Evaluation of Multidimensional Carbon Neutrality Policies in Transportation Using a Novel Quantum Picture Fuzzy Rough Modeling

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***Abstract*—The purpose of this study is to evaluate carbon neutrality policies in transportation industry with a novel decision-making model. First, selected indicators are evaluated by quantum picture fuzzy row sets-based multi-step wise weight assessment ratio analysis (M-SWARA) technique. Secondly, the alternatives for the carbon neutrality policies in this industry are ranked. For this purpose, multi-objective optimization on the basis of ratio analysis (MOORA) methodology is considered with quantum picture fuzzy row sets. The main motivation of making this study is the need for a novel and comprehensive decision-making model. The main reason behind this situation is that most of the existing models could not consider the causal directions among the indicators. Due to this situation, this proposed model is created by using causality relationships between the indicators of carbon neutrality policies in transportation industry. The main contribution of this study is that a new model is proposed by integrating quantum theory and picture fuzzy rough sets. This situation has a positive contribution to make sensitive evaluations. Additionally, a novel approach (M-SWARA) is proposed to weight the criteria so that causality relationship among the determinants can be considered in this process. The findings demonstrate that infrastructure development is the most important factor of effective carbon neutrality policies for transportation industry. Cost is another critical indicator in this respect. On the other hand, according to the ranking results, it is determined that reducing traditional fuels with zero-carbon alternatives is the most essential alternative for the carbon neutrality policies in transportation.**

***Index Terms*—Carbon neutrality, clean energy, multi-stepwise weight assessment ratio analysis (M-SWARA), picture fuzzy sets, rough sets, transportation sector.**

I. INTRODUCTION

CARBON neutrality policies are practices that aim to reduce the amount of carbon emissions of a country or a business. The problem of climate change has become quite dangerous, especially in recent years. This can lead to an increase in natural disasters and food shortages [1]. Therefore, these policies are of great importance both in minimizing these problems and in ensuring the sustainability of economic development. Moreover, to implement these policies, the use of renewable energy must be increased. This contributes significantly to the development of clean energy technologies. Carbon neutrality policies are vital for positively improving the image of both businesses and countries internationally. The ability of these institutions to make environmentally friendly policies enables cooperation with other countries and companies [2]. This, in turn, contributes significantly to economic development.

Carbon neutrality policies are of great importance for the transportation sector. One of the most important reasons for the carbon emission problem is the energy need in the transportation sector to be supplied from fossil fuels. As a result of the effective and correct implementation of carbon neutrality policies, it is possible to minimize the greenhouse gas emission problem caused by the transportation sector [3]. There are some actions that can be applied in this context. For example, the use of electric vehicles in the transportation sector contributes significantly to reducing air pollution. In addition to these, hydrogen energy can also be taken into consideration in meeting the energy need. This also helps to minimize carbon emissions. Furthermore, ensuring energy efficiency in the applications made allows less energy to be used [4]. Therefore, it is possible to consume fewer natural resources.

Some issues need to be taken into consideration to increase the effectiveness of carbon neutrality policies in the transportation sector. Financial considerations are of great importance

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in ensuring the effectiveness of carbon neutrality policies in this sector [5]. The provision of adequate financial incentives helps to successfully implement these policies [6], [7], [8], [9]. Ensuring customer satisfaction is also important for the correct implementation of these policies. If customer satisfaction is not ensured, this situation will become very difficult. To increase the effectiveness of carbon neutrality policies in the transportation sector, organizational effectiveness must be ensured. For these policies to be implemented successfully, the departments in the enterprises should work in harmony with each other [10]. To increase the effectiveness of carbon neutrality policies in the transportation sector, technological innovations should also be provided.

These issues need to be improved to correctly implement carbon neutral policies in the transportation sector. However, the biggest disadvantage of these improvements is that they increase costs. Therefore, the increase in costs as a result of numerous improvements leads to a decrease in profitability [11]. Instead of improving a large number of factors, it is more financially feasible to take action on the ones that are more important. Therefore, a priority analysis for these factors needs to be carried out. In the literature, the importance of carbon neutral policies has often been emphasized [12]. However, there are a limited number of studies in which priority analysis is made for the factors affecting this process. Therefore, it is thought that the main missing part in the literature is that a new study should be made in which the importance weights of these variables are determined.

Accordingly, this study aims to evaluate carbon neutrality policies in the transportation industry. In this context, the main research question is to understand which indicators are more critical to define appropriate carbon neutrality policies. For this purpose, a new fuzzy decision-making model has been constructed. In the first stage, selected indicators are examined with quantum picture fuzzy row sets-based multi-stepwise weight assessment ratio analysis (M-SWARA) technique. Moreover, the alternatives for the carbon neutrality policies in this industry are ranked. In this scope, multiobjective optimization on the basis of ratio analysis (MOORA) methodology is considered with quantum picture fuzzy row sets. The main motivation to make this study is that there is a strong need for a novel and comprehensive decision-making model. The main reason is that currently existing decision-making models are criticized due to many different reasons. For instance, analytical hierarchy process (AHP), analytical network process (ANP), and SWARA techniques cannot consider causal directions among the criteria. The authors in [13] and [14] focused on the priority evaluations of carbon neutrality policies in China. In this process, AHP methodology was taken into consideration to find the weights of the selected criteria. However, an impact-relation map of these factors cannot be created. Similarly, Muryani et al. [15] tried to identify prior strategies to minimize carbon emission in Indonesia. In this context, the most significant determinants of this problem are identified with the help of ANP approach. Nonetheless, the causal directions of these items cannot be defined. On the other side, the authors in [16] and [17] considered the SWARA technique to weight the factors with respect to the waste treatment technology selection. Nevertheless, the most influenced and influencing criteria cannot be determined. However, for some subjects, causality analysis should be used to reach more appropriate results. The indicators of carbon neutrality policies in transportation industry can have an influence on each other. For instance, providing the financial effectiveness of these policies can have a powerful contribution to improve the research and development activities. In this framework, the M-SWARA technique is newly generated in this proposed model. In this process, by making some improvements to the classical SWARA, the causal directions among these criteria can be shown.

The main contributions of this study are given as follows.

1) Integration of quantum theory and picture fuzzy rough sets has an increasing impact on the quality of the proposed model. Because quantum theory considers different probabilities, sensitive evaluations can be conducted. This issue provides opportunities to minimize uncertainties in decision-making models. Minimizing uncertainty can increase efficiency in decision-making processes. As the degree of uncertainty decreases, risk management can be carried out more effectively. Minimizing uncertainty often requires collecting more information. Therefore, in this model, it is aimed to reduce uncertainty by integrating picture fuzzy numbers with quantum theory. On the other hand, picture fuzzy rough sets are created by combination of the rough set theory and picture fuzzy sets. Uncertain information can be managed more effectively with the help of these sets. Identification of the most significant alternatives for the carbon neutrality policies in transportation is a very complex process. Due to high uncertainties in this process, more sensitive evaluations should be conducted to reach more appropriate findings. Hence, by integrating the quantum theory and picture fuzzy rough sets in this proposed model, it is aimed to minimize uncertainties.
2) A novel approach M-SWARA is proposed to weight the criteria so that causality relationship among the determinants can be considered in this process. Priority strategies can be presented for the improvements of the carbon neutrality policies in the transportation industry. With the help of these results, companies can implement appropriate policies without having extra costs. Hence, the causal directions between the indicators should be considered in the analysis process. Most of the previous studies mainly focused on the importance of the main indicators of the carbon emission problem, such as cost effectiveness [18], [19], customer satisfaction [20], [21], and technological development [22], [23]. However, these studies did not make a priority evaluation to understand the most critical factors. Hence, the main superiority of this study is that prior strategies can be presented to minimize the carbon emission problem.
3) Owing to the MOORA method, both positive and negative criteria can be taken into consideration together. There are different criteria that affect the effectiveness of carbon neutral policies in the transportation sector. Some of these criteria are negative and some are positive

factors. Therefore, considering only alternatives that have a positive effect may negatively affect the effectiveness of analysis processes. Hence, taking the MOORA technique into consideration in this process allows more accurate analysis to be performed. However, some previous studies could only consider the positive items due to the selected methodology. For instance, the authors in [24] and [25] focused on the main indicators of the carbon emission with the help of technique for order preference by similarity (TOPSIS) technique. Similarly, the authors in [26] and [27] used the vlse kriterijumska. optimizacija kompromisno resenje (VIKOR) approach to make evaluations regarding the carbon neutrality. In these studies, only the positive criteria were taken into consideration.

The rest of this article is organized as follows. Section II includes a literature review. The proposed methodology is explained in Section III. Analysis results are shown in Section IV. The discussion is presented in Section V. Section VI describes the policy implications. Finally, Section VII concludes this article.

II. LITERATURE REVIEW

This section consists of three different sections. First, different factors impacting the effectiveness of carbon neutrality programs are evaluated. Second, factor priority analysis techniques are explained. Finally, the main literature review results are discussed.

A. Literature on Different Factors Impacting the Effectiveness of Carbon Neutrality Programs

Financial issues are of high importance in increasing the effectiveness of carbon neutrality policies in the transportation sector. Lv et al. [28] defined that, to achieve carbon neutrality targets in the transportation sector, it is necessary to use up-to-date technology. This situation requires high amounts of investments. Talwar et al. [29] identified that, for these investments to be made on time, financial resources must be easily accessible. The most important reason why the transportation sector increases the carbon emission problem is the preference of fossil fuels for energy needs. Therefore, clean energy sources should be preferred instead of fossil fuels in this process. To achieve this goal, it is necessary to invest in high-volume projects [30]. Also, Zhou [31] mentioned that tax reductions and affordable loans provide financial convenience to investors. For carbon neutral policies to be implemented correctly in the transportation sector, environmentally friendly transportation technologies need to be developed [32]. According to Jenn [33], to achieve this, it is important to obtain a high amount of funds for research and development studies.

Ensuring customer satisfaction also plays a critical role in the successful implementation of these policies. Cai et al. [34] stated that, to increase environmentally friendly solutions for the transportation sector, customers' awareness of these issues must also increase. According to Mittal and Shah [35], to properly meet the expectations of these increasingly conscious customer groups, environmentally friendly practices must be offered. Otherwise, businesses will experience significant customer loss. In other words, environmental sustainability practices in the transportation sector need to be taken into consideration to ensure customer loyalty [36]. To be successful in this process, customers' expectations must be understood correctly. Zahoor et al. [37] identified that it is necessary to provide customer feedback on applications. This is also very necessary to attract the attention of new customers. Lin et al. [38] also defined that customer feedback is vital for transportation companies to properly design their applications. By taking these views into account, businesses can determine the most appropriate and correct policies for environmental issues.

It is extremely important to ensure organizational effectiveness to increase the effectiveness of carbon neutrality policies in the transportation sector. Shang and Lv [39] concluded that, to implement these policies correctly, first, the environmental targets of the enterprises must be determined correctly. Yang and Lo [40] underlined that it is essential for businesses to make correct strategies and plans. In this context, businesses need departments that work in harmony with each other to develop a correct action plan. On the other hand, Xiang et al. [41] demonstrated that businesses need to ensure resource efficiency to implement carbon neutrality policies correctly. In this context, both financial and personnel resources must be used correctly. This situation seriously supports the implementation of correct applications. Moreover, Xu et al. [42] underlined that, to increase the performance of carbon neutrality policies, businesses should monitor this process. The findings obtained as a result of these monitoring can help detect possible problems early. Pan et al. [43] highlighted that it is possible to increase the performance by taking the necessary actions in a timely manner.

It is essential to increase technological innovations in increasing the effectiveness of carbon neutrality policies in the transportation sector. Du et al. [44] determined that technological innovations enable the correct implementation of practices that reduce carbon emissions. In this context, businesses need to have up-to-date technology to develop applications, such as electric vehicles. According to Sun and Xia [45], to increase the effectiveness of this process, it is important for businesses to increase investments in the development of technological infrastructure. On the other hand, Rinawati et al. [46] underlined that the use of advanced technology also contributes to energy efficiency. Thus, it is possible to reduce carbon emissions by consuming less energy. In addition to these issues, Proskurina and Mendoza-Martinez [47] identified that, thanks to technological innovations, it is possible to follow the processes of businesses live. Ding and Liu [48] underlined that, owing to this tracking system, the problems that occur in the process can be resolved quickly. This supports the more successful implementation of carbon neutrality policies.

Different alternatives for the carbon neutrality policies were also discussed in the literature in a detailed way. Some of the scholars underlined the significance of presenting the low-emission targets. Low-carbon emission targets enable businesses to effectively contribute to the fight against climate change [49]. The authors in [50] and [51] denoted that meeting these goals also helps businesses fulfill their environmental responsibilities.

Moreover, using less fossil fuel in businesses is another prominent alternative to minimize carbon emissions [52]. The authors in [53] and [54] identified that using fewer fossil fuels plays an important role in combating climate change by reducing the carbon footprint. Similarly, turning to renewable energy sources instead of fossil fuels supports more sustainable energy production. Furthermore, ensuring energy efficiency in businesses is another alternative that can be taken into consideration in this process [55]. Hong et al. [56] also mentioned that, when energy efficiency is achieved in a business, less energy can be consumed to meet the same energy need. Issa et al. [57] defined that this situation allows natural resources to be consumed less. On the other hand, ensuring energy efficiency also reduces air pollution caused by energy production. This condition makes it possible to combat the carbon emission problem more effectively.

B. *Literature on Factor Priority Analysis Techniques*

Multicriteria decision-making models were considered by many different scholars in the literature with respect to the energy economics subject. In this process, factor priority evaluations are performed for the improvements of the clean energy projects, carbon emission reduction policies, and effective waste management. In some of these studies, models were proposed by using Pythagorean fuzzy sets. For example, Ding et al. [58] focused on sustainable energy pricing with the help of Pythagorean fuzzy DEMATEL. Moreover, the authors in [59] and [60] integrated SWARA, TOPSIS, and WASPAS approaches with these sets for the purpose of evaluating clean energy projects. Similarly, Yüksel and Dinçer [61] tried to identify strategic priorities of nuclear energy investments using Pythagorean fuzzy DEMATEL. On the other side, some other scholars integrated different decision-making techniques with spherical fuzzy sets to make factor priority analysis regarding renewable energy improvements [62], [63], [64]. In addition to them, some other studies considered trapezoidal fuzzy sets in the models to minimize uncertainties in the analysis process. Within this framework, the authors in [65], [66], and [67] used these fuzzy sets to identify key determinants of energy efficiency and energy storage effectiveness.

C. *Literature Review Results*

The main results of the literature review are indicated below. Carbon neutrality policies play a critical role in transportation industry. Due to this situation, this subject was evaluated in many different studies. The scholars mainly examined how to improve this situation. Within this framework, the indicators were highlighted for this condition. However, the biggest disadvantage of these improvements is that they increase costs. Because of this issue, trying to make lots of improvements at the same time is not financially optimal. For providing effectiveness in this process, there is a strong need for a priority analysis. With the help of this situation, it can be possible for the companies to implement prior strategies first. Nonetheless, there are limited studies in the literature with respect to this issue. This situation can be accepted as the main missing part in the literature regarding this subject. To fill this missing part, a new model is generated in this study to find more critical determinants of carbon neutrality policies in the transportation industry.

III. METHODOLOGY

The techniques considered in the proposed model are explained in this section. The equations are presented in the appendix part.

A. *Modeling Uncertainty With Quantum Picture Fuzzy Rough Sets With Golden Cuts*

Quantum theory is mainly used in the science of physics. While considering different probabilities, this theory can make sensitive assessments. Owing to this benefit, it is integrated with fuzzy decision-making logic with the purpose of handling uncertainties in a more effective manner. The details are identified in (1)–(3), where θ refers to the phase angle, u gives information about the event, and φ^2 indicates the amplitude [68].

Picture fuzzy sets are generated as an extension of the classical sets. Positive, neutral, negative, and refusal membership degrees are considered by these numbers [69]. While using them, it is mainly aimed to manage vagueness in the evaluation process more successfully. Equation (4) demonstrates the classical fuzzy sets and intuitionistic fuzzy sets are given in (5). Within this context, μ_A and v_A define membership and nonmembership functions. By considering this information, picture fuzzy sets are shown in (6) in which n_A and h_A indicate the neutral and refusal degrees [70]. General operations are explained in (7)–(11). Rough numbers are also created to minimize subjective and uncertain evaluations in the analysis process. Lower $(\underline{\mathrm{Apr}}(C_i))$, upper $(\overline{\mathrm{Apr}}(C_i))$ approximation, and boundary region $(\mathrm{Bnd}(C_i))$ are identified in (12)–(14) [71]. Moreover, lower $(\underline{\mathrm{Lim}}(C_i))$, upper $(\overline{\mathrm{Lim}}(C_i))$ limits, and the rough number $(\mathrm{RN}(C_i))$ are explained in (15)–(17), where N_L and N_U are the number of objects [72]. Equations (18)–(26) demonstrate the quantum picture fuzzy rough sets in which $C_{i\mu_A}$ refers to the membership, C_{in_A} denotes the neutral degree, C_{iv_A} shows the nonmembership, and C_{ih_A} means the refusal degrees. Also, $N_{L\mu_A}$, N_{Ln_A}, N_{Lv_A}, and N_{Lh_A} define the number of elements in $\underline{\mathrm{Apr}}(C_{i\mu_A})$, $\underline{\mathrm{Apr}}(C_{in_A})$, $\underline{\mathrm{Apr}}(C_{iv_A})$, and $\underline{\mathrm{Apr}}(C_{ih_A})$, whereas $N_{U\mu_A}$, N_{Un_A}, N_{Uv_A}, and N_{Uh_A} are identified for $\overline{\mathrm{Apr}}(C_{i\mu_A})$, $\overline{\mathrm{Apr}}(C_{in_A})$, $\overline{\mathrm{Apr}}(C_{iv_A})$, and $\overline{\mathrm{Apr}}(C_{ih_A})$. Equations (27)–(34) show the details of these items. In (35) and (36), general formulation of the quantum picture fuzzy sets is explained. The degrees are computed with a golden ratio (G) to increase the appropriateness of the findings [73]. Equations (37) and (38) explain this situation [74]. The phase angles of the degrees are formulated in (39)–(41). Equations (42)–(45) explain the operations of quantum picture fuzzy rough numbers.

The integration of quantum picture fuzzy rough sets in decision-making models stems from the inherent limitations of classical methodologies in addressing the formidable challenges posed by uncertainties. Classical decision-making techniques often falter when confronted with intricate scenarios characterized by dynamic variables and nuanced states of membership.

The conventional probabilistic frameworks, governed by classical logic, exhibit shortcomings in encapsulating the intricacies inherent in real-world problems. For instance, the complex decision problems could include several dynamic elements together, such as positive, negative, and neutral degrees. So, the use of quantum picture fuzzy rough sets could provide more sensitive results by using both amplitudes and phase angles of the related degrees at the same time.

B. M-SWARA With Quantum Picture Fuzzy Rough Sets

SWARA aims to compute the weights of different indicators. In this process, the hierarchical priorities of the experts are considered. However, this technique cannot create an impact-relation map of these factors. For this purpose, this method is extended with some improvements.

M-SWARA with quantum picture fuzzy rough sets is an extended methodology derived from SWARA to address the limitation of neglecting causal directions between indicators. This extension incorporates quantum picture fuzzy rough sets to identify causality relationships among different items. The motivation for introducing M-SWARA with quantum picture fuzzy rough sets stems from the limitations of the original SWARA methodology. While SWARA effectively weighs different indicators using hierarchical priorities, it falls short in considering causal directions between these indicators. This gap prompted the development of M-SWARA to enhance the methodology by incorporating quantum picture fuzzy rough sets. In this approach, the stable values of relation matrix with the values of w_j are defined by transposing and limiting the matrix to the power of $2t{+}1$. t is an arbitrarily large number. In addition, the impact-relation degrees of the criteria are constructed from the relation matrix by using the threshold value α. So, it is aimed to introduce a new extension of the SWARA to provide more accurate results along with the impact-relation degrees than the conventional SWARA methodology.

As a result, a new model is proposed with the name of M-SWARA. Hence, it is possible to make causality evaluation with the help of this new approach. Evaluations are obtained in the first step. Next, the decision matrix is identified by (46) [75]. The aggregated values are computed with (47). Equation (48) is considered to obtain defuzzified values. Equations (49)–(51) are used to generate s_j (importance), k_j (coefficient), q_j (recomputed weight), and w_j (weight) values. This matrix is transposed and limited to the power of "$2t{+}1$" so that stable values can be identified. Finally, the causal directions can be obtained with the help of threshold value.

C. MOORA With Quantum Picture Fuzzy Rough Sets

MOORA is used for ranking alternatives. The main superiority of this technique is that both positive and negative indicators can be taken into consideration. This methodology is extended with quantum picture fuzzy rough sets in this study. After the collection of the evaluations, decision matrix is constructed by (52) [76]. With the help of (48), defuzzified values can be computed. Equation (53) is considered for the calculation of the normalized values. Positive and negative impacts are examined in the next process. Within this context, (54) is used. Equation (55) is taken into consideration to identify the weighted results. These values are used to rank the alternatives.

IV. ANALYSIS RESULTS

For the purpose of examining carbon neutrality policies in the transportation industry, a two-stage model is created. The details of the proposed model are shown in Fig. 1.

In the first stage of the model, selected determinants are evaluated with quantum picture fuzzy row sets-based M-SWARA technique. There are lots of decision-making models for weighting the criteria, such as AHP and ANP. However, these methods cannot consider casual directions while weighting the factors. Nonetheless, the indicators of carbon neutrality policies in the transportation industry can have an impact on each other. Due to this issue, the causality relationship between these items should be taken into consideration to reach more effective results. As a result, it is seen that the M-SWARA methodology is more optimal for this evaluation. On the other side, uncertainty is one of the most critical problems in the decision-making process. Hence, a comprehensive evaluation is needed to solve the complex problems. Owing to this situation, in this proposed model, quantum theory is integrated with the picture fuzzy rough sets. The main reason for this situation is that quantum theory provides very successful solutions for future predictions. Thus, with the help of this integration, it becomes possible to minimize uncertainties in this process. Furthermore, the alternatives for the carbon neutrality policies in this industry are ranked. Within this framework, the MOORA technique is used with quantum picture fuzzy row sets. MOORA technique can handle many objective functions simultaneously. In this way, *d* can determine the most appropriate solutions by evaluating the relationships of variables with each other. In contrast, other methods, such as VIKOR, mostly use the weighted sum approach. Therefore, it may be more limited than MOORA in adapting to multiobjective targets. The results of this model are explained in the following sections.

A. Weighting the Criteria for the Evaluation of Carbon Neutrality

The indicators are identified with respect to the evaluation of carbon neutrality in the transportation industry. In this context, these criteria are selected based on balanced scorecard technique. This approach mainly focuses on four different perspectives that are financial, customer, internal process, and learning and growth. The main superiority of this approach is that both financial and nonfinancial issues can be considered together in the analysis process. With the help of this condition, more effective findings can be obtained. Selected indicators are explained in Table I.

Cost effectiveness in the process must be ensured to effectively implement carbon neutral policies in the transportation sector. Otherwise, the financial sustainability of the projects will not be possible. Meeting customers' expectations correctly also contributes to the proper implementation of these policies. This helps increase the preference of the projects. On the other hand, businesses with organizational effectiveness can also carry out

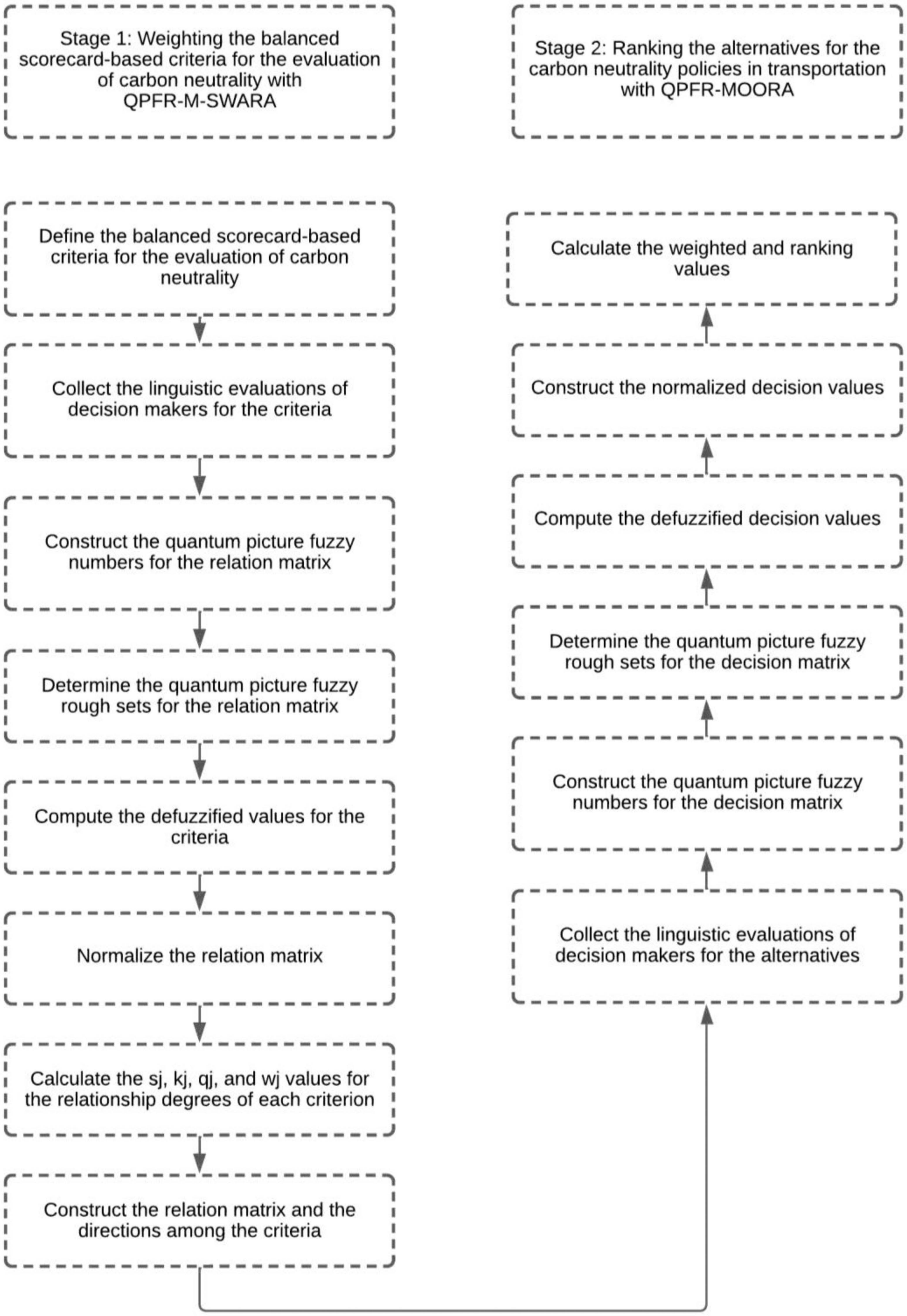

Fig. 1. Algorithm of hybrid model.

TABLE I
CRITERIA FOR THE EVALUATION OF CARBON NEUTRALITY

Balanced scorecard-perspectives	Criteria	References
Financial	Costs	[4]; [12]; [17]; [29]
Customer	Customer Satisfaction	[14]; [21]; [36]; [38]
Internal Process	Infrastructure Development	[12]; [13]; [20]; [45]
Learning and Growth	Innovation and Technology Adoption	[19]; [23]; [27]; [32]

TABLE II
RELATION MATRIX AND IMPACT DIRECTIONS

	Cost	**Customer**	**Infrastructure**	**Innovation**	**Impact directions**
Cost		0.246	0.322	0.432	Cost → Innovation
Customer	0.324		0.430	0.247	Customer → Infrastructure
Infrastructure	0.432	0.322		0.247	Infrastructure → Cost
Innovation	0.300	0.300	0.399		Innovation → Infrastructure

TABLE III
STABLE MATRIX

	Cost	**Customer**	**Infrastructure**	**Innovation**
Cost	0.263	0.263	0.263	0.263
Customer	0.224	0.224	0.225	0.224
Infrastructure	0.276	0.276	0.276	0.276
Innovation	0.237	0.237	0.237	0.237

these policies more effectively. Finally, businesses with a strong technological infrastructure can gain a significant competitive advantage. In this way, carbon neutral policies can be implemented effectively. In the following step, the evaluations are obtained from three different decision makers. These people have minimum 25 years of working experience. Two of these people work as general managers in international carbon emission companies. The third expert is the professor of energy economics and finance. He has lots of significant publications with respect to the renewable energy projects, carbon emission reduction strategies, and effective waste management. In this process, these people consider the scales in Table A1. Table A2 gives information about the evaluations. In the following step, quantum picture fuzzy numbers for the relation matrix are generated. Table A3 indicates these numbers. Quantum picture fuzzy rough sets for the relation matrix are presented in Table A4. Defuzzified values are computed in Table A5. These values are normalized in Table A6. Moreover, *sj, kj, qj,* and *wj* values are computed in Table A7. The relation matrix is constructed in the next step. The directions among the factors are computed based on these values. Table II gives information about these details.

Table II denotes that infrastructure development is the most influenced item because both customer satisfaction and innovation and technology adoption have an influence on this factor. Creating this impact-relation map can be the main contribution of this proposed model in comparison with some of the previously generated models in the literature. The decision-making models used AHP and ANP, which cannot identify the causal relationship between these indicators. Considering this relationship provides an opportunity to generate more effective investment strategies. For example, technological improvements have a strong impact on the financial issues. By considering these conditions, it is understood that these improvements play a crucial role for the cost effectiveness. Stable matrix is generated after this calculation. The details of this new matrix are demonstrated in Table III.

The values in stable matrix demonstrate the weights of the criteria. It is seen that infrastructure development is the most important factor of effective carbon neutrality policies for transportation industry with the highest weight (0.276). Cost is another critical indicator in this respect since it has the weight of 0.163. It is possible to offer policy recommendations that support the development of technological infrastructure to ensure the effectiveness of carbon neutrality policies in the transportation sector. In this context, incentives can be provided primarily for green transportation technologies. In this context, tax reductions should be offered to increase the use of electric vehicles. On the other hand, some measures should be taken to improve the network infrastructure. Increasing the number of charging stations for electric vehicles has a very important role in this process. Moreover, the development of smart transportation systems is also necessary to ensure the effectiveness of carbon neutrality policies in the transportation sector. This allows energy efficiency to be increased. Using less energy also contributes significantly to reducing carbon emissions.

B. Ranking the Alternatives for the Carbon Neutrality Policies in Transportation

The second stage includes the evaluation of the alternatives for the carbon neutrality policies for the transportation industry. For this purpose, five different alternatives are selected according to the literature review results. Table IV explains the details of these alternatives.

The evaluations regarding the alternatives are indicated in Table A8. Quantum picture fuzzy numbers for the decision matrix are computed in Table A9. Quantum picture fuzzy rough sets for the decision matrix are identified in Table A10. Defuzzified values are computed in the next process, and a new matrix is generated in Table A11. Normalized values are calculated in the following step. Table A12 explains the details of normalized matrix. After that, the weighted values are calculated. These results are considered to rank the alternatives. Table V demonstrates the ranking results.

Table V indicates that RTFZC alternatives are the most essential alternative for the carbon neutrality policies in transportation. Presenting the low-emission targets (PTLET) per

TABLE IV
ALTERNATIVES FOR THE CARBON NEUTRALITY POLICIES IN TRANSPORTATION

Alternatives	**References**
ETMWS alternatives	[20]
PTLET per passenger	[4]
RTFZC alternatives	[25]
SOVFW less-energy consumption	[30]
OECTG time	[14]

TABLE V
WEIGHTED VALUES AND RANKING VALUES

Alternatives	**Benefit Values**	**Cost Values**	**Weighted Scores**	**Ranking Results**
ETMWS	0.338	0.121	0.218	3
PTLET	0.324	0.105	0.219	2
RTFZC	0.351	0.121	0.230	1
SOVFW	0.313	0.125	0.188	5
OECTG	0.318	0.115	0.203	4

TABLE VI
COMPARATIVE RANKING RESULTS WITH SENSITIVITY ANALYSIS

Alternatives	Case 1		Case 2		Case 3		Case 4	
	Extended MOORA	Extended TOPSIS	Extended MOORA	Extended TOPSIS	Extended MOORA	Extended TOPSIS	Extended MOORA	Extended TOPSIS
ETMWS	3	3	2	3	2	3	3	3
PTLET	2	2	3	2	3	2	2	2
RTFZC	1	1	1	1	1	1	1	1
SOVFW	5	5	5	5	5	5	5	5
OECTG	4	4	4	4	4	4	4	4

passenger and encouraging the transportation modes with sustainable (ETMWS) alternatives are also important issues for this situation. However, OECTG time and SOVFW less-energy consumption are in the last ranks. In this proposed model, MOORA methodology is integrated with the quantum picture fuzzy rough sets. This integration plays a key role in the minimization of the uncertainties in the evaluation process. With the help of this condition, more effective results can be identified. Because of this issue, it is thought that this integration paves the way for future decision-making models.

In the last stage, the extended TOPSIS is also applied for providing the comparative ranking results and the robustness check of the proposed methodology. In addition, the sensitivity analysis is considered to understand the possible effects of the changing weighting results on the ranking performances of the cases. For that, four cases are defined by changing the weights of the criteria consecutively into the criteria set. The comparative ranking results by the cases are given in Table VI.

According to Table VI, PTLET has the best ranking result among the alternatives. However, the comparative results illustrate that the rankings of both methodologies are similar in the cases. This is clear evidence for the coherency of our proposed methodology in the case of the comparative results and the sensitivity analysis.

V. DISCUSSION

Infrastructure development of businesses is of great importance in increasing the effectiveness of carbon neutrality policies in the transportation sector. In this context, first, energy efficiency must be ensured. To achieve this goal, transportation companies must create an infrastructure that consumes much less energy in their business processes. In this way, it is possible to consume much smaller amounts of natural resources. Wu et al. [77] defined that this contributes to significantly reducing the carbon emission problem. On the other hand, Li et al. [78] discussed that effective data collection processes also play an important role in the process of transportation companies creating a good infrastructure. Thanks to the accuracy of the data collected through business processes, it is possible to test the effectiveness of these processes much more successfully. Similarly, the authors in [79] and [80] underlined that this situation allows malfunctions in the processes to be detected more easily and these problems to be resolved in a short time. Thus, it will be easier to implement carbon neutrality policies more successfully.

In addition, it is also important that the buildings and facilities of transportation companies are environmentally friendly. Designing these facilities in accordance with the green building concept allows for less carbon emissions in the production process. In this context, Arriet et al. [81] mentioned that providing the electricity needs in the production process from environmentally friendly energy sources, such as solar panels, instead of fossil fuels ensures less carbon emissions. On the other hand, Yu et al. [82] identified that it would be appropriate for transportation companies to attach importance to the use of electric vehicles. According to Tong et al. [83], owing to these vehicles, it is possible to seriously reduce the carbon emissions caused by this sector. In this context, government incentives for the use of electric vehicles need to be offered. For example, a tax reduction may increase the use of electric vehicles as it will provide a significant cost advantage. On the other hand, the authors in [84] and [85] denoted that for these vehicles to be used effectively, it is necessary to create a wide range of charging stations throughout the country. In this way, transportation businesses will cause less carbon emissions while continuing their activities.

VI. Policy Implications

The most important issue in increasing the effectiveness of carbon neutrality policies in the transportation sector is determined as infrastructure development. Therefore, it is important to implement some policies to ensure infrastructure development in this context. First, some infrastructure strengthening works should be carried out to develop electric transportation. In this context, the infrastructure of charging stations should be developed to encourage the use of electric vehicles. This situation contributes to people and businesses choosing electric vehicles. In addition, some practices should be implemented to reduce dependence on fossil fuels. In this context, alternative fuels based on renewable energy sources should be encouraged. In this process, incentives, such as tax deductions, provided by the government offer significant cost advantages to users. In this way, it is possible for the use of renewable energy to become more widespread.

VII. Conclusion

In this article, we examined carbon neutrality policies in the transportation industry with a novel decision-making model. In the first stage, determinants were evaluated by the quantum picture fuzzy row sets-based M-SWARA technique. Second, the alternatives for the carbon neutrality policies in this industry were ranked. For this purpose, MOORA methodology was considered with quantum picture fuzzy row sets. It was found that infrastructure development is the most influenced item because both customer satisfaction and innovation and technology adoption have an influence on this factor. Moreover, according to the weighting results, it was identified that infrastructure development is the most important factor of effective carbon neutrality policies for the transportation industry with the highest weight (0.276). Cost is another critical indicator in this respect because it has the weight of 0.163. On the other hand, the ranking results demonstrated that RTFZC alternatives are the most essential alternative for the carbon neutrality policies in transportation. PTLET per passenger and ETMWS alternatives are also important issues in this situation. However, OECTG time and SOVFW less-energy consumption are in the last ranks.

The main contribution of this study is that a new model is proposed by integrating quantum theory and picture fuzzy rough sets. This situation has a positive contribution to make sensitive evaluations. With the help of this issue, uncertainties in decision-making models can be handled more appropriately. Also, priority strategies can be presented for the improvements of the carbon neutrality policies in the transportation industry. Owing to these results, companies can implement effective policies without having extra costs. The evaluation in this study is made only for transportation industry that can be accepted as the main limitation. Carbon neutrality policies also play a critical role in other industries such as textiles. Thus, in the following studies, these industries can be examined in this context. In this way, it is possible to determine specific sector-based strategies and policies to minimize carbon emissions. In addition, the proposed model can be improved in future studies. The existing ranking models in the literature are criticized by the scholars. Therefore, a novel ranking technique can be developed to overcome these criticisms. On the other side, another significant limitation is that the evaluations of all experts are considered equal. However, the quality of the experts can differ based on some conditions, such as education level, work experience, and position in the company. Hence, regarding the future research direction, a new model can be created in which the significance weights of the experts are defined.

Appendix Appendix A – Equations

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

$$|C> = \left\{|u_1>, |u_2>, \ldots, |u_n>\right\} \tag{2}$$

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

$$A = \left\{\langle x, \mu_A(x)\rangle \,|\, x \in X\right\} \tag{4}$$

$$A = \left\{\langle x, \mu_A(x), v_A(x)\rangle \,|\, x \in X\right\} \tag{5}$$

$$A = \left\{\langle x, \mu_A(x), n_A(x), v_A(x), h_A(x)\rangle \,|\, x \in X\right\} \tag{6}$$

$$A \subseteq B \text{ if } \mu_A(x) \le \mu_B(x) \text{ and } n_A(x) \le n_B(x) \text{ and } v_A(x) \ge v_B(x)\ \forall x \in X \tag{7}$$

$$A = B \text{ if} A \subseteq B \text{ and } B \subseteq A \tag{8}$$

$$\begin{aligned} A \cup B = \{(x,\ &\max\left(\mu_A(x), \mu_B(x)\right),\\ &\min\left(n_A(x), n_B(x)\right),\\ &\min\left(v_A(x), v_B(x)\right))\,|\, x \in X\} \end{aligned} \tag{9}$$

$$\begin{aligned} A \cap B = \{(x,\ &\min\left(\mu_A(x), \mu_B(x)\right),\\ &\min\left(n_A(x), n_B(x)\right),\\ &\max\left(v_A(x), v_B(x)\right))\,|\, x \in X\} \end{aligned} \tag{10}$$

$$coA = \bar{A} = \{(x, v_A(x), n_A(x), \mu_A(x)) \,|\, x \in X\} \tag{11}$$

$$\underline{\mathrm{Apr}}(C_i) = \cup \{Y \in X/R(Y) \le C_i\} \tag{12}$$

$$\overline{\mathrm{Apr}}(C_i) = \cup \{Y \in X/R(Y) \ge C_i\} \tag{13}$$

$$\mathrm{Bnd}(C_i) = \cup \{Y \in X/R(Y) \ne C_i\} \tag{14}$$

$$\underline{\mathrm{Lim}}(C_i) = \sqrt[N_L]{\prod_{i=1}^{N_L} Y \in \underline{\mathrm{Apr}}(C_i)} \tag{15}$$

$$\overline{\mathrm{Lim}}(C_i) = \sqrt[N_U]{\prod_{i=1}^{N_U} Y \in \overline{\mathrm{Apr}}(C_i)} \tag{16}$$

$$\mathrm{RN}(C_i) = \lceil \underline{\mathrm{Lim}}(C_i)\ , \overline{\mathrm{Lim}}(C_i) \rfloor \tag{17}$$

$$|C_A> = \left\{ \begin{array}{c} \langle u\ , (\lceil \underline{\mathrm{Lim}}(C_{i\mu_A}), \overline{\mathrm{Lim}}(C_{i\mu_A}) \rfloor\ (u), \lceil \underline{\mathrm{Lim}}(C_{in_A}), \overline{\mathrm{Lim}}(C_{in_A}) \rfloor (u), \\ \lceil \underline{\mathrm{Lim}}(C_{iv_A}), \overline{\mathrm{Lim}}(C_{iv_A}) \rfloor\ (u), \lceil \underline{\mathrm{Lim}}(C_{ih_A}), \overline{\mathrm{Lim}}(C_{ih_A}) \rfloor (u)) \Big| \, u \in 2^{|C_A>} \end{array} \right\} \tag{18}$$

$$\underline{\mathrm{Lim}}(C_{i\mu_A}) = \frac{1}{N_{L\mu_A}} \sum_{i=1}^{N_{L\mu_A}} Y \in \underline{\mathrm{Apr}}(C_{i\mu_A}) \tag{19}$$

$$\underline{\mathrm{Lim}}(C_{in_A}) = \frac{1}{N_{Ln_A}} \sum_{i=1}^{N_{Ln_A}} Y \in \underline{\mathrm{Apr}}(C_{in_A}) \tag{20}$$

$$\underline{\mathrm{Lim}}(C_{iv_A}) = \frac{1}{N_{Lv_A}} \sum_{i=1}^{N_{Lv_A}} Y \in \underline{\mathrm{Apr}}(C_{iv_A}) \tag{21}$$

$$\underline{\mathrm{Lim}}(C_{ih_A}) = \frac{1}{N_{L\pi_A}} \sum_{i=1}^{N_{L\pi_A}} Y \in \underline{\mathrm{Apr}}(C_{ih_A}) \tag{22}$$

$$\overline{\mathrm{Lim}}(C_{i\mu_A}) = \frac{1}{N_{U\mu_A}} \sum_{i=1}^{N_{U\mu_A}} Y \in \overline{\mathrm{Apr}}(C_{i\mu_A}) \tag{23}$$

$$\overline{\mathrm{Lim}}(C_{in_A}) = \frac{1}{N_{Un_A}} \sum_{i=1}^{N_{Un_A}} Y \in \overline{\mathrm{Apr}}(C_{in_A}) \tag{24}$$

$$\overline{\mathrm{Lim}}(C_{iv_A}) = \frac{1}{N_{Uv_A}} \sum_{i=1}^{N_{Uv_A}} Y \in \overline{\mathrm{Apr}}(C_{iv_A}) \tag{25}$$

$$\overline{\mathrm{Lim}}(C_{ih_A}) = \frac{1}{N_{U\pi_A}} \sum_{i=1}^{N_{U\pi_A}} Y \in \overline{\mathrm{Apr}}(C_{ih_A}) \tag{26}$$

$$\underline{\mathrm{Apr}}(C_{i\mu_A}) = \cup \left\{ Y \in X/\tilde{R}(Y) \le C_{i\mu_A} \right\} \tag{27}$$

$$\underline{\mathrm{Apr}}(C_{in_A}) = \cup \left\{ Y \in X/\tilde{R}(Y) \le C_{in_A} \right\} \tag{28}$$

$$\underline{\mathrm{Apr}}(C_{iv_A}) = \cup \left\{ Y \in X/\tilde{R}(Y) \le C_{iv_A} \right\} \tag{29}$$

$$\underline{\mathrm{Apr}}(C_{ih_A}) = \cup \left\{ Y \in X/\tilde{R}(Y) \le C_{ih_A} \right\} \tag{30}$$

$$\overline{\mathrm{Apr}}(C_{i\mu_A}) = \cup \left\{ Y \in X/\tilde{R}(Y) \le C_{i\mu_A} \right\} \tag{31}$$

$$\overline{\mathrm{Apr}}(C_{in_A}) = \cup \left\{ Y \in X/\tilde{R}(Y) \le C_{in_A} \right\} \tag{32}$$

$$\overline{\mathrm{Apr}}(C_{iv_A}) = \cup \left\{ Y \in X/\tilde{R}(Y) \le C_{iv_A} \right\} \tag{33}$$

$$\overline{\mathrm{Apr}}(C_{ih_A}) = \cup \left\{ Y \in X/\tilde{R}(Y) \le C_{ih_A} \right\} \tag{34}$$

$$C = \left[C_\mu . e^{j2\pi.\alpha}, C_n . e^{j2\pi.\gamma}, C_v . e^{j2\pi.\beta}, C_h . e^{j2\pi.T}\right] \tag{35}$$

$$\varphi^2 = \left|C_\mu \left(|u_i>\right)\right| \tag{36}$$

$$C_n = \frac{C_\mu}{G} \tag{37}$$

$$C_h = \frac{C_v}{G} \tag{38}$$

$$\alpha = \left|C_\mu \left(|u_i>\right)\right| \tag{39}$$

$$\gamma = \frac{\alpha}{G} \tag{40}$$

$$T = \frac{\beta}{G} \tag{41}$$

$$\lambda * \tilde{A}_c = \left\{ \begin{matrix} \left[\underline{\text{Lim}}\left(C_{\mu_{\tilde{A}}}\right)\lambda, \overline{\text{Lim}}\left(C_{\mu_{\tilde{A}}}\right)\lambda\right] e^{j2\pi\cdot\left[\left(\frac{\underline{\alpha}_{\tilde{A}}}{2\pi}\right)\lambda, \left(\frac{\bar{\alpha}_{\tilde{A}}}{2\pi}\right)\lambda\right]}, \left[\underline{\text{Lim}}\left(C_{n_{\tilde{A}}}\right)\lambda, \overline{\text{Lim}}\left(C_{n_{\tilde{A}}}\right)\lambda\right] e^{j2\pi\cdot\left[\left(\frac{\underline{\gamma}_{\tilde{A}}}{2\pi}\right)\lambda, \left(\frac{\bar{\gamma}_{\tilde{A}}}{2\pi}\right)\lambda\right]}, \\ \left[\underline{\text{Lim}}\left(C_{v_{\tilde{A}}}\right)\lambda, \overline{\text{Lim}}\left(C_{v_{\tilde{A}}}\right)\lambda\right] e^{j2\pi\cdot\left[\left(\frac{\underline{\beta}_{\tilde{A}}}{2\pi}\right)\lambda, \left(\frac{\bar{\beta}_{\tilde{A}}}{2\pi}\right)\lambda\right]}, \left[\underline{\text{Lim}}\left(C_{h_{\tilde{A}}}\right)\lambda, \overline{\text{Lim}}\left(C_{h_{\tilde{A}}}\right)\lambda\right] e^{j2\pi\cdot\left[\left(\frac{\underline{T}_{\tilde{A}}}{2\pi}\right)\lambda, \left(\frac{\bar{T}_{\tilde{A}}}{2\pi}\right)\lambda\right]} \end{matrix} \right\}, \lambda > 0 \tag{42}$$

$$\tilde{A}_c^\lambda = \left\{ \begin{matrix} \left[\underline{\text{Lim}}\left(C_{\mu_{\tilde{A}}}\right)^\lambda, \overline{\text{Lim}}\left(C_{\mu_{\tilde{A}}}\right)^\lambda\right] e^{j2\pi\cdot\left[\left(\frac{\underline{\alpha}_{\tilde{A}}}{2\pi}\right)^\lambda, \left(\frac{\bar{\alpha}_{\tilde{A}}}{2\pi}\right)^\lambda\right]}, \left[\underline{\text{Lim}}\left(C_{n_{\tilde{A}}}\right)^\lambda, \overline{\text{Lim}}\left(C_{n_{\tilde{A}}}\right)^\lambda\right] e^{j2\pi\cdot\left[\left(\frac{\underline{\gamma}_{\tilde{A}}}{2\pi}\right)^\lambda, \left(\frac{\bar{\gamma}_{\tilde{A}}}{2\pi}\right)^\lambda\right]}, \\ \left[\underline{\text{Lim}}\left(C_{v_{\tilde{A}}}\right)^\lambda, \overline{\text{Lim}}\left(C_{v_{\tilde{A}}}\right)^\lambda\right] e^{j2\pi\cdot\left[\left(\frac{\underline{\beta}_{\tilde{A}}}{2\pi}\right)^\lambda, \left(\frac{\bar{\beta}_{\tilde{A}}}{2\pi}\right)^\lambda\right]}, \left[\underline{\text{Lim}}\left(C_{h_{\tilde{A}}}\right)^\lambda, \overline{\text{Lim}}\left(C_{h_{\tilde{A}}}\right)^\lambda\right] e^{j2\pi\cdot\left[\left(\frac{\underline{T}_{\tilde{A}}}{2\pi}\right)^\lambda, \left(\frac{\bar{T}_{\tilde{A}}}{2\pi}\right)^\lambda\right]}, \end{matrix} \right\}, \lambda > 0 \tag{43}$$

$$\begin{aligned} &\tilde{A}_c \cup \tilde{B}_c \\ &= \left\{ \begin{matrix} \left[\min\left(\underline{\text{Lim}}\left(C_{\mu_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\underline{\alpha}_{\tilde{A}}}{2\pi}\right)}, \underline{\text{Lim}}\left(C_{\mu_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\underline{\alpha}_{\tilde{B}}}{2\pi}\right)}\right), \max\left(\overline{\text{Lim}}\left(C_{\mu_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\bar{\alpha}_{\tilde{A}}}{2\pi}\right)}, \overline{\text{Lim}}\left(C_{\mu_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\bar{\alpha}_{\tilde{B}}}{2\pi}\right)}\right)\right], \\ \left[\min\left(\underline{\text{Lim}}\left(C_{n_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\underline{\gamma}_{\tilde{A}}}{2\pi}\right)}, \underline{\text{Lim}}\left(C_{n_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\underline{\gamma}_{\tilde{B}}}{2\pi}\right)}\right), \max\left(\overline{\text{Lim}}\left(C_{n_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\bar{\gamma}_{\tilde{A}}}{2\pi}\right)}, \overline{\text{Lim}}\left(C_{n_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\bar{\gamma}_{\tilde{B}}}{2\pi}\right)}\right)\right], \\ \left[\min\left(\underline{\text{Lim}}\left(C_{v_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\underline{\beta}_{\tilde{A}}}{2\pi}\right)}, \underline{\text{Lim}}\left(C_{v_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\underline{\beta}_{\tilde{B}}}{2\pi}\right)}\right), \max\left(\overline{\text{Lim}}\left(C_{v_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\bar{\beta}_{\tilde{A}}}{2\pi}\right)}, \overline{\text{Lim}}\left(C_{v_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\bar{\beta}_{\tilde{B}}}{2\pi}\right)}\right)\right], \\ \left[\min\left(\underline{\text{Lim}}\left(C_{h_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\underline{T}_{\tilde{A}}}{2\pi}\right)}, \underline{\text{Lim}}\left(C_{h_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\underline{T}_{\tilde{B}}}{2\pi}\right)}\right), \max\left(\overline{\text{Lim}}\left(C_{h_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\bar{T}_{\tilde{A}}}{2\pi}\right)}, \overline{\text{Lim}}\left(C_{h_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\bar{T}_{\tilde{B}}}{2\pi}\right)}\right)\right] \end{matrix} \right\} \end{aligned} \tag{44}$$

$$\begin{aligned} &\tilde{A}_c \cap \tilde{B}_c \\ &= \left\{ \begin{matrix} \left[\max\left(\underline{\text{Lim}}\left(C_{\mu_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\underline{\alpha}_{\tilde{A}}}{2\pi}\right)}, \underline{\text{Lim}}\left(C_{\mu_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\underline{\alpha}_{\tilde{B}}}{2\pi}\right)}\right), \min\left(\overline{\text{Lim}}\left(C_{\mu_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\bar{\alpha}_{\tilde{A}}}{2\pi}\right)}, \overline{\text{Lim}}\left(C_{\mu_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\bar{\alpha}_{\tilde{B}}}{2\pi}\right)}\right)\right], \\ \left[\max\left(\underline{\text{Lim}}\left(C_{n_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\underline{\gamma}_{\tilde{A}}}{2\pi}\right)}, \underline{\text{Lim}}\left(C_{n_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\underline{\gamma}_{\tilde{B}}}{2\pi}\right)}\right), \min\left(\overline{\text{Lim}}\left(C_{n_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\bar{\gamma}_{\tilde{A}}}{2\pi}\right)}, \overline{\text{Lim}}\left(C_{n_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\bar{\gamma}_{\tilde{B}}}{2\pi}\right)}\right)\right], \\ \left[\max\left(\underline{\text{Lim}}\left(C_{v_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\underline{\beta}_{\tilde{A}}}{2\pi}\right)}, \underline{\text{Lim}}\left(C_{v_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\underline{\beta}_{\tilde{B}}}{2\pi}\right)}\right), \min\left(\overline{\text{Lim}}\left(C_{v_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\bar{\beta}_{\tilde{A}}}{2\pi}\right)}, \overline{\text{Lim}}\left(C_{v_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\bar{\beta}_{\tilde{B}}}{2\pi}\right)}\right)\right], \\ \left[\max\left(\underline{\text{Lim}}\left(C_{h_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\underline{T}_{\tilde{A}}}{2\pi}\right)}, \underline{\text{Lim}}\left(C_{h_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\underline{T}_{\tilde{B}}}{2\pi}\right)}\right), \min\left(\overline{\text{Lim}}\left(C_{h_{\tilde{A}}}\right) e^{j2\pi\cdot\left(\frac{\bar{T}_{\tilde{A}}}{2\pi}\right)}, \overline{\text{Lim}}\left(C_{h_{\tilde{B}}}\right) e^{j2\pi\cdot\left(\frac{\bar{T}_{\tilde{B}}}{2\pi}\right)}\right)\right] \end{matrix} \right\} \end{aligned} \tag{45}$$

$$C_k = \begin{bmatrix} 0 & C_{12} & \cdots & \cdots & C_{1n} \\ C_{21} & 0 & \cdots & \cdots & C_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ C_{n1} & C_{n2} & \cdots & \cdots & 0 \end{bmatrix} \tag{46}$$

$$C = \begin{pmatrix} \left[\min_{i=1}^{k}\left(\underline{\mathrm{Lim}}\left(C_{\mu_{ij}}\right)\right), \max_{i=1}^{k}\left(\overline{\mathrm{Lim}}\left(C_{\mu_{ij}}\right)\right)\right]\ e^{j2\pi\cdot\left[\min_{i=1}^{k}\left(\frac{\underline{\alpha}_{ij}}{2\pi}\right), \max_{i=1}^{k}\left(\frac{\bar{\alpha}_{ij}}{2\pi}\right)\right]}, \\ \left[\min_{i=1}^{k}\left(\underline{\mathrm{Lim}}\left(C_{n_{ij}}\right)\right), \max_{i=1}^{k}\left(\overline{\mathrm{Lim}}\left(C_{n_{ij}}\right)\right)\right]\ e^{j2\pi\cdot\left[\min_{i=1}^{k}\left(\frac{\underline{\gamma}_{ij}}{2\pi}\right), \max_{i=1}^{k}\left(\frac{\bar{\gamma}_{ij}}{2\pi}\right)\right]}, \\ \left[\min_{i=1}^{k}\left(\underline{\mathrm{Lim}}\left(C_{v_{ij}}\right)\right), \max_{i=1}^{k}\left(\overline{\mathrm{Lim}}\left(C_{v_{ij}}\right)\right)\right]\ e^{j2\pi\cdot\left[\min_{i=1}^{k}\left(\frac{\underline{\beta}_{ij}}{2\pi}\right), \max_{i=1}^{k}\left(\frac{\bar{\beta}_{ij}}{2\pi}\right)\right]}, \\ \left[\min_{i=1}^{k}\left(\underline{\mathrm{Lim}}\left(C_{h_{ij}}\right)\right), \max_{i=1}^{k}\left(\overline{\mathrm{Lim}}\left(C_{h_{ij}}\right)\right)\right]\ e^{j2\pi\cdot\left[\min_{i=1}^{k}\left(\frac{\underline{T}_{ij}}{2\pi}\right), \max_{i=1}^{k}\left(\frac{\bar{T}_{ij}}{2\pi}\right)\right]} \end{pmatrix} \tag{47}$$

$$\mathrm{Defc}_i = \frac{\begin{pmatrix} \underline{\mathrm{Lim}}\left(C_{\mu_i}\right) - \underline{\mathrm{Lim}}\left(C_{n_i}\right) + \underline{\mathrm{Lim}}\left(C_{\mu_i}\right)\cdot\left(\underline{\mathrm{Lim}}\left(C_{v_i}\right) - \underline{\mathrm{Lim}}\left(C_{h_i}\right)\right) + \left(\frac{\underline{\alpha}_{ij}}{2\pi}\right) - \left(\frac{\underline{\gamma}_{ij}}{2\pi}\right) + \left(\frac{\underline{\alpha}_{ij}}{2\pi}\right)\cdot\left(\left(\frac{\underline{\beta}_{ij}}{2\pi}\right) - \left(\frac{\underline{T}_{ij}}{2\pi}\right)\right) \\ +\overline{\mathrm{Lim}}\left(C_{\mu_i}\right) - \overline{\mathrm{Lim}}\left(C_{n_i}\right) + \overline{\mathrm{Lim}}\left(C_{\mu_i}\right)\cdot\left(\overline{\mathrm{Lim}}\left(C_{v_i}\right) - \overline{\mathrm{Lim}}\left(C_{h_i}\right)\right) + \left(\frac{\bar{\alpha}_{ij}}{2\pi}\right) - \left(\frac{\bar{\gamma}_{ij}}{2\pi}\right) + \left(\frac{\bar{\alpha}_{ij}}{2\pi}\right)\cdot\left(\left(\frac{\bar{\beta}_{ij}}{2\pi}\right) - \left(\frac{\bar{T}_{ij}}{2\pi}\right)\right) \end{pmatrix}}{2} \tag{48}$$

$$k_j = \begin{cases} 1\ j = 1 \\ s_j + 1\ j > 1 \end{cases} \tag{49}$$

$$q_j = \begin{cases} 1\ j = 1 \\ \frac{q_{j-1}}{k_j}\ j > 1 \end{cases} \tag{50}$$

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

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \tag{51}$$

$$X_k = \begin{bmatrix} 0 & X_{12} & \cdots & \cdots & X_{1m} \\ X_{21} & 0 & \cdots & \cdots & X_{2m} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_{n1} & X_{n2} & \cdots & \cdots & 0 \end{bmatrix} \tag{52}$$

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}. \tag{53}$$

$$Y_i = \sum_{j=1}^{h} X_{ij}^* - \sum_{j=h+1}^{n} X_{ij}^* \tag{54}$$

$$Y_i^* = \sum_{j=1}^{h} W_j X_{ij}^* - \sum_{j=h+1}^{n} W_j X_{ij}^* \tag{55}$$

APPENDIX B – TABLES

TABLE A1
SCALES AND FUZZY NUMBERS

Scales for Criteria	Scales for Alternatives	Degrees	Fuzzy Numbers
No (n)	Weakest (w)	0.40	$\begin{bmatrix}\sqrt{0.16}e^{j2\pi.0.4}, \\ \sqrt{0.10}e^{j2\pi.0.25}, \\ \sqrt{0.46}e^{j2\pi.0.22}, \\ \sqrt{0.28}e^{j2\pi.0.13}\end{bmatrix}$
some (s)	low (p)	0.45	$\begin{bmatrix}\sqrt{0.20}e^{j2\pi.0.45}, \\ \sqrt{0.13}e^{j2\pi.0.28}, \\ \sqrt{0.42}e^{j2\pi.0.17}, \\ \sqrt{0.25}e^{j2\pi.0.10}\end{bmatrix}$
normal (m)	normal (f)	0.50	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50}, \\ \sqrt{0.15}e^{j2\pi.0.31}, \\ \sqrt{0.37}e^{j2\pi.0.12}, \\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$
significant (h)	successful (g)	0.55	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55}, \\ \sqrt{0.19}e^{j2\pi.0.34}, \\ \sqrt{0.32}e^{j2\pi.0.07}, \\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$
perfect (vh)	wonderful (b)	0.60	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6}, \\ \sqrt{0.22}e^{j2\pi.0.37}, \\ \sqrt{0.26}e^{j2\pi.0.02}, \\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$

TABLE A2
EVALUATIONS FOR THE CRITERIA

Expert 1				
	Cost	**Customer**	**Infrastructure**	**Innovation**
Cost		M	M	M
Customer	M		H	M
Infrastructure	VH	H		M
Innovation	M	M	M	
Expert 2				
	Cost	**Customer**	**Infrastructure**	**Innovation**
Cost		M	H	VH
Customer	M		H	M
Infrastructure	VH	VH		H
Innovation	M	M	M	
Expert 3				
	Cost	**Customer**	**Infrastructure**	**Innovation**
Cost		S	M	S
Customer	M		H	S
Infrastructure	VH	H		S
Innovation	H	H	VH	

TABLE A3
QUANTUM PICTURE FUZZY NUMBERS FOR THE RELATION MATRIX

Expert 1				
	Cost	**Customer**	**Infrastructure**	**Innovation**
Cost		$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$
Customer	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$
Infrastructure	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$
Innovation	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	
Expert 2				
	Cost	**Customer**	**Infrastructure**	**Innovation**
Cost		$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$
Customer	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$
Infrastructure	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$
Innovation	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	
Expert 3				
	Cost	**Customer**	**Infrastructure**	**Innovation**
Cost		$\begin{bmatrix}\sqrt{0.20}e^{j2\pi.0.45},\\ \sqrt{0.13}e^{j2\pi.0.28},\\ \sqrt{0.42}e^{j2\pi.0.17},\\ \sqrt{0.25}e^{j2\pi.0.10}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.20}e^{j2\pi.0.45},\\ \sqrt{0.13}e^{j2\pi.0.28},\\ \sqrt{0.42}e^{j2\pi.0.17},\\ \sqrt{0.25}e^{j2\pi.0.10}\end{bmatrix}$
Customer	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.20}e^{j2\pi.0.45},\\ \sqrt{0.13}e^{j2\pi.0.28},\\ \sqrt{0.42}e^{j2\pi.0.17},\\ \sqrt{0.25}e^{j2\pi.0.10}\end{bmatrix}$
Infrastructure	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$		$\begin{bmatrix}\sqrt{0.20}e^{j2\pi.0.45},\\ \sqrt{0.13}e^{j2\pi.0.28},\\ \sqrt{0.42}e^{j2\pi.0.17},\\ \sqrt{0.25}e^{j2\pi.0.10}\end{bmatrix}$
Innovation	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	

TABLE A4
QUANTUM PICTURE FUZZY ROUGH SETS FOR THE DIRECT RELATION MATRIX

	Cost	**Customer**	**Infrastructure**	**Innovation**
Cost		$\left[\sqrt{0.20},\sqrt{0.25}\right] e^{j2\pi.[0.45,0.50]}$, $\left[\sqrt{0.13},\sqrt{0.15}\right] e^{j2\pi.[0.28,0.31]}$, $\left[\sqrt{0.37},\sqrt{0.42}\right] e^{j2\pi.[0.12,0.17]}$, $\left[\sqrt{0.23},\sqrt{0.25}\right] e^{j2\pi.[0.07,0.10]}$	$\left[\sqrt{0.25},\sqrt{0.30}\right] e^{j2\pi.[0.50,0.55]}$, $\left[\sqrt{0.15},\sqrt{0.19}\right] e^{j2\pi.[0.31,0.34]}$, $\left[\sqrt{0.32},\sqrt{0.37}\right] e^{j2\pi.[0.07,0.12]}$, $\left[\sqrt{0.19},\sqrt{0.23}\right] e^{j2\pi.[0.04,0.07]}$	$\left[\sqrt{0.20},\sqrt{0.36}\right] e^{j2\pi.[0.55,0.60]}$, $\left[\sqrt{0.13},\sqrt{0.22}\right] e^{j2\pi.[0.34,0.37]}$, $\left[\sqrt{0.32},\sqrt{0.42}\right] e^{j2\pi.[0.07,0.17]}$, $\left[\sqrt{0.19},\sqrt{0.25}\right] e^{j2\pi.[0.04,0.10]}$
Customer	$\left[\sqrt{0.25},\sqrt{0.25}\right] e^{j2\pi.[0.50,0.50]}$, $\left[\sqrt{0.15},\sqrt{0.15}\right] e^{j2\pi.[0.31,0.31]}$, $\left[\sqrt{0.37},\sqrt{0.37}\right] e^{j2\pi.[0.12,0.12]}$, $\left[\sqrt{0.23},\sqrt{0.23}\right] e^{j2\pi.[0.07,0.07]}$		$\left[\sqrt{0.30},\sqrt{0.36}\right] e^{j2\pi.[0.55,0.60]}$, $\left[\sqrt{0.19},\sqrt{0.22}\right] e^{j2\pi.[0.34,0.37]}$, $\left[\sqrt{0.26},\sqrt{0.32}\right] e^{j2\pi.[0.02,0.07]}$, $\left[\sqrt{0.16},\sqrt{0.19}\right] e^{j2\pi.[0.01,0.04]}$	$\left[\sqrt{0.20},\sqrt{0.25}\right] e^{j2\pi.[0.45,0.50]}$, $\left[\sqrt{0.13},\sqrt{0.15}\right] e^{j2\pi.[0.28,0.31]}$, $\left[\sqrt{0.37},\sqrt{0.42}\right] e^{j2\pi.[0.12,0.17]}$, $\left[\sqrt{0.23},\sqrt{0.25}\right] e^{j2\pi.[0.07,0.10]}$
Infrastructure	$\left[\sqrt{0.36},\sqrt{0.36}\right] e^{j2\pi.[0.60,0.60]}$, $\left[\sqrt{0.22},\sqrt{0.22}\right] e^{j2\pi.[0.37,0.37]}$, $\left[\sqrt{0.26},\sqrt{0.26}\right] e^{j2\pi.[0.02,0.02]}$, $\left[\sqrt{0.16},\sqrt{0.16}\right] e^{j2\pi.[0.01,0.01]}$	$\left[\sqrt{0.30},\sqrt{0.36}\right] e^{j2\pi.[0.55,0.60]}$, $\left[\sqrt{0.19},\sqrt{0.22}\right] e^{j2\pi.[0.34,0.37]}$, $\left[\sqrt{0.26},\sqrt{0.32}\right] e^{j2\pi.[0.02,0.07]}$, $\left[\sqrt{0.16},\sqrt{0.19}\right] e^{j2\pi.[0.01,0.04]}$		$\left[\sqrt{0.20},\sqrt{0.30}\right] e^{j2\pi.[0.45,0.55]}$, $\left[\sqrt{0.13},\sqrt{0.19}\right] e^{j2\pi.[0.28,0.34]}$, $\left[\sqrt{0.37},\sqrt{0.42}\right] e^{j2\pi.[0.12,0.17]}$, $\left[\sqrt{0.23},\sqrt{0.25}\right] e^{j2\pi.[0.07,0.10]}$
Innovation	$\left[\sqrt{0.25},\sqrt{0.30}\right] e^{j2\pi.[0.50,0.55]}$, $\left[\sqrt{0.15},\sqrt{0.19}\right] e^{j2\pi.[0.31,0.34]}$, $\left[\sqrt{0.32},\sqrt{0.37}\right] e^{j2\pi.[0.07,0.12]}$, $\left[\sqrt{0.19},\sqrt{0.23}\right] e^{j2\pi.[0.04,0.07]}$	$\left[\sqrt{0.25},\sqrt{0.30}\right] e^{j2\pi.[0.50,0.55]}$, $\left[\sqrt{0.15},\sqrt{0.19}\right] e^{j2\pi.[0.31,0.34]}$, $\left[\sqrt{0.32},\sqrt{0.37}\right] e^{j2\pi.[0.07,0.12]}$, $\left[\sqrt{0.19},\sqrt{0.23}\right] e^{j2\pi.[0.04,0.07]}$	$\left[\sqrt{0.25},\sqrt{0.36}\right] e^{j2\pi.[0.50,0.60]}$, $\left[\sqrt{0.15},\sqrt{0.22}\right] e^{j2\pi.[0.31,0.37]}$, $\left[\sqrt{0.32},\sqrt{0.37}\right] e^{j2\pi.[0.07,0.12]}$, $\left[\sqrt{0.19},\sqrt{0.23}\right] e^{j2\pi.[0.04,0.07]}$	

TABLE A5
DEFUZZIFIED VALUES

	Cost	**Customer**	**Infrastructure**	**Innovation**
Cost	0.000	0.332	0.365	0.372
Customer	0.346	0.000	0.381	0.332
Infrastructure	0.409	0.396	0.000	0.352
Innovation	0.365	0.365	0.382	0.000

TABLE A6
NORMALIZED MATRIX

	Cost	**Customer**	**Infrastructure**	**Innovation**
Cost	0.000	0.311	0.341	0.348
Customer	0.327	0.000	0.360	0.313
Infrastructure	0.353	0.343	0.000	0.304
Innovation	0.328	0.328	0.344	0.000

TABLE A7
SJ, *KJ*, *QJ*, AND *WJ* VALUES

Cost	**sj**	**kj**	**qj**	**wj**	**Customer**	**sj**	**kj**	**qj**	**wj**
Innovation	0.348	1.000	1.000	0.432	Infrastructure	0.360	1.000	1.000	0.430
Infrastructure	0.341	1.341	0.746	0.322	Cost	0.327	1.327	0.754	0.324
Customer	0.311	1.311	0.569	0.246	Innovation	0.313	1.313	0.574	0.247
Infrastructure	**sj**	**kj**	**qj**	**wj**	**Innovation**	**sj**	**kj**	**qj**	**wj**
Cost	0.353	1.000	1.000	0.432	Infrastructure	0.344	1.000	1.000	0.399
Customer	0.343	1.343	0.745	0.322	Cost	0.328	1.328	0.753	0.300
Innovation	0.304	1.304	0.571	0.247	Customer	0.328	1.000	0.753	0.300

TABLE A8
EVALUATIONS FOR THE ALTERNATIVES

Expert 1				
	Cost	**Customer**	**Infrastructure**	**Innovation**
ETMWS	G	G	B	B
PTLET	F	B	F	G
RTFZC	G	G	B	G
SOVFW	B	F	F	G
OECTG	G	G	G	F
Expert 2				
	Cost	**Customer**	**Infrastructure**	**Innovation**
ETMWS	G	F	B	F
PTLET	F	B	F	G
RTFZC	G	B	B	B
SOVFW	B	F	F	B
OECTG	F	G	F	F
Expert 3				
	Cost	**Customer**	**Infrastructure**	**Innovation**
ETMWS	G	G	B	B
PTLET	P	B	P	G
RTFZC	G	G	B	G
SOVFW	G	P	F	G
OECTG	G	G	G	F

TABLE A9
QUANTUM PICTURE FUZZY NUMBERS FOR THE DECISION MATRIX

Expert 1				
	Cost	**Customer**	**Infrastructure**	**Innovation**
ETMWS	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$
PTLET	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$
RTFZC	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$
SOVFW	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$
OECTG	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$
Expert 2				
	Cost	**Customer**	**Infrastructure**	**Innovation**
ETMWS	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$
PTLET	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$
RTFZC	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$
SOVFW	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$
OECTG	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$
Expert 3				
	Cost	**Customer**	**Infrastructure**	**Innovation**
ETMWS	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$
PTLET	$\begin{bmatrix}\sqrt{0.20}e^{j2\pi.0.45},\\ \sqrt{0.13}e^{j2\pi.0.28},\\ \sqrt{0.42}e^{j2\pi.0.17},\\ \sqrt{0.25}e^{j2\pi.0.10}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.20}e^{j2\pi.0.45},\\ \sqrt{0.13}e^{j2\pi.0.28},\\ \sqrt{0.42}e^{j2\pi.0.17},\\ \sqrt{0.25}e^{j2\pi.0.10}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$
RTFZC	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.36}e^{j2\pi.0.6},\\ \sqrt{0.22}e^{j2\pi.0.37},\\ \sqrt{0.26}e^{j2\pi.0.02},\\ \sqrt{0.16}e^{j2\pi.0.01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$
SOVFW	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.20}e^{j2\pi.0.45},\\ \sqrt{0.13}e^{j2\pi.0.28},\\ \sqrt{0.42}e^{j2\pi.0.17},\\ \sqrt{0.25}e^{j2\pi.0.10}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$
OECTG	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.30}e^{j2\pi.0.55},\\ \sqrt{0.19}e^{j2\pi.0.34},\\ \sqrt{0.32}e^{j2\pi.0.07},\\ \sqrt{0.19}e^{j2\pi.0.04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{0.25}e^{j2\pi.0.50},\\ \sqrt{0.15}e^{j2\pi.0.31},\\ \sqrt{0.37}e^{j2\pi.0.12},\\ \sqrt{0.23}e^{j2\pi.0.07}\end{bmatrix}$

TABLE A10
QUANTUM PICTURE FUZZY ROUGH SETS FOR THE DECISION MATRIX

	Cost	**Customer**	**Infrastructure**	**Innovation**
ETMWS	$\left\lceil\sqrt{0.30},\sqrt{0.30}\right\rfloor e^{j2\pi.\lceil 0.55,0.55\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.34,0.34\rfloor}$, $\left\lceil\sqrt{0.32},\sqrt{0.32}\right\rfloor e^{j2\pi.\lceil 0.07,0.07\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.04,0.04\rfloor}$	$\left\lceil\sqrt{0.25},\sqrt{0.30}\right\rfloor e^{j2\pi.\lceil 0.50,0.55\rfloor}$, $\left\lceil\sqrt{0.15},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.31,0.34\rfloor}$, $\left\lceil\sqrt{0.32},\sqrt{0.37}\right\rfloor e^{j2\pi.\lceil 0.07,0.12\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.23}\right\rfloor e^{j2\pi.\lceil 0.04,0.07\rfloor}$	$\left\lceil\sqrt{0.36},\sqrt{0.36}\right\rfloor e^{j2\pi.\lceil 0.60,0.60\rfloor}$, $\left\lceil\sqrt{0.22},\sqrt{0.22}\right\rfloor e^{j2\pi.\lceil 0.37,0.37\rfloor}$, $\left\lceil\sqrt{0.26},\sqrt{0.26}\right\rfloor e^{j2\pi.\lceil 0.02,0.02\rfloor}$, $\left\lceil\sqrt{0.16},\sqrt{0.16}\right\rfloor e^{j2\pi.\lceil 0.01,0.01\rfloor}$	$\left\lceil\sqrt{0.25},\sqrt{0.36}\right\rfloor e^{j2\pi.\lceil 0.50,0.60\rfloor}$, $\left\lceil\sqrt{0.15},\sqrt{0.22}\right\rfloor e^{j2\pi.\lceil 0.31,0.37\rfloor}$, $\left\lceil\sqrt{0.32},\sqrt{0.37}\right\rfloor e^{j2\pi.\lceil 0.07,0.12\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.23}\right\rfloor e^{j2\pi.\lceil 0.04,0.07\rfloor}$
PTLET	$\left\lceil\sqrt{0.20},\sqrt{0.25}\right\rfloor e^{j2\pi.\lceil 0.45,0.50\rfloor}$, $\left\lceil\sqrt{0.13},\sqrt{0.15}\right\rfloor e^{j2\pi.\lceil 0.28,0.31\rfloor}$, $\left\lceil\sqrt{0.37},\sqrt{0.42}\right\rfloor e^{j2\pi.\lceil 0.12,0.17\rfloor}$, $\left\lceil\sqrt{0.23},\sqrt{0.25}\right\rfloor e^{j2\pi.\lceil 0.07,0.10\rfloor}$	$\left\lceil\sqrt{0.36},\sqrt{0.36}\right\rfloor e^{j2\pi.\lceil 0.60,0.60\rfloor}$, $\left\lceil\sqrt{0.22},\sqrt{0.22}\right\rfloor e^{j2\pi.\lceil 0.37,0.37\rfloor}$, $\left\lceil\sqrt{0.26},\sqrt{0.26}\right\rfloor e^{j2\pi.\lceil 0.02,0.02\rfloor}$, $\left\lceil\sqrt{0.16},\sqrt{0.16}\right\rfloor e^{j2\pi.\lceil 0.01,0.01\rfloor}$	$\left\lceil\sqrt{0.20},\sqrt{0.25}\right\rfloor e^{j2\pi.\lceil 0.45,0.50\rfloor}$, $\left\lceil\sqrt{0.13},\sqrt{0.15}\right\rfloor e^{j2\pi.\lceil 0.28,0.31\rfloor}$, $\left\lceil\sqrt{0.37},\sqrt{0.42}\right\rfloor e^{j2\pi.\lceil 0.12,0.17\rfloor}$, $\left\lceil\sqrt{0.23},\sqrt{0.25}\right\rfloor e^{j2\pi.\lceil 0.07,0.10\rfloor}$	$\left\lceil\sqrt{0.30},\sqrt{0.30}\right\rfloor e^{j2\pi.\lceil 0.55,0.55\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.34,0.34\rfloor}$, $\left\lceil\sqrt{0.32},\sqrt{0.32}\right\rfloor e^{j2\pi.\lceil 0.07,0.07\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.04,0.04\rfloor}$
RTFZC	$\left\lceil\sqrt{0.30},\sqrt{0.30}\right\rfloor e^{j2\pi.\lceil 0.55,0.55\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.34,0.34\rfloor}$, $\left\lceil\sqrt{0.32},\sqrt{0.32}\right\rfloor e^{j2\pi.\lceil 0.07,0.07\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.04,0.04\rfloor}$	$\left\lceil\sqrt{0.30},\sqrt{0.36}\right\rfloor e^{j2\pi.\lceil 0.55,0.60\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.22}\right\rfloor e^{j2\pi.\lceil 0.34,0.37\rfloor}$, $\left\lceil\sqrt{0.26},\sqrt{0.32}\right\rfloor e^{j2\pi.\lceil 0.02,0.07\rfloor}$, $\left\lceil\sqrt{0.16},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.01,0.04\rfloor}$	$\left\lceil\sqrt{0.36},\sqrt{0.36}\right\rfloor e^{j2\pi.\lceil 0.60,0.60\rfloor}$, $\left\lceil\sqrt{0.22},\sqrt{0.22}\right\rfloor e^{j2\pi.\lceil 0.37,0.37\rfloor}$, $\left\lceil\sqrt{0.26},\sqrt{0.26}\right\rfloor e^{j2\pi.\lceil 0.02,0.02\rfloor}$, $\left\lceil\sqrt{0.16},\sqrt{0.16}\right\rfloor e^{j2\pi.\lceil 0.01,0.01\rfloor}$	$\left\lceil\sqrt{0.30},\sqrt{0.36}\right\rfloor e^{j2\pi.\lceil 0.55,0.60\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.22}\right\rfloor e^{j2\pi.\lceil 0.34,0.37\rfloor}$, $\left\lceil\sqrt{0.26},\sqrt{0.32}\right\rfloor e^{j2\pi.\lceil 0.02,0.07\rfloor}$, $\left\lceil\sqrt{0.16},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.01,0.04\rfloor}$
SOVFW	$\left\lceil\sqrt{0.30},\sqrt{0.36}\right\rfloor e^{j2\pi.\lceil 0.55,0.60\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.22}\right\rfloor e^{j2\pi.\lceil 0.34,0.37\rfloor}$, $\left\lceil\sqrt{0.26},\sqrt{0.32}\right\rfloor e^{j2\pi.\lceil 0.02,0.07\rfloor}$, $\left\lceil\sqrt{0.16},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.01,0.04\rfloor}$	$\left\lceil\sqrt{0.20},\sqrt{0.25}\right\rfloor e^{j2\pi.\lceil 0.45,0.50\rfloor}$, $\left\lceil\sqrt{0.13},\sqrt{0.15}\right\rfloor e^{j2\pi.\lceil 0.28,0.31\rfloor}$, $\left\lceil\sqrt{0.37},\sqrt{0.42}\right\rfloor e^{j2\pi.\lceil 0.12,0.17\rfloor}$, $\left\lceil\sqrt{0.23},\sqrt{0.25}\right\rfloor e^{j2\pi.\lceil 0.07,0.10\rfloor}$	$\left\lceil\sqrt{0.25},\sqrt{0.25}\right\rfloor e^{j2\pi.\lceil 0.50,0.50\rfloor}$, $\left\lceil\sqrt{0.15},\sqrt{0.15}\right\rfloor e^{j2\pi.\lceil 0.31,0.31\rfloor}$, $\left\lceil\sqrt{0.37},\sqrt{0.37}\right\rfloor e^{j2\pi.\lceil 0.12,0.12\rfloor}$, $\left\lceil\sqrt{0.23},\sqrt{0.23}\right\rfloor e^{j2\pi.\lceil 0.07,0.07\rfloor}$	$\left\lceil\sqrt{0.30},\sqrt{0.36}\right\rfloor e^{j2\pi.\lceil 0.55,0.60\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.22}\right\rfloor e^{j2\pi.\lceil 0.34,0.37\rfloor}$, $\left\lceil\sqrt{0.26},\sqrt{0.32}\right\rfloor e^{j2\pi.\lceil 0.02,0.07\rfloor}$, $\left\lceil\sqrt{0.16},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.01,0.04\rfloor}$
OECTG	$\left\lceil\sqrt{0.25},\sqrt{0.30}\right\rfloor e^{j2\pi.\lceil 0.50,0.55\rfloor}$, $\left\lceil\sqrt{0.15},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.31,0.34\rfloor}$, $\left\lceil\sqrt{0.32},\sqrt{0.37}\right\rfloor e^{j2\pi.\lceil 0.07,0.12\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.23}\right\rfloor e^{j2\pi.\lceil 0.04,0.07\rfloor}$	$\left\lceil\sqrt{0.30},\sqrt{0.30}\right\rfloor e^{j2\pi.\lceil 0.55,0.55\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.34,0.34\rfloor}$, $\left\lceil\sqrt{0.32},\sqrt{0.32}\right\rfloor e^{j2\pi.\lceil 0.07,0.07\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.04,0.04\rfloor}$	$\left\lceil\sqrt{0.25},\sqrt{0.30}\right\rfloor e^{j2\pi.\lceil 0.50,0.55\rfloor}$, $\left\lceil\sqrt{0.15},\sqrt{0.19}\right\rfloor e^{j2\pi.\lceil 0.31,0.34\rfloor}$, $\left\lceil\sqrt{0.32},\sqrt{0.37}\right\rfloor e^{j2\pi.\lceil 0.07,0.12\rfloor}$, $\left\lceil\sqrt{0.19},\sqrt{0.23}\right\rfloor e^{j2\pi.\lceil 0.04,0.07\rfloor}$	$\left\lceil\sqrt{0.25},\sqrt{0.25}\right\rfloor e^{j2\pi.\lceil 0.50,0.50\rfloor}$, $\left\lceil\sqrt{0.15},\sqrt{0.15}\right\rfloor e^{j2\pi.\lceil 0.31,0.31\rfloor}$, $\left\lceil\sqrt{0.37},\sqrt{0.37}\right\rfloor e^{j2\pi.\lceil 0.12,0.12\rfloor}$, $\left\lceil\sqrt{0.23},\sqrt{0.23}\right\rfloor e^{j2\pi.\lceil 0.07,0.07\rfloor}$

TABLE A11
DEFUZZIFIED VALUES

	Cost	**Customer**	**Infrastructure**	**Innovation**
ETMWS	0.381	0.365	0.409	0.382
PTLET	0.332	0.409	0.332	0.381
RTFZC	0.381	0.396	0.409	0.396
SOVFW	0.396	0.332	0.346	0.396
OECTG	0.365	0.381	0.365	0.346

TABLE A12
NORMALIZED VALUES

	Cost	**Customer**	**Infrastructure**	**Innovation**
ETMWS	0.459	0.432	0.489	0.448
PTLET	0.399	0.484	0.398	0.448
RTFZC	0.459	0.470	0.489	0.465
SOVFW	0.477	0.393	0.415	0.465
OECTG	0.439	0.452	0.437	0.407

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