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Serving SDGs via Bank Mergers: A Neuro Quantum Fuzzy Approach for Qatari Banks

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ABSTRACT Determining the right merger strategy for banks is an important step. In this way, risks can be managed more effectively, and long-term financial performance can be achieved. However, there are many different factors that affect this process. It is not optimal for banks to consider all factors due to budget constraints. In this context, it is important to determine the most important ones among these criteria. Accordingly, the purpose of this study is to evaluate alternative merger strategies for banks. For this purpose, 12 different Sustainable Development Goals (SDGs)-based criteria are selected. Multi stepwise weight assessment ratio analysis (M-SWARA) methodology is used to compute the weights of these items. The main contribution of this study is that the implications of the merger process on SDGs can be examined. Furthermore, a new methodology (M-SWARA) is proposed in this study that has an increasing impact on the methodological originality. The findings indicate that increasing profitability has the greatest weight (0.095). Similarly, market share is found as the second most critical factor (0.092) for merger decisions in the banking industry. A profitable bank can attract more investors and with the help of this situation it can be much easier to raise capital and access funding from capital markets. These issues can be used to finance projects that align with SDGs, such as renewable energy, affordable housing, or clean water initiatives. In addition to this situation, profitability can also have a positive impact on innovation and technological advancement. With sufficient resources, a bank can invest in research and development, technological infrastructure, and innovative products and services. Owing to these investments, sustainable development can be promoted.

INDEX TERMS balanced scorecard, SDGs, M&A, banking, M-SWARA, quantum spherical fuzzy sets

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I. INTRODUCTION

Bank mergers have been a matter of interest for economists and financial professionals for many decades, beginning in the early 20th century. However, the frequency and importance of bank mergers have changed over time. The banking industry started to deregulate more quickly in the 1970s. This included repealing the Glass-Steagall Act, which divided commercial and investment banking, eased branching limitations, and removed interest rate restrictions. The effects of bank mergers on the banking sector and the economy have long been discussed. On the one hand, bank mergers can boost productivity and reduce costs for the combined company, which benefits customers. They may also result in the establishment of more diversified institutions with a more remarkable ability to withstand economic downturns [1]. Similarly, bank mergers may result in a concentration of power in the hands of a few major banks and a reduction in competition, which would raise consumer prices and stagnate innovation.

There are lots of benefits of bank mergers. A significant financial benefit of bank mergers is economies of scale. It alludes to the financial savings realized by expanding business operations. The new organization can reduce costs by combining two banks by eliminating redundant operations like technology, marketing, and human resources. This may result in lower costs, raising the combined entity's profitability. The increased revenue from cross-selling is another financial advantage of bank mergers. Cross-selling offers existing consumers new goods or services. By combining two banks, the new firm can access a more extensive customer base, expanding the potential for cross-selling [2]. Finally, through increasing diversification, bank mergers can lower risks. In this process, to lower a portfolio's risk, diversification refers to investing in various assets. The combined firm can diversify its portfolio by merging two banks, which lowers the portfolio's risk.

It is crucial to remember that bank mergers come with dangers and difficulties, such as the need to comply with regulations, integrate people and systems, and maybe eliminate jobs. The possibility for greater market power concentration is one of bank mergers' most frequently mentioned dangers. When two or more banks combine, they frequently grow into a more prominent organization that can control a specific market or area. As a result, there may be less competition, higher consumer prices, and fewer options for consumers [3]. The possibility that bank mergers may lessen competition in the financial sector is a significant worry. A monopoly develops in a nation or an area due to the merger of two already sizable banks. Fewer banks mean less competition, which raises prices and limits consumer options. Regulations must ensure that mergers will not create monopolies or market dominance that could harm consumers [4]. Additionally, authorities need to ensure the combined bank has sufficient capital and liquidity to survive potential future shocks and implement the necessary measures to reduce systemic risks.

It is necessary to determine the correct merger strategy for banks. Otherwise, these bank mergers will bring more harm than good, and this will negatively affect both the performance of the business and the national economy. In this process, many different issues need to be taken into consideration to determine an effective merger strategy [5]. Another point that comes to the fore here is that banks have budget constraints. Therefore, for the merger strategy to be implemented effectively and efficiently, very high costs should not occur. In this framework, it is necessary to determine the most important factors among the factors that affect the merger strategies of the banks. In this way, banks will be able to implement the most accurate merger strategy [6]. This will significantly contribute to improving the performance of both banks and the financial sector in the country.

In this study, it is aimed to evaluate alternative merger strategies for banks. In this framework, 12 different SDGs-based criteria are identified. M-SWARA methodology is taken into consideration to calculate the weights of these items for Qatari banks. In this process, the evaluations of five different experts are considered. The main contributions of this study are given as follows: (i) A new methodology (M-SWARA) is proposed. In spite of many different benefits, it is impossible to make causality analysis of the criteria in the classical SWARA technique. However, the critical items of bank merger process can have an influence on each other. Hence, some improvements are implemented to this method and M-SWARA methodology is created. (ii) The implications of the merger process on SDGs can be examined. Hence, with the help of priority analysis, the most critical items in bank merger process can be identified. Therefore, more appropriate merger strategies can be presented for Qatari banks to provide sustainability in this process.

The paper is structured as follows. Chapter two presents the current literature. Chapter three explains the data and methodology used in the research. Chapter four includes the results of the analysis. Chapter five discussed the research results, including policy recommendations and short/long term suggestions for the merged entity. And lastly chapter six concludes the article.

II. LITERATURE REVIEW

It is possible to talk about the very important financial advantages of mergers of banks. Bank mergers have a significant impact on increasing profitability [7]. According to Lu [8], thanks to the merger practice, banks have a larger scale. This allows banks to benefit from economies of scale. Doumpos et al. [9] stated that owing to the bank merger, it is possible to reduce costs with high transaction volumes. This allows businesses to increase their operational efficiency. On the other hand, Eaton et al. [10] mentioned that it is possible to distribute risks through bank mergers. In other words, as a result of the merger, it is possible for the bank to have many different types of customers. In this way, effective risk

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management can be made. This allows banks to increase their long-term profitability in a solid way. Increasing market share is also one of the most important benefits of bank mergers [11]. Additionally, Milenković et al. [12] identified that thanks to the number of customers from different geographies belonging to different banks that have merged, it is possible for the bank to reach a wider customer segment. In this way, it will be easier for banks to provide income diversity [13]. Thus, the competitiveness of banks will increase significantly.

Bank mergers also include some advantages that can contribute to customer satisfaction. The effect of bank mergers in improving service quality is very important [14]. Also, Caiazza et al. [15] defined that thanks to the bank merger, it is possible to have larger-scale resources. In other words, with the help of the financial resources and technological infrastructure of different banks, it is possible for the merged new bank to have stronger assets. Lu et al. [16] determined that by using these resources, banks can improve customer service and significantly improve service quality. On the other hand, Arunachalam et al. [17] denoted that by having more advanced technology systems, the bank can offer products that are easier to use to its customers. Moreover, the expertise of different banks can provide synergies through bank mergers. In other words, by combining these different forces, the new bank can provide better services to customers. This contributes significantly to increasing customer satisfaction [18]. Satisfied customers will also prefer the bank more. This shows that the competitive power of the merged bank can be increased significantly compared to its competitors. Ashta and Herrmann [19] showed that Banks can have many different types of customers. Therefore, it is very difficult to provide specific service for each type of customer. Bank mergers also contribute significantly to minimizing this problem [20].

Bank mergers also have some effects on increasing operational efficiency. Bank mergers mean combining the resources of different banks [21]. This means that the new bank has more financial, technological, and human resources [22]. According to Hensmans [23], this contributes to increasing profitability, as it will ensure that costs can be reduced significantly. Furthermore, Hudaefi and Badeges [24] stated that bank mergers also reveal the potential to create cooperation and synergy. This allows for a significant increase in operational efficiency. Nguyen [25] identified that bank mergers offer opportunities for management and organizational efficiency. Thanks to the merger of the bank, management and operational processes can be restructured [26]. This helps to have faster decision-making processes. Moreover, Echarte Fernández et al. [27] mentioned that bank mergers also contribute to the development of the technological infrastructure. Yin [28] determined that thanks to the merger of different banks, it is possible to combine their technological powers in these banks. This situation increases the potential of banks to develop innovative products [29]. This, in turn, enables the bank to reach a wider market and gain a stronger competitive position.

By considering the literature review results, the following key points can be identified.

(i) Bank mergers provide many different benefits, such as increasing long-term profitability and effective risk management.

(ii) On the other hand, this process also contains some risks like the need to comply with regulations.

(iii) The correct merger strategy for banks should be defined. Otherwise, these bank mergers will bring more drawbacks than advantages.

(iv) In this framework, it is necessary to determine the most important factors among the factors that affect the merger strategies of the banks.

While focusing on these factors, in this study, it is aimed to identify the most significant merger strategies for banks by creating a new methodology.

III. METHODOLOGY

Quantum Spherical fuzzy sets, M-SWARA and neuro decision-making with facial action coding system are explained in this section.

A. Quantum Spherical Fuzzy Sets with Golden Cut

Quantum mechanics aim to understand the probabilities of various conditions. In this context, angles (θ^2) and amplitude results (φ^2) are taken into consideration [30]. This situation helps to solve complex problems in a more effective manner [31]. This theory is explained in Equations (1)-(3). In this context, ς states collective events and u refers to the event [32].

$$Q(|u>) = \varphi e^{j\theta} \tag{1}$$

$$|\varsigma> = \{|u_1>, |u_2>, \dots, |u_n>\} \tag{2}$$

$$\sum_{|u>\subseteq|\varsigma>} |Q(|u>)| = 1 \tag{3}$$

For decision-making models to be formed correctly, it is necessary to minimize the uncertainty in the process. To achieve this goal, these techniques can be used with different fuzzy numbers. Within this scope, Spherical fuzzy sets ($\tilde{A}_S$) are also introduced to increase the precise results [33]. For this purpose, generalized forms of Neutrosophic and Pythagorean fuzzy numbers are taken into consideration [34]. These sets consider both membership, non-membership, and hesitancy parameters (μ, ν and π) together that is accepted as the main benefit of them. Equations (4) and (5) indicate the details of these sets [35].

$$\tilde{A}_S = \left\{\langle u, (\mu_{\tilde{A}_S}(u), \nu_{\tilde{A}_S}(u), h_{\tilde{A}_S}(u))|u \in U\right\} \tag{4}$$

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$$0 \le \mu_{\tilde{A}_S}^2(u) + v_{\tilde{A}_S}^2(u) + h_{\tilde{A}_S}^2(u) \le 1\ , \forall_u \in U \quad (5)$$

In this model, Quantum mechanisms and Spherical fuzzy sets are integrated as in Equations (6)-(8) where $\varsigma_{\mu_{\tilde{A}_S}}$, $\varsigma_{v_{\tilde{A}_S}}$, and $\varsigma_{h_{\tilde{A}_S}}$ refer to the parameters.

$$|\varsigma_{\tilde{A}_S}> = \left\{\langle u, (\varsigma_{\mu_{\tilde{A}_S}}(u), \varsigma_{v_{\tilde{A}_S}}(u), \varsigma_{h_{\tilde{A}_S}}(u))|u \in 2^{|\varsigma_{\tilde{A}_S}>}\right\} \quad (6)$$

$$\varsigma = \left[\varsigma_\mu . e^{j2\pi.\alpha}, \varsigma_v . e^{j2\pi.\gamma}, \varsigma_h . e^{j2\pi.\beta}\right] \quad (7)$$

$$\varphi^2 = \left|\varsigma_\mu(|u_i>)\right| \quad (8)$$

Another key point to increase the appropriateness of the decision-making process is to compute the degrees effectively. For this purpose, golden ratio (G) is used in this proposed model. Equations (9) and (10) give information about this process in which *a* and *b* demonstrate the large and small quantities [36,37].

$$G = \frac{a}{b} \quad (9)$$

$$G = \frac{1+\sqrt{5}}{2} = 1.618\ldots \quad (10)$$

Equations (11) and (12) explain the amplitude of non-membership and hesitancy degrees and Equations (13)-(15) refer to the phase angles of membership, non-membership, and hesitancy degrees in Quantum Spherical fuzzy sets.

$$\varsigma_v = \frac{\varsigma_\mu}{G} \quad (11)$$

$$\varsigma_h = 1 - \varsigma_\mu - \varsigma_v \quad (12)$$

$$\alpha = \left|\varsigma_\mu(|u_i>)\right| \quad (13)$$

$$\gamma = \frac{\alpha}{G} \quad (14)$$

$$\beta = 1 - \alpha - \gamma \quad (15)$$

The details of the mathematical operations are shown in Equations (16)-(19).

$$\lambda * \tilde{A}_\varsigma = \left\{ \begin{array}{c} \left(1 - \left(1 - {\varsigma_{\mu_{\tilde{A}}}}^2\right)^\lambda\right)^{\frac{1}{2}} e^{j2\pi.\left(1-\left(1-\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)^2\right)^\lambda\right)^{\frac{1}{2}}}, \\ {\varsigma_{v_{\tilde{A}}}}^\lambda e^{j2\pi.\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^\lambda}, \\ \left(\begin{array}{c} \left(1 - {\varsigma_{h_{\tilde{A}}}}^2\right)^\lambda \\ -\left(1 - {\varsigma_{\mu_{\tilde{A}}}}^2 - {\varsigma_{h_{\tilde{A}}}}^2\right)^\lambda \end{array}\right)^{\frac{1}{2}} e^{j2\pi.\left(\left(1-\left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^2\right)^\lambda - \left(1-\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)^2 - \left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^2\right)^\lambda\right)^{\frac{1}{2}}} \end{array} \right\} \quad (16)$$

$$\tilde{A}_\varsigma{}^\lambda = \left\{ \begin{array}{c} {\varsigma_{\mu_{\tilde{A}}}}^\lambda e^{j2\pi.\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)^\lambda}, \\ \left(1 - \left(1 - {\varsigma_{v_{\tilde{A}}}}^2\right)^\lambda\right)^{\frac{1}{2}} e^{j2\pi.\left(1-\left(1-\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^2\right)^\lambda\right)^{\frac{1}{2}}}, \\ \left(\begin{array}{c} \left(1 - {\varsigma_{v_{\tilde{A}}}}^2\right)^\lambda \\ -\left(1 - {\varsigma_{v_{\tilde{A}}}}^2 - {\varsigma_{h_{\tilde{A}}}}^2\right)^\lambda \end{array}\right)^{\frac{1}{2}} e^{j2\pi.\left(\left(1-\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^2\right)^\lambda - \left(1-\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^2 - \left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^2\right)^\lambda\right)^{\frac{1}{2}}} \end{array} \right\} \quad (17)$$

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$$\tilde{A}_{\varsigma} \oplus \tilde{B}_{\varsigma} = \left\{ \begin{array}{c} \begin{pmatrix} {\varsigma_{\mu_{\tilde{A}}}}^2 \\ +{\varsigma_{\mu_{\tilde{B}}}}^2 \\ -{\varsigma_{\mu_{\tilde{A}}}}^2{\varsigma_{\mu_{\tilde{B}}}}^2 \end{pmatrix}^{\frac{1}{2}} e^{j2\pi.\left(\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)^2+\left(\frac{\alpha_{\tilde{B}}}{2\pi}\right)^2-\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)^2\left(\frac{\alpha_{\tilde{B}}}{2\pi}\right)^2\right)^{\frac{1}{2}}}, \\ {\varsigma_{v_{\tilde{A}}}}{\varsigma_{v_{\tilde{B}}}} e^{j2\pi.\left(\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)\left(\frac{\gamma_{\tilde{B}}}{2\pi}\right)\right)}, \\ \begin{pmatrix} \left(1-{\varsigma_{\mu_{\tilde{B}}}}^2\right){\varsigma_{h_{\tilde{A}}}}^2 \\ +\left(1-{\varsigma_{\mu_{\tilde{A}}}}^2\right){\varsigma_{h_{\tilde{B}}}}^2 \\ -{\varsigma_{h_{\tilde{A}}}}^2{\varsigma_{h_{\tilde{B}}}}^2 \end{pmatrix}^{\frac{1}{2}} e^{j2\pi.\left(\begin{array}{c}\left(1-\left(\frac{\alpha_{\tilde{B}}}{2\pi}\right)^2\right)\left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^2+\left(1-\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)^2\right)\left(\frac{\beta_{\tilde{B}}}{2\pi}\right)^2- \\ \left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^2\left(\frac{\beta_{\tilde{B}}}{2\pi}\right)^2\end{array}\right)^{\frac{1}{2}}} \end{array} \right\} \quad (18)$$

$$\tilde{A}_{\varsigma} \otimes \tilde{B}_{\varsigma} = \left\{ \begin{array}{c} {\varsigma_{\mu_{\tilde{A}}}}{\varsigma_{\mu_{\tilde{B}}}} e^{j2\pi.\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)\left(\frac{\alpha_{\tilde{B}}}{2\pi}\right)}, \\ \begin{pmatrix} {\varsigma_{v_{\tilde{A}}}}^2 \\ +{\varsigma_{v_{\tilde{B}}}}^2 \\ -{\varsigma_{v_{\tilde{A}}}}^2{\varsigma_{v_{\tilde{B}}}}^2 \end{pmatrix} e^{j2\pi.\left(\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^2+\left(\frac{\gamma_{\tilde{B}}}{2\pi}\right)^2-\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^2\left(\frac{\gamma_{\tilde{B}}}{2\pi}\right)^2\right)^{\frac{1}{2}}}, \\ \begin{pmatrix} \left(1-{\varsigma_{v_{\tilde{B}}}}^2\right){\varsigma_{h_{\tilde{A}}}}^2 \\ +\left(1-{\varsigma_{v_{\tilde{A}}}}^2\right){\varsigma_{h_{\tilde{B}}}}^2 \\ -{\varsigma_{h_{\tilde{A}}}}^2{\varsigma_{h_{\tilde{B}}}}^2 \end{pmatrix}^{\frac{1}{2}} e^{j2\pi.\left(\begin{array}{c}\left(1-\left(\frac{\gamma_{\tilde{B}}}{2\pi}\right)^2\right)\left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^2+ \\ \left(1-\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^2\right)\left(\frac{\beta_{\tilde{B}}}{2\pi}\right)^2-\left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^2\left(\frac{\beta_{\tilde{B}}}{2\pi}\right)^2\end{array}\right)^{\frac{1}{2}}} \end{array} \right\} \quad (19)$$

B. The extension of M-SWARA

SWARA method is a multi-purpose decision making method. SWARA is used to select the most suitable one among a set of options or alternatives. SWARA performs a weight evaluation ratio analysis that determines the weight of each alternative for each criterion [38]. The SWARA method can also be considered in determining the importance of each criterion. On the other hand, one of the most criticized aspects of the SWARA technique is that it does not consider the causal relationship between the factors [39]. In this framework, in this study, some improvements were made on the classical SWARA method, and a new technique called M-SWARA is created. Thanks to this technique, it will be possible to calculate the importance weights of the criteria and to determine the causality relationship between the criteria [40]. Firstly, evaluations are obtained from the expert team. Secondly, relation matrix is created with Equation (20) [41].

$$\varsigma_k = \begin{bmatrix} 0 & \varsigma_{12} & \cdots & \cdots & \varsigma_{1n} \\ \varsigma_{21} & 0 & \cdots & \cdots & \varsigma_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \varsigma_{n1} & \varsigma_{n2} & \cdots & \cdots & 0 \end{bmatrix} \quad (20)$$

Equation (21) is used to generate aggregated value.

$$\varsigma = \left\{ \begin{array}{c} \left[1-\prod_{i=1}^{k}\left(1-{\varsigma_{\mu_i}}^2\right)^{\frac{1}{k}}\right]^{\frac{1}{2}} e^{2\pi.\left[1-\prod_{i=1}^{k}\left(1-\left(\frac{\alpha_i}{2\pi}\right)^2\right)^{\frac{1}{k}}\right]^{\frac{1}{2}}}, \\ \prod_{i=1}^{k}{\varsigma_{v_i}}^{\frac{1}{k}} e^{2\pi.\prod_{i=1}^{k}\left(\frac{\gamma_i}{2\pi}\right)^{\frac{1}{k}}}, \\ \left[\begin{array}{c}\prod_{i=1}^{k}\left(1-{\varsigma_{\mu_i}}^2\right)^{\frac{1}{k}} \\ -\prod_{i=1}^{k}\left(1-{\varsigma_{\mu_i}}^2-{\varsigma_{h_i}}^2\right)^{\frac{1}{k}}\end{array}\right]^{\frac{1}{2}} e^{2\pi.\left[\begin{array}{c}\prod_{i=1}^{k}\left(1-\left(\frac{\alpha_i}{2\pi}\right)^2\right)^{\frac{1}{k}} \\ -\prod_{i=1}^{k}\left(1-\left(\frac{\alpha_i}{2\pi}\right)^2-\left(\frac{\beta_i}{2\pi}\right)^2\right)^{\frac{1}{k}}\end{array}\right]^{\frac{1}{2}}} \end{array} \right\} \quad (21)$$

After that, defuzzification processes are applied. It is a process used to convert fuzzy output values to a specific value in a fuzzy logic system. In this process, Equation (22) is taken into consideration.

$$Def\varsigma_i = \varsigma_{\mu_i} + \left(\frac{\varsigma_{\mu_i}}{\varsigma_{\mu_i}+\varsigma_{h_i}+\varsigma_{v_i}}\right) + \left(\frac{\alpha_i}{2\pi}\right) + \left(\frac{\left(\frac{\alpha_i}{2\pi}\right)}{\left(\frac{\alpha_i}{2\pi}\right)+\left(\frac{\gamma_i}{2\pi}\right)+\left(\frac{\beta_i}{2\pi}\right)}\right) \quad (22)$$

In the fourth stage, s_j (comparative significance), k_j (coefficient), q_j (recalculated weight), and w_j (weight) values are computed by Equations (23)-(25).

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases} \quad (23)$$

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$$q_j = \begin{cases} 1 & j = 1 \\ \frac{q_{j-1}}{k_j} & j > 1 \end{cases} \quad (24)$$

$$If\ s_{j-1} = s_j,\ q_{j-1} = q_j; If\ s_j = 0,\ k_{j-1} = k_j$$

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \quad (25)$$

To generate M-SWARA, the following improvements are made to the classical SWARA. Relation matrix is created by using w_j values. In this process, the matrix is limited and transposed by the power of "2t+1". Finally, a threshold value is computed by taking the average value of the matrix. With the help of this situation, the causal directions can be identified. In this process, when the values are higher than the threshold, it means that the factor on the row has an influence on the item on the column.

C. Neuro decision-making with facial action coding system

Collecting expert opinions is very important in decision making analysis. In this process, facial expressions can increase the accuracy and reliability of expert opinions. In other words, these statements can be an extra source of information in the evaluation of expert opinions. Neuro decision-making methodology considers the nonverbal expression of emotion, such as happiness and surprise. Facial Action Coding System focuses on the facial expressions by considering 46 different action units (AUs) [42]. Within this framework, these units are used for coding facial expressions. Owing to this condition, it is aimed to reach more appropriate findings [43].

IV. ANALYSIS RESULTS

In this study, a novel model is constructed by using M-SWARA methodology to weight the influencing factors of the bank mergers. The flowchart of the analysis process is indicated in Figure 1.

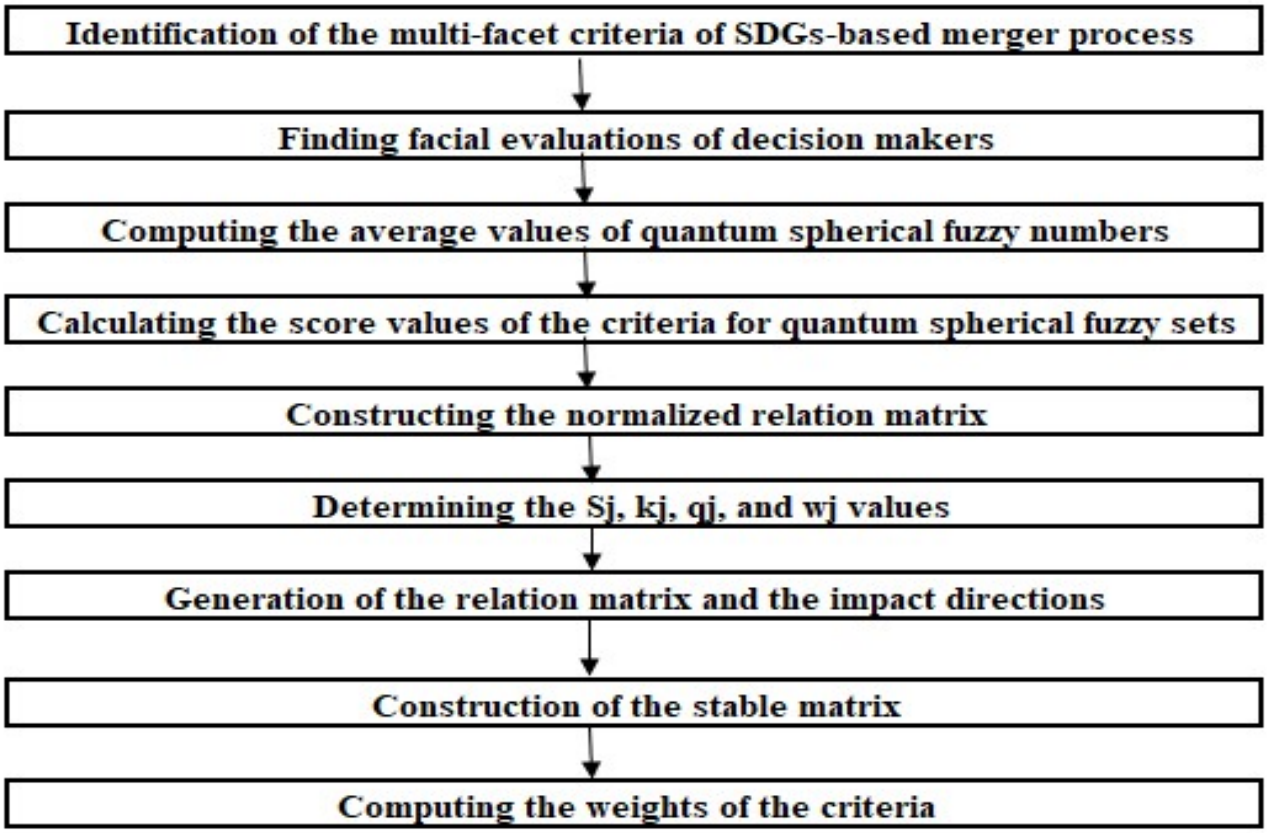


FIGURE 1. Flowchart

In this study, it is aimed to find significant indicators of merger process. In the analysis process, firstly, similar studies in literature are evaluated. As a result, 12 different SDGs-based criteria are selected. The details of these items are indicated in Table A1. The Barwa Bank & International Bank of Qatar (IBQ) merger is examined in this study using the balanced scorecard method. A balanced scorecard typically has four categories: financial, customer satisfaction, internal business, and learning and growth.

These carefully selected criteria are analyzed under a quantum spherical fuzzy set technique with balanced scorecard analysis. Secondly, the evaluations are collected from the expert team that consists of 5 different decision-makers. The details of these scales, AUs and fuzzy numbers are explained in Table A2. In Table A3, facial evaluations of the decision-makers are demonstrated. Thirdly, the average values of the fuzzy numbers are computed. These values are shown in Table A4. In the fourth step, score functions of the

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criteria are computed as in Table A5. The fifth step includes the normalization of the values. With the help of this process, it can be more possible to make more effective evaluation with the data. Normalized matrix is constructed in Table A6. After that, the sj, kj, qj, and wj values are calculated in the following step. For this purpose, Equations (23)-(25) are taken into consideration. Table A7 gives information about these values. The seventh step is related to the construction of the relation matrix. With the help of this matrix, impact directions among the items can be identified. Table A8 explains the details of this matrix. On the other side, Table 1 gives information about the causal directions among the criteria.

TABLE 1. Impact Relation Directions

Criteria	Impact directions
C1	C1→C2,C6,C7,C8,C10
C2	C2→C1,C4,C5,C7,C8,C12
C3	C3→C1,C2,C8,C9,C11,C12
C4	C4→C1,C2,C5,C6,C11,C12
C5	C5→C1,C2,C4,C6,C11,C12
C6	C6→C1,C2,C3,C4,C5,
C7	C7→C1,C2,C3,C4,C5,C11
C8	C8→C2,C5,C6,C10,C11,C12
C9	C9→C4,C6,C7,C12
C10	C10→C1,C2,C3,C4,C5,C6,
C11	C11→C1,C2,C3,C5,C8,C12,
C12	C12→C1,C2,C3,C11

Table 1 demonstrates that increasing Profitability (C1) and market share (C2) are the most influenced criteria. On the other side, increase in agility & human capital (C9) is effective on fewer criteria than others. Finally, the stable matrix is created. In this matrix, the weights of the criteria can be understood. The details of this matrix are shown in Table A9. Finally, Table 2 shows the weight ranking of the KPIs as the analysis results.

TABLE 2. Weighting Results

KPIs	Weight	Ranking
Increasing Profitability	0.095	1
Market Share	0.092	2
Improvement in Service Quality	0.086	3
Customer Loyalty	0.085	4
Sustainable Finance Products	0.085	5
Satisfying the customer needs with Islamic banking services	0.084	6
Technological & Organizational Infrastructure	0.084	7
Future Readiness & Adaptability	0.084	8
Managerial & Organizational Quality	0.081	9
Financial Resilience	0.08	10
Information Enhancement of the Customers and Doing Business	0.075	11
Increase in Agility & Human Capital	0.069	12

It is seen that increasing profitability (C1) has the greatest weight (0.095). Similarly, market share (C2) is the second most critical factor (0.092) for merger decisions in the banking industry.

V. DISCUSSIONS

This part of the paper will discuss the scorecard KPIs with the highest value of weight based on the analysis results. The highest weight belongs to profitability, meaning that it is the most important criteria of the case bank merger from an SDGs perspective. Profitability is often considered a critical criterion in evaluating bank mergers from an SDG perspective, as it directly influences a bank's ability to contribute to sustainable development. There are several reasons why profitability is deemed significant in this context.

Moreover, profitability can facilitate innovation and technological advancement. Zhu et al. [44] also demonstrated that with sufficient resources, a bank can invest in research and development, technological infrastructure, and innovative products and services that promote sustainable development. For example, digital banking solutions can improve financial inclusion, promote responsible lending, and facilitate efficient payments and remittances, which can contribute to SDGs related to financial inclusion, responsible consumption, and sustainable economic growth.

Profitability can also create social impact. A profitable bank can allocate a portion of its profits to support initiatives aligned with SDGs, such as education, health, and poverty alleviation. Tampakoudis et al. [45] and Grodecka-Messi et al. [46] also identified that by investing in socially responsible projects and supporting community development initiatives, banks can contribute to social welfare and inclusive development, thereby fulfilling their role as responsible corporate citizens. Lastly, profitability is significant from a shareholder's perspective. Shareholders, including institutional investors, may have expectations for a return on their investment. According to Gustafson et al. [47] and Krastev et al. [48], a profitable bank is better positioned to deliver sustainable returns over the long term, which can attract more investment in the bank and provide additional resources to support SDG-related initiatives. The second weight belongs to the market share. Market share is a critical criterion in evaluating bank mergers from an SDG perspective due to its potential impact on the ability of the merged entity to contribute to sustainable development. From an academic standpoint, there are several reasons why market share is considered significant in this context.

Market share reflects the scale and reach of the merged entity in the financial market. A bank with a larger market share

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has a broader customer base, higher transaction volume, and wider geographic coverage, which can translate into increased access to financial services for a larger population. This can contribute to SDGs related to financial inclusion, poverty alleviation, and economic empowerment by enabling more people, especially those in underserved or remote areas, to access banking services and participate in formal financial systems. Belotti [49] determined that market share can also influence the pricing and availability of financial products and services. Banks with a larger market share often have more pricing power and bargaining leverage, which can result in more competitive rates and fees for customers. This can benefit consumers and businesses alike, particularly those in vulnerable or marginalized communities, by making financial services more affordable and accessible. Lower transaction costs and fees can encourage savings, investments, and responsible borrowing, which are aligned with SDGs related to responsible consumption, economic growth, and reduced inequality.

Additionally, it encompasses various dimensions, including accessibility, responsiveness, reliability, empathy, and tangibles, which collectively determine the level of customer satisfaction and experience. Bhowmik and Sarker [50] and Yu et al. [51] discussed that high service quality in a bank merger can lead to improved financial inclusion, increased customer well-being, enhanced financial literacy, and responsible financial behavior among customers. Moreover, it can foster a positive corporate culture within the merged entity, promoting responsible business practices and ethical conduct. Also, by ensuring reliable and empathetic customer service, the merged entity can enhance financial literacy, promote responsible financial behavior, and foster a positive corporate culture, thus contributing to industry innovation and infrastructure development. Service quality is a crucial criterion for evaluating bank mergers from an SDG perspective. It encompasses various dimensions that directly impact customer satisfaction, financial inclusion, customer well-being, and corporate culture (Nguyen, 2019). By aligning with multiple SDGs, service quality in a bank merger can contribute to achieving sustainable development outcomes and fostering responsible business practices. However, it should be assessed in conjunction with other relevant factors, and appropriate methodologies, such as the Balanced Scorecard, can provide a comprehensive analysis of the merger's alignment with the SDGs.

Moudud-Ul-Huq [52] identified that the merged bank could develop strategies to expand its market share by targeting specific customer segments, regions, or product lines. This may involve conducting market research to identify untapped opportunities, developing targeted marketing campaigns to attract and retain customers, and enhancing customer acquisition and retention efforts through tailored product offerings, personalized customer service, and competitive pricing. Regular market monitoring and competitive analysis can guide the bank in making informed decisions to capture a larger market share. Moreover, it should prioritize service quality by enhancing customer experience through improved customer service, faster response times to customer inquiries or complaints, and efficient complaint resolution processes. This may involve investing in customer service training for bank staff, implementing customer feedback mechanisms, and leveraging technology to enhance digital banking experiences. Regular customer feedback analysis, benchmarking against industry standards, and continuous improvement initiatives can help ensure that service quality remains a top priority for the merged bank.

VI. CONCLUSIONS

This study contributes to the literature on bank mergers and acquisitions by examining their implications for the SDGs. It provides insights on how profitability, market share, and service quality can impact sustainability and responsible banking practices of a merged bank, aligning them with the SDGs. These findings enrich the literature on sustainable finance, responsible banking, and bank mergers, benefiting scholars and researchers. The study also has policy implications for regulators, policymakers, and stakeholders in the banking industry. Policymakers and regulators can use the insights to develop regulations and guidelines that encourage responsible banking practices and align bank mergers with the SDGs, promoting sustainable lending, responsible customer service, and market competition in line with SDG objectives.

Bank managers and executives involved in or considering bank mergers can also benefit from the findings. By implementing these policy recommendations, bank managers and boards can contribute to the achievement of the SDGs, promote sustainable banking practices, and ensure that bank mergers are conducted in a manner that aligns with sustainability principles. This can result in long-term value creation for the bank, its stakeholders, and society at large, and contribute to a more sustainable and inclusive financial system that supports the realization of the SDGs.

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Appendix

TABLE A1. Multi-facet criteria of SDGs-based M&A process in Qatar banking industry

Balanced Scorecard Perspective	KPIs	Details	Related SDGs	Relevant SDG Indicator
Financial Statement Based Perspective	Increasing Profitability	Profit and its consistency, Earning quality, profitability ratios	8 - Decent work & Economic Growth	8.2 Increase economic productivity by diversifying, innovating, and focusing on industries with a high level of added value and labor-intensive processes.
	Market Share	Market Share, Rivals, Competitiveness	8 - Decent work & Economic Growth	8.2 Increase economic productivity by diversifying, innovating, and focusing on industries with a high level of added value and labor-intensive processes.
	Financial Resilience	Risk Management, Capital Adequacy, Strong Financial Discipline, Clear Strategy, Productivity.	9 - Industry, Innovation & Infrastructure	9.1 Build top-notch, dependable, long-lasting, robust infrastructure, including regional and transnational infrastructure, to promote economic growth and people's well-being, with an emphasis on fair and affordable access for everyone
Consumer Based Perspective	Improvement in Service Quality	Demand Customization, Meeting customer expectations, Smooth operations, Quality software & User face.	9 - Industry, Innovation & Infrastructure	9.1 Create infrastructure that is high-quality, dependable, sustainable, and resilient, including regional and transnational infrastructure, with an emphasis on ensuring that everyone may access it at an affordable price.
	Satisfying the customer needs with Islamic banking services	Having Shariah-compliant products, Giving Trust to customers who have sensitivity to Islamic values.	10 - Reduced Inequalities	10.5 Strengthen the enforcement of existing regulations and increase their oversight of international financial markets and institutions.
	Customer Loyalty	Satisfaction, Loyalty, reducing complaints, higher positive feedback	8 - Decent work & Economic Growth	8.1 Maintain per capita economic growth in conformity with local conditions, with the least developed countries experiencing annual GDP growth of at least 7%.
Operations Based Perspective	Managerial & Organizational Quality	Institutionalization, Employee Competencies, Managerial Structure of the Merged Bank, Employee Age,	8 - Decent work & Economic Growth	8.2 Increase economic productivity through innovation, technical advancement, and diversity, with a concentration on high-value-added and labor-intensive industries.
	Technological & Organizational Infrastructure	Market Data, Infrastructure, Technological competency, Databases, etc.	9 - Industry, Innovation & Infrastructure	9.5 By 2030, promote innovation, significantly increase the number of research and development workers per million people, and increase public and private research and development spending. This includes improving scientific research and industrial sector technological capabilities in all countries, especially developing ones.
	Increase in Agility & Human Capital	Employee Age, Experience & Other Dynamics, Islamic finance knowledge of the employee,	4- Quality Education	4.4 Significantly increase by 2030 the proportion of teenagers and adults with technical and vocational skills necessary for employment, good jobs, and entrepreneurship.
Competition Based Perspective	Information Enhancement of the Customers and Doing Business	Learning from Each Other, Skill Enhancement in an Islamic-Conventional Bank Merger, Skill transition, Market-based information, Innovativeness	9 - Industry, Innovation & Infrastructure	9.5 By 2030, promote innovation, significantly increase the number of research and development workers per million people, and increase public and private research and development spending. This includes improving scientific research and industrial sector technological capabilities in all countries, especially developing ones.
	Future Readiness & Adaptability	Competitive power, Being Ready for Future Market Place, Adaption Speed and Flexibility	9 - Industry, Innovation & Infrastructure	9.a Encourage the development of robust infrastructure in developing nations by providing increased financial, technological, and technical assistance to African nations, least developed nations, landlocked developing nations, and small island developing States.
	Sustainable Finance Products	ESG approach, Integrated reporting, Sustainable Programs.	17 - Partnership for the Goal	17.14 Strengthen the coherence of policies for sustainable development

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TABLE A2. Linguistic scales, facial action units, and golden cut-based quantum spherical fuzzy numbers

Emotions	Selected AUs	Pair combinations of AUs	Scales for Criteria	Scales for Alternatives	Possibility Degrees	QASH
Contempt (Disdain)	7, 10, 14, 15	(7, 10), (7, 14), (7, 15), (10, 14), (10, 15), (14, 15)	No (n)	Weakest (w)	0.40	$\begin{bmatrix}\sqrt{0.16}e^{j2\pi.0.4},\\ \sqrt{0.10}e^{j2\pi.0.25},\\ \sqrt{0.74}e^{j2\pi.0.35}\end{bmatrix}$
Intermediate Emotion	1 AU of Contempt +1 AU of Surprise	(7, 1), (7, 2), (7, 5), (7, 27), (10, 1), (10, 2), (10, 5), (10, 27), (14, 1), (14, 2), (14, 5), (14, 27), (15, 1), (15, 2), (15, 5), (15, 27)	some (s)	Poor (p)	0.45	$\begin{bmatrix}\sqrt{0.20}e^{j2\pi.0.45},\\ \sqrt{0.13}e^{j2\pi.0.28},\\ \sqrt{0.67}e^{j2\pi.0.27}\end{bmatrix}$
Surprise	1, 2, 5, 27 1 AU of Contempt +1 AU of Happy	(1, 2), (1, 5), (1, 27), (2, 5), (2, 27), (5, 27) (7, 6), (7, 12), (7, 25), (7, 26), (10, 6), (10, 12), (10, 25), (10, 26), (14, 6), (14, 12), (14, 25), (14, 26), (15, 6), (15, 12), (15, 25), (15, 26)	medium (m)	Fair (f)	0.50	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.60}e^{j2\pi.0.19}\end{bmatrix}$
Intermediate Emotion	1 AU of Surprise +1 AU of Happy	(1, 6), (1, 12), (1, 25), (1, 26), (2, 6), (2, 12), (2, 25), (2, 26), (5, 6), (5, 12), (5, 25), (5, 26), (27, 6), (27, 12), (27, 25), (27, 26)	high (h)	Good (g)	0.55	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.11}\end{bmatrix}$
Happiness	6, 12, 25, 26	(6, 12), (6, 25), (6, 26), (12, 25), (12, 26), (25, 26)	very high (vh)	Best (b)	0.60	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.42}e^{j2\pi.0.03}\end{bmatrix}$

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TABLE A3. Facial evaluations of decision makers

DM 1												
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
C1		(1, 6)	(2, 27)	(2, 25)	(2, 27)	(1, 6)	(6, 12)	(5, 6)	(1, 6)	(5, 27)	(2, 27)	(2, 27)
C2	(2, 27)		(5, 27)	(7, 5)	(7, 5)	(10, 27)	(5, 27)	(10, 27)	(5, 27)	(7, 5)	(10, 27)	(2, 27)
C3	(1, 6)	(1, 6)		(2, 27)	(5, 6)	(6, 12)	(2, 27)	(2, 25)	(2, 25)	(10, 27)	(6, 26)	(5, 6)
C4	(6, 12)	(6, 26)	(5, 12)		(6, 26)	(6, 12)	(2, 25)	(2, 25)	(6, 12)	(5, 6)	(6, 26)	(6, 26)
C5	(5, 6)	(5, 6)	(2, 27)	(2, 25)		(2, 25)	(5, 27)	(7, 12)	(7, 5)	(2, 25)	(2, 25)	(5, 6)
C6	(25, 26)	(5, 6)	(2, 25)	(2, 25)	(5, 6)		(10, 27)	(2, 27)	(10, 27)	(7, 12)	(2, 27)	(5, 27)
C7	(6, 12)	(6, 12)	(6, 12)	(6, 12)	(6, 12)	(5, 6)		(2, 27)	(2, 27)	(2, 27)	(6, 25)	(1, 6)
C8	(2, 27)	(2, 25)	(5, 27)	(2, 27)	(6, 26)	(6, 26)	(6, 25)		(6, 26)	(6, 26)	(6, 25)	(1, 6)
C9	(10, 27)	(7, 5)	(5, 27)	(2, 27)	(2, 27)	(5, 27)	(7, 12)	(5, 6)		(5, 27)	(5, 27)	(5, 6)
C10	(5, 6)	(2, 25)	(2, 25)	(2, 25)	(2, 25)	(2, 25)	(5, 12)	(6, 26)	(1, 6)		(7, 12)	(2, 27)
C11	(6, 12)	(6, 12)	(5, 6)	(1, 6)	(1, 6)	(5, 27)	(1, 6)	(1, 6)	(7, 12)	(10, 27)		(5, 12)
C12	(6, 26)	(5, 6)	(6, 25)	(5, 6)	(2, 27)	(2, 27)	(1, 6)	(1, 6)	(2, 25)	(6, 12)	(6, 12)	
DM 2												
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
C1		(5, 6)	(5, 6)	(2, 27)	(2, 25)	(2, 25)	(5, 27)	(2, 27)	(5, 27)	(7, 5)	(5, 12)	(2, 27)
C2	(5, 27)		(7, 12)	(10, 27)	(7, 5)	(5, 27)	(7, 5)	(7, 12)	(10, 27)	(10, 27)	(7, 5)	(7, 12)
C3	(5, 12)	(1, 6)		(5, 27)	(14, 2)	(7, 5)	(10, 27)	(5, 27)	(7, 5)	(5, 27)	(2, 27)	(2, 27)
C4	(5, 6)	(1, 6)	(2, 27)		(6, 25)	(6, 12)	(14, 2)	(5, 27)	(7, 5)	(1, 6)	(1, 6)	(1, 6)
C5	(5, 6)	(1, 6)	(7, 12)	(2, 25)		(5, 12)	(5, 27)	(2, 27)	(14, 2)	(5, 6)	(2, 25)	(2, 25)
C6	(6, 26)	(1, 6)	(5, 6)	(2, 25)	(5, 12)		(10, 27)	(5, 27)	(14, 2)	(5, 27)	(2, 27)	(7, 12)
C7	(5, 12)	(2, 25)	(5, 6)	(2, 25)	(2, 25)	(2, 25)		(2, 27)	(7, 12)	(2, 27)	(5, 6)	(2, 25)
C8	(5, 27)	(2, 25)	(5, 27)	(2, 27)	(5, 6)	(5, 6)	(7, 12)		(7, 5)	(5, 27)	(5, 6)	(2, 25)
C9	(10, 27)	(7, 5)	(2, 27)	(5, 27)	(2, 27)	(5, 27)	(5, 6)	(5, 27)		(5, 27)	(5, 27)	(2, 25)
C10	(5, 6)	(2, 25)	(2, 25)	(5, 6)	(2, 25)	(2, 25)	(5, 27)	(2, 27)	(7, 12)		(2, 27)	(5, 27)
C11	(6, 26)	(6, 12)	(2, 25)	(2, 25)	(2, 25)	(2, 25)	(5, 27)	(2, 25)	(5, 27)	(10, 27)		(2, 25)
C12	(5, 12)	(2, 25)	(2, 25)	(5, 27)	(2, 27)	(5, 27)	(14, 2)	(7, 5)	(7, 5)	(5, 27)	(2, 27)	
DM 3												
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
C1		(2, 25)	(2, 27)	(2, 25)	(7, 12)	(5, 6)	(6, 25)	(2, 25)	(2, 25)	(5, 27)	(2, 27)	(2, 27)
C2	(5, 12)		(5, 6)	(14, 2)	(7, 5)	(10, 14)	(7, 12)	(2, 27)	(5, 12)	(7, 5)	(7, 5)	(5, 27)
C3	(1, 6)	(1, 6)		(5, 27)	(5, 12)	(6, 26)	(2, 27)	(5, 6)	(5, 6)	(14, 2)	(6, 26)	(5, 12)
C4	(6, 26)	(6, 26)	(2, 25)		(6, 26)	(6, 26)	(1, 6)	(1, 6)	(6, 26)	(2, 25)	(6, 12)	(6, 12)
C5	(6, 12)	(6, 26)	(6, 26)	(6, 26)		(6, 26)	(1, 6)	(1, 6)	(5, 6)	(2, 25)	(1, 6)	(1, 6)
C6	(6, 12)	(6, 26)	(6, 12)	(6, 12)	(6, 26)		(2, 27)	(2, 27)	(5, 6)	(5, 27)	(5, 12)	(2, 27)
C7	(6, 12)	(6, 25)	(6, 25)	(6, 25)	(6, 25)	(6, 25)		(6, 12)	(6, 12)	(5, 6)	(6, 26)	(6, 26)
C8	(2, 25)	(2, 25)	(5, 27)	(6, 26)	(6, 26)	(6, 26)	(6, 26)		(6, 26)	(6, 26)	(6, 12)	(6, 26)
C9	(6, 26)	(6, 26)	(6, 26)	(6, 26)	(6, 26)	(6, 26)	(6, 26)	(6, 26)		(6, 26)	(6, 12)	(6, 26)
C10	(6, 26)	(6, 26)	(1, 6)	(1, 6)	(2, 25)	(1, 6)	(1, 6)	(2, 25)	(2, 25)		(2, 27)	(5, 27)
C11	(6, 26)	(5, 6)	(6, 26)	(6, 26)	(6, 26)	(6, 12)	(6, 12)	(6, 12)	(6, 12)	(6, 12)		(6, 26)
C12	(6, 26)	(6, 26)	(5, 6)	(6, 12)	(6, 12)	(6, 26)	(6, 26)	(6, 26)	(6, 26)	(6, 26)	(6, 26)	
DM 4												
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
C1		(6, 26)	(6, 26)	(2, 27)	(7, 12)	(6, 26)	(6, 12)	(6, 12)	(5, 27)	(2, 25)	(7, 2)	(7, 5)
C2	(6, 26)		(5, 27)	(6, 26)	(6, 26)	(6, 26)	(6, 12)	(6, 12)	(2, 27)	(7, 5)	(6, 26)	(2, 25)
C3	(5, 27)	(2, 27)		(7, 5)	(10, 14)	(10, 14)	(6, 26)	(6, 26)	(6, 26)	(14, 27)	(1, 6)	(1, 6)
C4	(6, 26)	(6, 26)	(14, 2)		(6, 26)	(6, 26)	(6, 26)	(6, 26)	(2, 25)	(2, 25)	(6, 12)	(6, 26)
C5	(6, 12)	(6, 12)	(10, 14)	(6, 25)		(2, 25)	(14, 2)	(5, 12)	(10, 14)	(7, 5)	(6, 12)	(6, 26)

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C6	(6, 12)	(6, 12)	(5, 6)	(6, 25)	(6, 26)		(10, 14)	(6, 25)	(10, 14)	(5, 6)	(6, 12)	(6, 26)
C7	(6, 12)	(6, 12)	(6, 26)	(6, 25)	(6, 26)	(6, 26)		(6, 25)	(2, 27)	(6, 26)	(6, 12)	(5, 6)
C8	(6, 25)	(6, 25)	(6, 25)	(6, 25)	(6, 26)	(6, 26)	(2, 25)		(5, 27)	(6, 26)	(6, 12)	(6, 26)
C9	(1, 6)	(1, 6)	(2, 27)	(6, 25)	(5, 27)	(6, 26)	(6, 26)	(2, 27)		(14, 27)	(2, 25)	(6, 26)
C10	(6, 26)	(6, 26)	(5, 6)	(6, 25)	(6, 25)	(6, 26)	(14, 27)	(7, 5)	(10, 14)		(2, 27)	(5, 6)
C11	(6, 26)	(6, 26)	(6, 26)	(6, 25)	(6, 25)	(6, 12)	(6, 12)	(6, 12)	(5, 6)	(6, 26)		(6, 26)
C12	(6, 26)	(6, 26)	(6, 26)	(2, 25)	(6, 25)	(6, 25)	(6, 25)	(6, 25)	(5, 27)	(2, 27)	(6, 26)	

DM 5

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
C1		(6, 26)	(6, 26)	(2, 27)	(1, 6)	(5, 6)	(6, 26)	(6, 26)	(1, 6)	(1, 6)	(2, 27)	(5, 27)
C2	(6, 26)		(2, 27)	(6, 26)	(6, 25)	(2, 25)	(2, 25)	(6, 26)	(2, 27)	(5, 27)	(1, 6)	(1, 6)
C3	(5, 12)	(1, 6)		(2, 27)	(7, 5)	(7, 5)	(6, 26)	(6, 26)	(2, 25)	(7, 5)	(2, 25)	(2, 25)
C4	(6, 26)	(6, 26)	(7, 5)		(5, 6)	(6, 12)	(6, 12)	(6, 12)	(1, 6)	(5, 12)	(6, 12)	(6, 12)
C5	(6, 26)	(2, 25)	(7, 5)	(6, 25)		(5, 12)	(7, 5)	(2, 27)	(10, 14)	(7, 5)	(6, 12)	(6, 12)
C6	(6, 12)	(6, 12)	(1, 6)	(6, 25)	(2, 25)		(7, 5)	(6, 25)	(10, 14)	(5, 12)	(6, 26)	(6, 26)
C7	(6, 12)	(6, 12)	(6, 26)	(6, 26)	(6, 26)	(6, 26)		(6, 25)	(1, 6)	(1, 6)	(6, 26)	(5, 12)
C8	(6, 12)	(6, 12)	(6, 26)	(6, 26)	(6, 26)	(6, 26)	(5, 6)		(2, 27)	(6, 12)	(6, 12)	(6, 12)
C9	(5, 12)	(2, 25)	(2, 27)	(6, 26)	(5, 27)	(5, 6)	(6, 26)	(5, 27)		(7, 5)	(2, 25)	(6, 26)
C10	(6, 26)	(6, 26)	(5, 6)	(2, 25)	(1, 6)	(1, 6)	(7, 5)	(5, 6)	(10, 14)		(2, 27)	(5, 6)
C11	(6, 12)	(6, 12)	(6, 12)	(5, 12)	(6, 26)	(2, 25)	(2, 25)	(6, 26)	(2, 25)	(1, 6)		(6, 26)
C12	(6, 25)	(6, 25)	(5, 12)	(6, 26)	(5, 6)	(6, 25)	(6, 25)	(6, 25)	(2, 27)	(1, 6)	(6, 26)	

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TABLE A4. Average values of quantum spherical fuzzy numbers

	C1	C2	C3	C4	C5	C6
C1		$\begin{bmatrix}\sqrt{0.33}e^{j2\pi.0.57},\\ \sqrt{0.20}e^{j2\pi.0.35},\\ \sqrt{0.49}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.31}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.13}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.27}e^{j2\pi.0.52},\\ \sqrt{0.17}e^{j2\pi.0.32},\\ \sqrt{0.56}e^{j2\pi.0.16}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.27}e^{j2\pi.0.52},\\ \sqrt{0.17}e^{j2\pi.0.32},\\ \sqrt{0.56}e^{j2\pi.0.16}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$
C2	$\begin{bmatrix}\sqrt{0.31}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.13}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.26}e^{j2\pi.0.51},\\ \sqrt{0.16}e^{j2\pi.0.31},\\ \sqrt{0.58}e^{j2\pi.0.18}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.28}e^{j2\pi.0.52},\\ \sqrt{0.16}e^{j2\pi.0.32},\\ \sqrt{0.58}e^{j2\pi.0.19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.28}e^{j2\pi.0.52},\\ \sqrt{0.16}e^{j2\pi.0.32},\\ \sqrt{0.58}e^{j2\pi.0.19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.27}e^{j2\pi.0.52},\\ \sqrt{0.17}e^{j2\pi.0.32},\\ \sqrt{0.56}e^{j2\pi.0.16}\end{bmatrix}$
C3	$\begin{bmatrix}\sqrt{0.29}e^{j2\pi.0.53},\\ \sqrt{0.18}e^{j2\pi.0.33},\\ \sqrt{0.54}e^{j2\pi.0.14}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.29}e^{j2\pi.0.53},\\ \sqrt{0.18}e^{j2\pi.0.33},\\ \sqrt{0.54}e^{j2\pi.0.14}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.24}e^{j2\pi.0.48},\\ \sqrt{0.14}e^{j2\pi.0.30},\\ \sqrt{0.62}e^{j2\pi.0.22}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.24}e^{j2\pi.0.48},\\ \sqrt{0.14}e^{j2\pi.0.30},\\ \sqrt{0.62}e^{j2\pi.0.22}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.27}e^{j2\pi.0.52},\\ \sqrt{0.17}e^{j2\pi.0.32},\\ \sqrt{0.56}e^{j2\pi.0.16}\end{bmatrix}$
C4	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.26}e^{j2\pi.0.51},\\ \sqrt{0.16}e^{j2\pi.0.31},\\ \sqrt{0.58}e^{j2\pi.0.18}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.60},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.42}e^{j2\pi.0.03}\end{bmatrix}$
C5	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.33}e^{j2\pi.0.57},\\ \sqrt{0.20}e^{j2\pi.0.35},\\ \sqrt{0.49}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.60}e^{j2\pi.0.19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$
C6	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.60},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.42}e^{j2\pi.0.03}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.33}e^{j2\pi.0.57},\\ \sqrt{0.20}e^{j2\pi.0.35},\\ \sqrt{0.49}e^{j2\pi.0.11}\end{bmatrix}$	
C7	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$
C8	$\begin{bmatrix}\sqrt{0.31}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.13}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.33}e^{j2\pi.0.57},\\ \sqrt{0.20}e^{j2\pi.0.35},\\ \sqrt{0.49}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$
C9	$\begin{bmatrix}\sqrt{0.28}e^{j2\pi.0.52},\\ \sqrt{0.16}e^{j2\pi.0.32},\\ \sqrt{0.58}e^{j2\pi.0.19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.28}e^{j2\pi.0.52},\\ \sqrt{0.16}e^{j2\pi.0.32},\\ \sqrt{0.58}e^{j2\pi.0.19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.28}e^{j2\pi.0.52},\\ \sqrt{0.16}e^{j2\pi.0.32},\\ \sqrt{0.58}e^{j2\pi.0.19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.28}e^{j2\pi.0.52},\\ \sqrt{0.16}e^{j2\pi.0.32},\\ \sqrt{0.58}e^{j2\pi.0.19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.31}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.13}\end{bmatrix}$
C10	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$
C11	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.60},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.42}e^{j2\pi.0.03}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.33}e^{j2\pi.0.57},\\ \sqrt{0.20}e^{j2\pi.0.35},\\ \sqrt{0.49}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$
C12	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.33}e^{j2\pi.0.57},\\ \sqrt{0.20}e^{j2\pi.0.35},\\ \sqrt{0.49}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.31}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.13}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$
	C7	**C8**	**C9**	**C10**	**C11**	**C12**
C1	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.28}e^{j2\pi.0.52},\\ \sqrt{0.16}e^{j2\pi.0.32},\\ \sqrt{0.58}e^{j2\pi.0.19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.26}e^{j2\pi.0.51},\\ \sqrt{0.16}e^{j2\pi.0.31},\\ \sqrt{0.58}e^{j2\pi.0.18}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.60}e^{j2\pi.0.19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.24}e^{j2\pi.0.48},\\ \sqrt{0.14}e^{j2\pi.0.30},\\ \sqrt{0.62}e^{j2\pi.0.22}\end{bmatrix}$
C2	$\begin{bmatrix}\sqrt{0.28}e^{j2\pi.0.52},\\ \sqrt{0.16}e^{j2\pi.0.32},\\ \sqrt{0.58}e^{j2\pi.0.19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.29}e^{j2\pi.0.53},\\ \sqrt{0.18}e^{j2\pi.0.33},\\ \sqrt{0.54}e^{j2\pi.0.14}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.60}e^{j2\pi.0.19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.21}e^{j2\pi.0.45},\\ \sqrt{0.12}e^{j2\pi.0.28},\\ \sqrt{0.67}e^{j2\pi.0.28}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.26}e^{j2\pi.0.51},\\ \sqrt{0.16}e^{j2\pi.0.31},\\ \sqrt{0.58}e^{j2\pi.0.18}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.27}e^{j2\pi.0.52},\\ \sqrt{0.17}e^{j2\pi.0.32},\\ \sqrt{0.56}e^{j2\pi.0.16}\end{bmatrix}$
C3	$\begin{bmatrix}\sqrt{0.29}e^{j2\pi.0.53},\\ \sqrt{0.18}e^{j2\pi.0.33},\\ \sqrt{0.54}e^{j2\pi.0.14}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.21}e^{j2\pi.0.45},\\ \sqrt{0.12}e^{j2\pi.0.28},\\ \sqrt{0.67}e^{j2\pi.0.28}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.29}e^{j2\pi.0.53},\\ \sqrt{0.18}e^{j2\pi.0.33},\\ \sqrt{0.54}e^{j2\pi.0.14}\end{bmatrix}$
C4	$\begin{bmatrix}\sqrt{0.31}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.13}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.31}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.13}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$
C5	$\begin{bmatrix}\sqrt{0.24}e^{j2\pi.0.48},\\ \sqrt{0.14}e^{j2\pi.0.30},\\ \sqrt{0.62}e^{j2\pi.0.22}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.27}e^{j2\pi.0.52},\\ \sqrt{0.17}e^{j2\pi.0.32},\\ \sqrt{0.56}e^{j2\pi.0.16}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.21}e^{j2\pi.0.45},\\ \sqrt{0.12}e^{j2\pi.0.28},\\ \sqrt{0.67}e^{j2\pi.0.28}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.27}e^{j2\pi.0.52},\\ \sqrt{0.17}e^{j2\pi.0.32},\\ \sqrt{0.56}e^{j2\pi.0.16}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.33}e^{j2\pi.0.57},\\ \sqrt{0.20}e^{j2\pi.0.35},\\ \sqrt{0.49}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.33}e^{j2\pi.0.57},\\ \sqrt{0.20}e^{j2\pi.0.35},\\ \sqrt{0.49}e^{j2\pi.0.11}\end{bmatrix}$

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C6	$\begin{bmatrix}\sqrt{0.21}e^{j2\pi.0.45},\\ \sqrt{0.12}e^{j2\pi.0.28},\\ \sqrt{0.67}e^{j2\pi.0.28}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.21}e^{j2\pi.0.45},\\ \sqrt{0.12}e^{j2\pi.0.28},\\ \sqrt{0.67}e^{j2\pi.0.28}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.27}e^{j2\pi.0.52},\\ \sqrt{0.17}e^{j2\pi.0.32},\\ \sqrt{0.56}e^{j2\pi.0.16}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.31}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.13}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.11}\end{bmatrix}$
C7		$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.29}e^{j2\pi.0.53},\\ \sqrt{0.18}e^{j2\pi.0.33},\\ \sqrt{0.54}e^{j2\pi.0.14}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$
C8	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.29}e^{j2\pi.0.53},\\ \sqrt{0.18}e^{j2\pi.0.33},\\ \sqrt{0.54}e^{j2\pi.0.14}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.35}e^{j2\pi.0.59},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.44}e^{j2\pi.0.05}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$
C9	$\begin{bmatrix}\sqrt{0.33}e^{j2\pi.0.57},\\ \sqrt{0.20}e^{j2\pi.0.35},\\ \sqrt{0.49}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.29}e^{j2\pi.0.53},\\ \sqrt{0.18}e^{j2\pi.0.33},\\ \sqrt{0.54}e^{j2\pi.0.14}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.26}e^{j2\pi.0.51},\\ \sqrt{0.16}e^{j2\pi.0.31},\\ \sqrt{0.58}e^{j2\pi.0.18}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$
C10	$\begin{bmatrix}\sqrt{0.26}e^{j2\pi.0.51},\\ \sqrt{0.16}e^{j2\pi.0.31},\\ \sqrt{0.58}e^{j2\pi.0.18}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.29}e^{j2\pi.0.53},\\ \sqrt{0.18}e^{j2\pi.0.33},\\ \sqrt{0.54}e^{j2\pi.0.14}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.24}e^{j2\pi.0.48},\\ \sqrt{0.14}e^{j2\pi.0.30},\\ \sqrt{0.62}e^{j2\pi.0.22}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.60}e^{j2\pi.0.19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.27}e^{j2\pi.0.52},\\ \sqrt{0.17}e^{j2\pi.0.32},\\ \sqrt{0.56}e^{j2\pi.0.16}\end{bmatrix}$
C11	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.11}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$
C12	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.32}e^{j2\pi.0.56},\\ \sqrt{0.18}e^{j2\pi.0.34},\\ \sqrt{0.52}e^{j2\pi.0.15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.28}e^{j2\pi.0.52},\\ \sqrt{0.16}e^{j2\pi.0.32},\\ \sqrt{0.58}e^{j2\pi.0.19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.31}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.51}e^{j2\pi.0.13}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.34}e^{j2\pi.0.58},\\ \sqrt{0.21}e^{j2\pi.0.36},\\ \sqrt{0.46}e^{j2\pi.0.07}\end{bmatrix}$	

TABLE A5. Score function of the criteria for quantum spherical fuzzy sets

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	0.000	1.790	1.711	1.584	1.584	1.748	1.831	1.750	1.624	2.040	1.506	1.462
C2	1.711	0.000	1.542	1.571	1.571	1.528	1.594	1.638	1.506	1.346	1.524	1.584
C3	1.665	1.665	0.000	1.462	1.443	1.541	1.638	1.750	1.671	1.346	1.750	1.665
C4	1.874	1.874	1.511	0.000	1.874	1.920	1.713	1.750	1.713	1.705	1.874	1.874
C5	1.832	1.790	1.487	1.832	0.000	1.748	1.469	1.584	1.327	1.552	1.790	1.790
C6	1.920	1.832	1.748	1.832	1.790	0.000	1.312	1.673	1.327	1.584	1.711	1.673
C7	1.874	1.874	1.874	1.874	1.874	1.832	0.000	1.752	1.629	1.669	1.874	1.748
C8	1.711	1.790	1.673	1.752	1.874	1.874	1.750	0.000	1.638	1.831	1.874	1.832
C9	1.598	1.598	1.590	1.752	1.590	1.711	1.791	1.629	0.000	1.519	1.669	1.832
C10	1.832	1.832	1.705	1.748	1.748	1.748	1.511	1.633	1.448	0.000	1.500	1.584
C11	1.920	1.874	1.832	1.790	1.832	1.750	1.750	1.832	1.669	1.642	0.000	1.832
C12	1.874	1.832	1.790	1.750	1.711	1.752	1.754	1.754	1.594	1.711	1.831	0.000

TABLE A6. Normalized relation matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	0.000	0.096	0.092	0.085	0.085	0.094	0.098	0.094	0.087	0.109	0.081	0.078
C2	0.100	0.000	0.090	0.092	0.092	0.089	0.093	0.096	0.088	0.079	0.089	0.093
C3	0.095	0.095	0.000	0.083	0.082	0.088	0.093	0.099	0.095	0.076	0.099	0.095
C4	0.095	0.095	0.077	0.000	0.095	0.098	0.087	0.089	0.087	0.087	0.095	0.095
C5	0.101	0.098	0.082	0.101	0.000	0.096	0.081	0.087	0.073	0.085	0.098	0.098
C6	0.104	0.100	0.095	0.100	0.097	0.000	0.071	0.091	0.072	0.086	0.093	0.091
C7	0.094	0.094	0.094	0.094	0.094	0.092	0.000	0.088	0.082	0.084	0.094	0.088
C8	0.087	0.091	0.085	0.089	0.096	0.096	0.089	0.000	0.084	0.093	0.096	0.093
C9	0.087	0.087	0.087	0.096	0.087	0.094	0.098	0.089	0.000	0.083	0.091	0.100
C10	0.100	0.100	0.093	0.096	0.096	0.096	0.083	0.089	0.079	0.000	0.082	0.087
C11	0.097	0.095	0.093	0.091	0.093	0.089	0.089	0.093	0.085	0.083	0.000	0.093
C12	0.097	0.095	0.092	0.090	0.088	0.091	0.091	0.091	0.082	0.088	0.095	0.000

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TABLE A7. Sj, kj, qj, and wj values for the relationship degrees of each criterion

C1	Sj	kj	qj	wj	C2	Sj	Kj	qj	Wj	C3	Sj	kj	qj	wj
C10	0.109	1.000	1.000	0.128	C1	0.100	1.000	1.000	0.121	C8	0.099	1.000	1.000	0.108
C7	0.098	1.098	0.911	0.116	C8	0.096	1.096	0.913	0.111	C11	0.099	1.000	1.000	0.108
C2	0.096	1.096	0.831	0.106	C7	0.093	1.093	0.835	0.101	C2	0.095	1.095	0.914	0.099
C6	0.094	1.094	0.759	0.097	C12	0.093	1.093	0.835	0.101	C1	0.095	1.095	0.914	0.099
C8	0.094	1.094	0.759	0.097	C5	0.092	1.092	0.765	0.093	C12	0.095	1.095	0.914	0.099
C3	0.092	1.092	0.696	0.089	C4	0.092	1.092	0.765	0.093	C9	0.095	1.095	0.914	0.099
C9	0.087	1.087	0.640	0.082	C3	0.090	1.090	0.701	0.085	C7	0.093	1.093	0.836	0.091
C4	0.085	1.085	0.590	0.075	C11	0.089	1.089	0.644	0.078	C6	0.088	1.088	0.768	0.083
C5	0.085	1.085	0.590	0.075	C6	0.089	1.089	0.644	0.078	C4	0.083	1.083	0.709	0.077
C11	0.081	1.081	0.546	0.070	C9	0.088	1.088	0.592	0.072	C5	0.082	1.082	0.656	0.071
C12	0.078	1.078	0.506	0.065	C10	0.079	1.079	0.549	0.067	C10	0.076	1.076	0.609	0.066
C4	**Sj**	**kj**	**qj**	**wj**	**C5**	**Sj**	**Kj**	**qj**	**Wj**	**C6**	**Sj**	**kj**	**qj**	**wj**
C6	0.098	1.000	1.000	0.106	C1	0.101	1.000	1.000	0.113	C1	0.104	1.000	1.000	0.125
C2	0.095	1.095	0.913	0.097	C4	0.101	1.000	1.000	0.113	C2	0.100	1.100	0.909	0.114
C5	0.095	1.095	0.913	0.097	C2	0.098	1.098	0.910	0.103	C4	0.100	1.100	0.909	0.114
C1	0.095	1.095	0.913	0.097	C11	0.098	1.098	0.910	0.103	C5	0.097	1.097	0.829	0.104
C11	0.095	1.095	0.913	0.097	C12	0.098	1.098	0.910	0.103	C3	0.095	1.095	0.757	0.095
C12	0.095	1.095	0.913	0.097	C6	0.096	1.096	0.831	0.094	C11	0.093	1.093	0.693	0.087
C8	0.089	1.089	0.839	0.089	C8	0.087	1.087	0.764	0.086	C8	0.091	1.091	0.635	0.079
C7	0.087	1.087	0.771	0.082	C10	0.085	1.085	0.704	0.080	C12	0.091	1.091	0.635	0.079
C9	0.087	1.087	0.771	0.082	C3	0.082	1.082	0.651	0.074	C10	0.086	1.086	0.585	0.073
C10	0.087	1.087	0.771	0.082	C7	0.081	1.081	0.602	0.068	C9	0.072	1.072	0.545	0.068
C3	0.077	1.077	0.716	0.076	C9	0.073	1.073	0.561	0.063	C7	0.071	1.071	0.509	0.064
C7	**Sj**	**kj**	**qj**	**wj**	**C8**	**Sj**	**Kj**	**qj**	**Wj**	**C9**	**Sj**	**kj**	**qj**	**wj**
C5	0.094	1.000	1.000	0.107	C5	0.096	1.000	1.000	0.109	C12	0.100	1.000	1.000	0.129
C1	0.094	1.094	0.914	0.098	C6	0.096	1.096	1.000	0.109	C7	0.098	1.098	0.911	0.118
C3	0.094	1.094	0.914	0.098	C11	0.096	1.096	1.000	0.109	C4	0.096	1.096	0.831	0.107
C4	0.094	1.094	0.914	0.098	C10	0.093	1.093	0.915	0.100	C6	0.094	1.094	0.760	0.098
C2	0.094	1.094	0.914	0.098	C12	0.093	1.093	0.915	0.100	C11	0.091	1.091	0.696	0.090
C11	0.094	1.094	0.914	0.098	C2	0.091	1.091	0.838	0.091	C8	0.089	1.089	0.639	0.083
C6	0.092	1.092	0.837	0.090	C4	0.089	1.089	0.769	0.084	C1	0.087	1.087	0.588	0.076
C8	0.088	1.088	0.769	0.083	C7	0.089	1.089	0.769	0.084	C2	0.087	1.087	0.588	0.076
C12	0.088	1.088	0.769	0.083	C1	0.087	1.087	0.707	0.077	C3	0.087	1.087	0.588	0.076
C10	0.084	1.084	0.709	0.076	C3	0.085	1.085	0.652	0.071	C5	0.087	1.087	0.588	0.076
C9	0.082	1.082	0.656	0.070	C9	0.084	1.084	0.602	0.066	C10	0.083	1.083	0.543	0.070
C10	**Sj**	**kj**	**qj**	**wj**	**C11**	**Sj**	**Kj**	**qj**	**Wj**	**C12**	**Sj**	**kj**	**qj**	**wj**
C1	0.100	1.000	1.000	0.113	C1	0.097	1.000	1.000	0.115	C1	0.097	1.000	1.000	0.117
C2	0.100	1.100	1.000	0.113	C2	0.095	1.095	0.913	0.105	C2	0.095	1.095	0.914	0.107
C4	0.096	1.096	0.913	0.103	C3	0.093	1.093	0.836	0.096	C11	0.095	1.095	0.914	0.107
C5	0.096	1.096	0.913	0.103	C8	0.093	1.093	0.836	0.096	C3	0.092	1.092	0.836	0.098
C6	0.096	1.096	0.913	0.103	C12	0.093	1.093	0.836	0.096	C6	0.091	1.091	0.767	0.090
C3	0.093	1.093	0.835	0.094	C5	0.093	1.093	0.836	0.096	C7	0.091	1.091	0.767	0.090
C8	0.089	1.089	0.766	0.087	C4	0.091	1.091	0.766	0.088	C8	0.091	1.091	0.767	0.090
C12	0.087	1.087	0.705	0.080	C6	0.089	1.089	0.704	0.081	C4	0.090	1.090	0.703	0.082
C7	0.083	1.083	0.652	0.074	C7	0.089	1.089	0.704	0.081	C5	0.088	1.088	0.646	0.076
C11	0.082	1.082	0.602	0.068	C9	0.085	1.085	0.649	0.075	C10	0.088	1.088	0.646	0.076
C9	0.079	1.079	0.558	0.063	C10	0.083	1.083	0.599	0.069	C9	0.082	1.082	0.597	0.070

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TABLE A8. Relation Matrix with the values of wj and the impact directions

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1		0.106	0.089	0.075	0.075	0.097	0.116	0.097	0.082	0.128	0.070	0.065
C2	0.121		0.085	0.093	0.093	0.078	0.101	0.111	0.072	0.067	0.078	0.101
C3	0.099	0.099		0.077	0.071	0.083	0.091	0.108	0.099	0.066	0.108	0.099
C4	0.097	0.097	0.076		0.097	0.106	0.082	0.089	0.082	0.082	0.097	0.097
C5	0.113	0.103	0.074	0.113		0.094	0.068	0.086	0.063	0.080	0.103	0.103
C6	0.125	0.114	0.095	0.114	0.104		0.064	0.079	0.068	0.073	0.087	0.079
C7	0.098	0.098	0.098	0.098	0.107	0.090		0.083	0.070	0.076	0.098	0.083
C8	0.077	0.091	0.071	0.084	0.109	0.109	0.084		0.066	0.100	0.109	0.100
C9	0.076	0.076	0.076	0.107	0.076	0.098	0.118	0.083		0.070	0.090	0.129
C10	0.113	0.113	0.094	0.103	0.103	0.103	0.074	0.087	0.063		0.068	0.080
C11	0.115	0.105	0.096	0.088	0.096	0.081	0.081	0.096	0.075	0.069		0.096
C12	0.117	0.107	0.098	0.082	0.076	0.090	0.090	0.090	0.070	0.076	0.107	

TABLE A9. Stable Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095
C2	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092
C3	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
C4	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086
C5	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084
C6	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085
C7	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
C8	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084
C9	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069
C10	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
C11	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084
C12	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085

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