	4.28
Ch13	0.43	0.96	0.11	0.48	0.00	0.21	0.57	0.14	0.87	0.46	4.25
Ch14	0.74	0.74	0.13	0.27	0.07	0.02	0.72	0.16	0.87	0.26	3.99
Ch15	0.58	0.96	0.45	0.66	0.05	0.49	0.38	0.62	0.47	0.65	5.32
Ch16	0.58	1.00	0.13	0.27	0.07	0.49	0.56	0.16	0.87	0.26	4.40
Ch17	0.57	0.94	0.30	0.21	0.14	0.21	0.54	0.40	0.87	0.21	4.39
Ch18	0.44	1.31	0.45	0.66	0.05	0.90	0.72	0.62	0.47	0.65	6.26

Table 17
Fuzzy negative ideal solution

	ST	S	C	SM	R	T	SF	A	C	SE	di-
Ch1	0.72	1.32	0.39	0.69	0.02	0.90	0.00	0.55	0.84	0.67	6.10
Ch2	0.51	0.98	0.38	0.46	0.59	0.89	0.35	0.55	0.64	0.45	5.80
Ch3	0.50	0.61	0.36	0.22	0.59	0.88	0.34	0.53	0.83	0.22	5.07
Ch4	0.60	1.02	0.45	1.27	0.04	0.90	0.72	0.62	0.68	0.41	6.71
Ch5	0.53	0.31	0.38	0.43	0.58	0.87	0.00	0.55	0.42	0.43	4.49
Ch6	0.53	0.59	0.21	0.23	0.61	0.89	0.34	0.29	0.41	0.22	4.33
Ch7	0.68	1.06	0.17	0.50	0.58	0.64	0.51	0.26	0.00	0.48	4.87
Ch8	0.18	0.97	0.37	0.44	0.59	0.88	0.00	0.54	0.00	0.43	4.39
Ch9	0.33	0.59	0.35	0.21	0.60	0.86	0.18	0.52	0.67	0.21	4.51
Ch10	0.33	0.31	0.37	0.14	0.59	0.67	0.00	0.54	0.00	0.12	3.07
Ch11	0.57	0.98	0.35	0.21	0.60	0.63	0.18	0.52	0.67	0.21	4.90
Ch12	0.00	0.61	0.39	0.21	0.61	0.89	0.00	0.55	0.00	0.21	3.47
Ch13	0.34	0.38	0.38	0.21	0.61	0.69	0.16	0.55	0.00	0.21	3.54
Ch14	0.00	0.61	0.37	0.44	0.59	0.89	0.00	0.54	0.00	0.43	3.86
Ch15	0.17	0.38	0.00	0.09	0.60	0.42	0.34	0.00	0.42	0.08	2.50
Ch16	0.17	0.35	0.37	0.44	0.59	0.42	0.17	0.54	0.00	0.43	3.48
Ch17	0.18	0.44	0.17	0.50	0.58	0.69	0.18	0.26	0.00	0.48	3.48
Ch18	0.34	0.08	0.00	0.09	0.60	0.00	0.00	0.00	0.42	0.08	1.60

Step 8

Using Eq. 9, the closeness coefficient was calculated, and the results are given in Table 18.

Step 9

Considering the closeness coefficient values, the ranks for each challenging factor were determined. Higher the cci value of a challenging factor shows their higher ranking (Table 18). For example, Ch4 (Limited scalability, CCi = 0.78) is the highest challenging factor for the quantum computing in social business paradigm. We further noted that Ch1 (Regulatory challenges, CCi = 0.77), Ch2 (High initial cost, CCi = 0.74) are ranked as the 2nd and 3rd most critical challenging factors for the quantum computing implication in social business.

Table 18
Closeness coefficient values and Ranks

Categories	Sr.NO.	Challenging factors	CCi	Local Ranks	Global Ranks
Secure Testing (KA1)	Ch1	Regulatory challenges	0.77	1	2
	Ch2	High initial cost	0.74	2	3
Standards (KA2)	Ch3	Limited availability of quantum resources	0.61	2	4
	Ch4	Limited scalability	0.78	1	1
Compliance and policy (KA3)	Ch5	Security	0.56	2	5
	Ch6	Regulatory challenges	0.56	2	5
	Ch7	Education and training	0.61	1	4
Strategy and matrices (KA4)	Ch8	Ethical considerations	0.56	1	5
Requirements (KA5)	Ch9	Lack of standards	0.56	1	5
Training (KA6)	Ch10	Integration with existing systems	0.38	1	9
Security feature and design (KA7)	Ch11	Interdisciplinary collaboration	0.61	1	4
	Ch12	Limited expertise	0.45	2	7
Architecture analysis (KA8)	Ch13	Uncertainty	0.45	1	7
Configuration management (KA9)	Ch14	Limited applications	0.49	1	6
	Ch15	Resistance to change	0.32	3	10
	Ch16	Intellectual property	0.44	2	8
Software Environment (KA10)	Ch17	Limited access to sustainable funding	0.44	1	8
	Ch18	Environmental impact	0.20	2	11

According to the final determined ranks presented in Table 18, "Ch4 (Limited scalability, CCi = 0.78) is ranked as the highest priority challenging factor. For example, Prates et al.[55] stated that standards can be positive ("do it this way") or negative ("do not use this API"), but they must be enforced to be useful. Furthermore, Rahul et al.[56] defined that an obligatory phase of a firm's secure coding standards mostly begins as sufficient grounds for rejecting a piece of code[5]. Other useful coding standard topics might include proper use of cloud APIs, approved cryptography, memory sanitization, and many others. They further indicated that the code review against standards must be objective: it should not become a debate about whether the non-compliant code is exploitable. Tony [57] underlined that the coding standards are specific to language constructs and enforced with tools (e.g., codified into SAST rules) in some situations. In other cases, published coding standards are specific to technology stacks and enforced during the code review process" or using automation. Ch1 (Regulatory challenges, CCi = 0.77) is ranked as the 2nd most critical challenging factor for the quantum computing implication in social business paradigm. In quantum computing implication in social business, the adoption of black-box security testing tools is vital for the quality assessment process. Automated testing tools are also essential to encapsulate the attacker [58]. Ch2 (High initial cost, CCi = 0.74) is ranked as the 3rd most significant challenging factor for the successful execution of the quantum computing implication in social business paradigm.

An interesting observation is that the Ch5 (Security, CCi = 0.56), Ch6 (Regulatory challenges, CCi = 0.56), Ch8 (Ethical considerations, CCi = 0.56) and Ch9 (Lack of standards, CCi = 0.56) are ranked as 5th most important challenging factors for quantum computing implication in social business. According to the experts, this renders that these four challenging factors are equally crucial for quantum computing implication in social business process execution.

4.5 Holistic model challenges of quantum in social business

Finally, we developed a holistic model of quantum computing implication in social business challenging factors and their leveling determined via the ISM approach. The developed model (Fig. 9) indicated the global ranking (GR) and local ranking (LR) of each of the challenging factors. The global ranking presents the priority order of each challenging factor by applying the step-by-step protocols of fuzzy-TOPSIS. It indicates the priority order of the challenging factors compared to all the reported challenging factors. The local ranking then presents the priority order of each challenge within its respective category, which is useful when checking the impact of a challenging factor locally (within the category).

Figures 7 and 8 show that the C2 (Standards) category stands on the top for selecting quantum computing implication in social business challenging factors categories. This indicated that C2 is an independent category of the quantum computing implication in social business challenging factor, which shows that all the other challenging categories are dependent on C2. Considering the local rankings (Fig. 9, Table 18), Ch4 (Lack of secure coding standards) is the highest-ranked challenging factor for the quantum computing paradigm. We further noted that Ch4 is also declared the highest priority challenging factor for global ranking. Practitioners need to consider Ch4 as a priority for the success and progression of quantum computing implication in social business in real-world projects [5].

Moreover, the results (Fig. 9 and Table 18) show that Ch3 (Limited availability of quantum resources) is ranked as the 2nd category, i.e., C2 (Standards) category. Still, considering the global ranking, it stands as the 4th priority challenging factor for quantum computing implication in social business. This analysis shows that the global ranking of the challenging factors could vary by comparing the weights of all 18 identified challenging factors. Thus, the practitioners need to pay due attention to considering the priority of the quantum computing implication in social business challenging factors concerning their designation (nature of work) and interest[5].

Furthermore, the results (Figs. 7 and 9) presented that C1 (Secure Testing), C4 (Strategy and matrices), C5 (Requirements), and C6 (Training) are ranked on level 4, and these categories depend on only one category, C2 (Standards), i.e., level 5. According to the ISM analysis results, the rest of all: levels 3, level 2, and level 1, categories depend on level 4.

The fuzzy-TOPSIS results indicated that Ch1 (Regulatory challenges), Ch2 (High initial cost) are ranked as the 2nd and 3rd most critical challenging factors for quantum computing implication in social business. The practitioners should consider the challenging and individual factors, considering their category level and local and global rankings.

5 Summary Of Study Findings

This study explores and analyzes the challenges faced while adopting quantum computing implication in social business, as reported by academic and industry researchers and faced by real-world practitioners. Firstly, to investigate the challenging factors of quantum computing implication in social business, we did a multivocal literature review. We collected most potential literature published as scientific research and grey literature, including experience reports, blogs, white papers, case studies, etc. With the protocols of multivocal literature review, 46 formal and 41 grey literature studies were selected for the final data extraction process. By carefully reviewing the final selected literature, we identified the list of 18 challenging factors that are related to 10 key categories of quantum computing implication in social business. Secondly, the questionnaire survey was conducted with experts; it evaluated the significance of the identified challenging factors in real-world practices. During the survey data collection process, 113 complete responses were collected. The frequency analysis showed that the identified list of 18 challenging factors and their core categories are related to industry practices.

We further applied the ISM approach to examine the relationships between the ten core categories of quantum computing implication in social business. The results show that KA3 (Compliance and policy) and KA8 (Architecture analysis) criteria are autonomous elements. This indicated that these both had only weak links to other criteria. KA4 (Strategy and matrices), KA6 (Training), KA7 (Security feature and design), and KA10 (Software Environment) have strong driving and dependence power and affect other enablers due to solid linkage. KA1 (Secure Testing) and KA5 (Requirements) belong to an independent cluster indicating a weak dependent but strong driving power. This meant that it is not dependent on other categories but has practical significance. They can also be considered key enablers. KA2 (Standards) and KA9 (Configuration management) belong to the dependent cluster, rendering KA2 and KA9 have a strong dependence power but a weak driving power.

The uncertainty in experts' opinions can be a problem when identifying challenging factors. We applied the fuzzy TOPSIS approach to address this concern to fix the multicriteria decision-making problem. The results show that Ch4 (Limited scalability) is the highest challenging factor. Ch1 (Regulatory challenges), Ch2 (High initial cost), and Ch3 (Limited availability of quantum resources) are the top four challenging factors for the successful execution of quantum computing implication in social business.

6 Study Implications

The study implications for researchers and practitioners are as follows:

For researchers

The study provides a state-of-the-art overview of the challenges that can impact quantum computing implication in social business processes by providing a review of both academic and grey literature. The study's findings offer a body of knowledge to researchers to develop strategies for the successful implementation of quantum computing implications in social business. The study also provides a rank-based framework of the identified challenging factors. The investigated factors are examined in their priority ranking and the relationship between the core categories of the identified challenging factors. We believe that prioritization-based ranking helps the researchers to consider the most significant challenging factors in their future research.

For Practitioners

The in-depth multivocal literature study and empirical investigations provide industry experts with knowledge about the challenging areas of the quantum computing in social business. This study presents 18 challenges, and each challenge calls on the industry practitioners to focus on during the implementation of quantum computing in social business. The prioritization of the identified challenges will assist the practitioners in considering the most significant challenging factor on priority. Identifying challenges and their prioritization will help the practitioners revise and develop the new strategies for the successful execution of quantum computing in social business. Moreover, this study provides a holistic model of quantum computing in social business challenges, informing practitioners about which challenge is vital in which category. This study also induced ISM and fuzzy TOPSIS as novel approaches in this domain that assist the industry experts in fixing the uncertainty and vague opinions of quantum computing in social business experts.

Future work

To date, little research has been conducted on developing models and strategies for quantum computing in social business practices in the real-world industry. Hence, despite the importance of incorporating security into quantum computing in social business, no maturity model supports quantum computing in social business processes by highlighting critical success factors, critical challenges, and best practices, and a road map. Considering the importance of security concerns in social business, we are motivated to develop a specific quantum computing in social business maturity model that will assist the software organizations in measuring their maturity level and suggest the best practices for successful implementation execution of quantum computing activities. quantum computing in social business will be based on the empirically uncovered challenges, success factors, and best practices of quantum computing in social business and existing maturity models of other software engineering domains.

The quantum computing in social business model will be developed using the steps of maturity model paradigm. The quantum computing in social business model consists of three core components, i.e., maturity level component, factors component (critical success factors (CSFs), critical challenges (CCHs)) and assessment component. The current study only contributed to developing a one-factor component, i.e., critical challenging factors. The association between the key components of quantum computing in social business model. The maturity level component is considered to assess an organization's maturity level regarding the quantum computing in social business. The factors component consists of the CSFs and CCHs representing the quantum computing in social business process's key areas. The assessment component is used to assess an organization's specific maturity level and suggest the best practices to boost the quantum computing in social business capabilities." The proposed model will assist in executing quantum computing in social business activities in the real-world industry.

7. Limitations

The literature review was performed to collect the formal and grey literature related to the study's objective. The first author of this study executed the literature searching and collection process, and the second author of this study reviewed the selected literature and performed the data extraction. Thus, there might be a threat of bias in the extracted data. Authors no-3 and 4 carried out the inclusion, exclusion, quality assessment, and data extraction process for five formal and five grey studies to address this threat. Moreover, we applied the inter-rater reliability test with external experts, and the results show that there is no significant bias and that the collected data and analysis are consistent.

Secondly, there might be a chance of missing some related literature during the data collection process. Our study has a representative set of 87 literature items, and therefore this limitation is not systematic [30, 59]. The questionnaire survey approach has been applied to investigate the identified challenging factors with industry experts empirically. There is always a threat in the survey instrument development. This threat has been addressed by piloting and assessing the development questionnaire with external experts and lab mates. The findings of ISM and the fuzzy TOPSIS approach are based on the decisions of ten experts, and this might be a small data set. These studies are subjective in types, and various existing studies [37–39] also used the small data set for such kind of analysis. Thus, the results of ISM and fuzzy TOPSIS approaches are generalizable.

8. Conclusions

We further applied the ISM approach examine the relationship between the 10 knowledge areas. The results revolved that 'Scope' is the independent knowledge area of quantum computing in social business challenging factors as it has strong driving power and zero dependence power. Furthermore, it is observed that 'Human Resource Management' and 'Stakeholders' both had strong driving power and week dependent power.

Finally, considering the findings of the fuzzy-AHP and ISM approach, we developed the holistic model which gives the information about the priorities of success factors within their respective knowledge area and for overall quantum computing in social business project management paradigm. We believed that the study results and analysis will help the industry practitioners to revise and develop the new strategies for the successful execution of quantum computing in social business.

KA2 (Human Resource Management) and KA3 (Stakeholders) both belong to independent cluster which indicated that KA2 and KA3 has weak dependent power and strong driving power. For example, the stakeholders need to arrange or allow training session for the educating the human resources according to their tasks; besides, the human resources management needs to perform efficient task to meet the stakeholder's objectives.

The knowledge areas 'Communication', 'Risk', 'Quality' and 'Cost' have both driving and dependence power. The knowledge areas 'Integration', 'Procurement' and 'Schedule' has weak driving power but have strong dependent power. Interestingly, out of 10 knowledge areas of quantum computing in social business, no knowledge area is autonomous.

Declarations

Ethical Approval: Not applicable as no human and/ or animal data is involved.

Competing interests: 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 paper.

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Figures

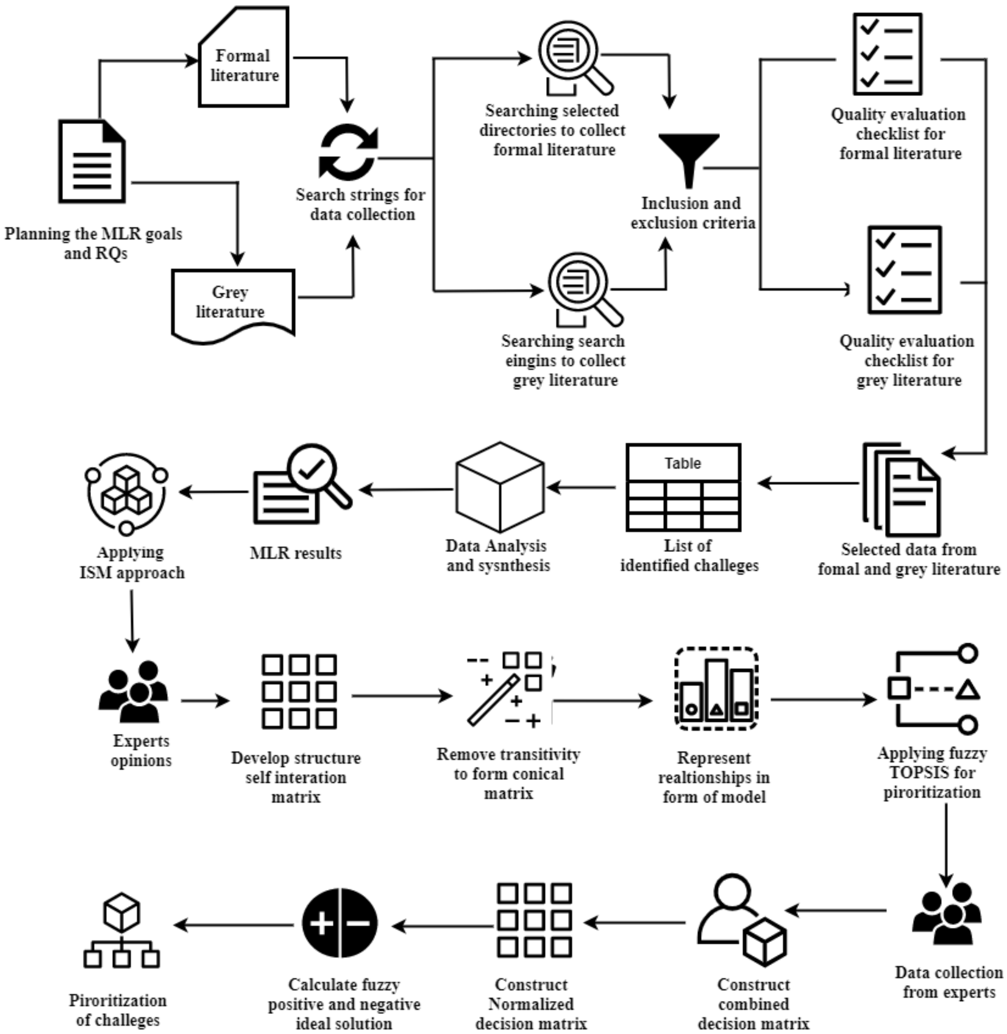

Figure 1

Research Approach

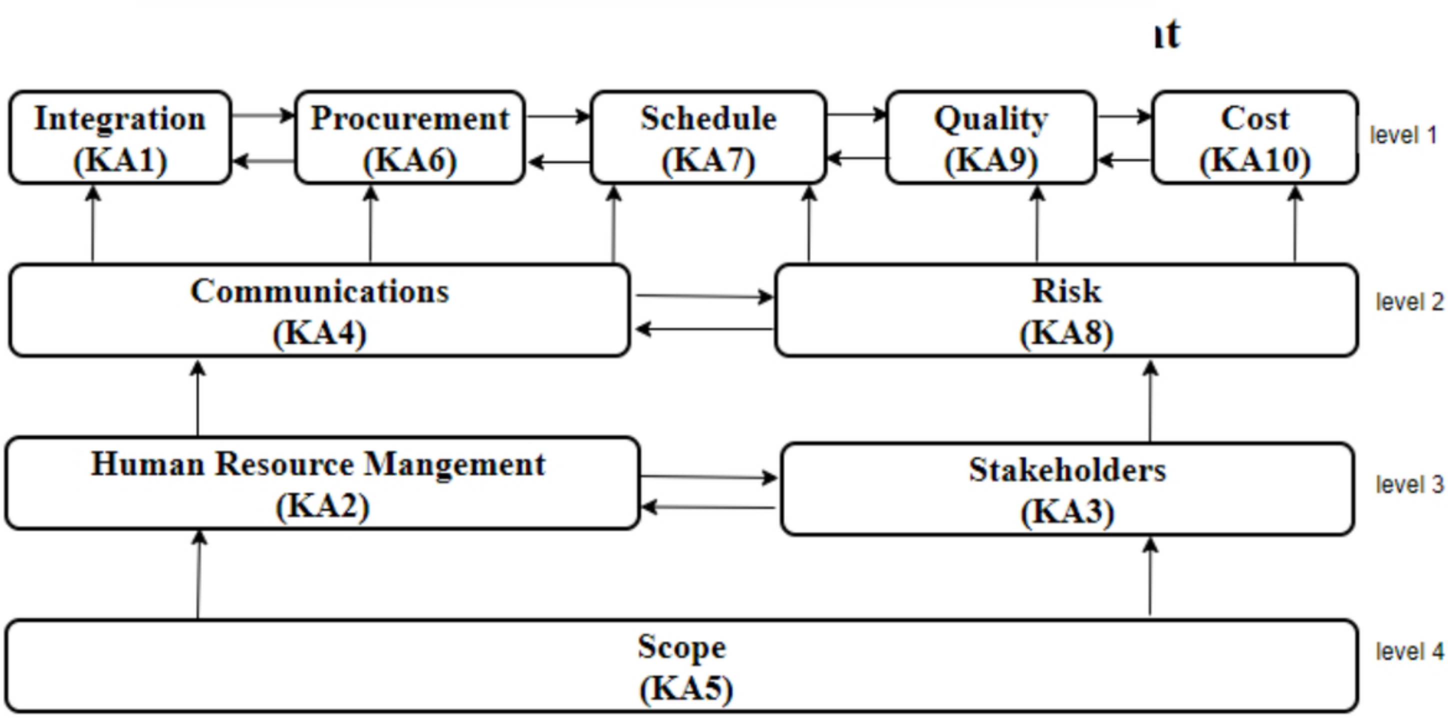

Figure 2

Figure 11: Leveling of core knowledge areas of quantum computing in social business challenges

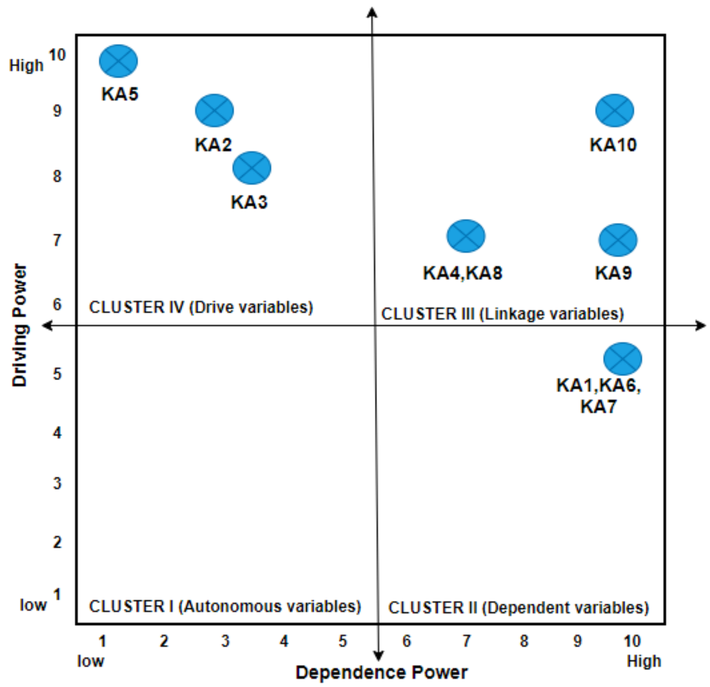

Figure 3

Figure 12: Graphical presentation of MICMAC analysis

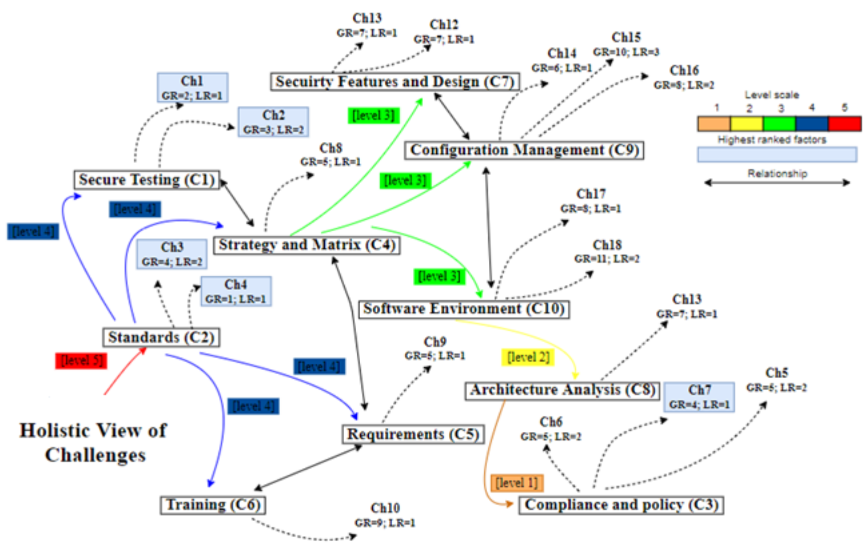

Figure 4

Figure 9: Holistic model of quantum computing implication in social business challenges