International Scientific Spectrum Volume 2, Issue 1 (2026) 73-98

International Scientific Spectrum

Journal homepage: www.iscis-journal.org
ISSN: 3104-3305

Assessment of Knowledge-Based Innovative Business Investments in Electric Vehicle Industry Through Artificial Intelligence and Integrated Quantum Fuzzy Model

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ARTICLE INFO

Article history:
Received 7 November 2025
Received in revised form 29 December 2025
Accepted 14 January 2026
Available online 24 December 2026

Keywords:
Knowledge management; Knowledge-based investments; Innovative business projects; Electric vehicle

ABSTRACT

Appropriate policies should be implemented to increase the performance of knowledge-based innovative business investments in electric vehicle projects. However, these practices also lead to an increase in the operational costs of companies. Therefore, businesses should determine priority areas for performance improvement. This situation increases the need for priority analysis in this area. Accordingly, the purpose of this study is to evaluate knowledge-based innovative business investments in the electric vehicle industry. Within this context, a new fuzzy decision-making model is proposed. The first stage includes prioritization of the decision-makers with the help of an artificial intelligence (AI) methodology. Next, the missing evaluations of knowledge-based innovative business investments in the electric vehicle industry are estimated using an expert recommender system. In the following stage, the criteria for innovative solutions in electric vehicles are weighted via a quantum picture fuzzy rough set-based (QPFR) M-SWARA method. In the final stage, the business alternatives for the electric vehicle industry are ranked with the help of QPFR VIKOR. The main contribution of this study to the literature is the integration of AI techniques into the fuzzy decision-making methodology. This approach creates an opportunity to compute the weights of the decision-makers. With the help of this issue, it is possible to obtain more effective findings. It is concluded that the most important criteria for innovative solutions in electric vehicles are technology transfer among industries and incentives for research and development. On the other hand, the ranking results demonstrate that efficient material selection with recycling processes and flexible transportation using data-driven services are the most significant business alternatives for the electric vehicle industry.

1. Introduction

Electric vehicle projects are very important investments due to issues such as ensuring energy efficiency and reducing carbon emissions. Therefore, necessary measures must be taken for the

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https://doi.org/10.66972/iscis2120269

development of electric vehicles. Knowledge-based innovative business investments play an important role in technology-oriented areas such as electric vehicle projects. This is especially important in terms of ensuring technological innovation. Thanks to knowledge-based investments, it is possible to focus more on research and development studies. This allows the costs of electric vehicle production to be reduced [1]. On the other hand, a more successful new product development process can be achieved with innovative business investments. Thus, it is possible to develop more successful electric vehicles. This helps us to meet customer expectations more successfully. In addition to them, these projects also enable the production processes of electric vehicles to be more innovative and successful [2]. This supports the more reliable development of electric vehicles. In summary, knowledge-based investments enable the development of the electric vehicle industry in many different aspects [3].

Necessary actions need to be taken to increase the performance of knowledge-based innovative business investments in electric vehicle projects. First, it is very important to ensure the organizational competence of the business to achieve this goal [4]. The organizational effectiveness of the business enables the resources to be used more effectively. Moreover, increasing research and development studies is another important issue in this process. Thanks to these studies, advantages such as extending the life of the batteries and increasing the charging time can be achieved [5]. On the other hand, ensuring global competition is another issue that should be taken into consideration in this process. Thanks to global competition, electric vehicle companies can capture more growth opportunities. Owing to this situation, businesses can significantly increase their market share. Ensuring intersectoral technology transfer supports the advancement of electric vehicle technology [6]. This increases the performance of projects and provides businesses with a significant competitive advantage.

Improving all performance indicators at the same time to increase the performance of these projects significantly increases financial costs. In this case, excessively high costs lead to a decrease in the profitability of the projects. If profitability is not ensured, it will be very difficult to ensure the sustainability of the projects [7]. Therefore, businesses should determine priority areas for performance improvement. In this way, the limited resources of businesses can be managed more effectively. In this context, it would be better to determine the priority issues and focus on the more important criteria. Therefore, it is necessary to determine the most important variables that affect the performance of electric vehicle projects [8]. However, there are a limited number of studies in this context in literature. This situation increases the need for priority analysis in this area.

Accordingly, the purpose of this study is to evaluate the knowledge-based innovative business investments in electric vehicle industry. Therefore, the main question of research is to understand which business alternatives should be implemented first for electric vehicle industry. In this framework, a new fuzzy decision-making model is generated. The first stage consists of prioritization of the decision makers by the help of AI methodology. Secondly, the missing evaluations of knowledge-based innovative business investments in electric vehicle industry are estimated with expert recommender system. Thirdly, the criteria for innovative solutions in electric vehicles are weighed via QPFR M-SWARA. In the final stage, the business alternatives for electric vehicle industry are ranked with the help of QPFR VIKOR. The motivation of this study is the need for a comprehensive decision-making analysis with respect to the knowledge-based innovative business investments in electric vehicle industry. The most important criticism of existing models is that the importance weights of experts with different characteristics are considered the same. On the other hand, the evaluations of experts with more knowledge and experience should be taken into account with a higher coefficient. To achieve this goal, in this model, a decision matrix is created with AI and importance weights are calculated according to the demographic characteristics of the experts.

The main contributions of this study to the literature are shown below: (i) Considering M-SWARA methodology to weigh the criteria provides some advantages. This technique is created by making some improvements to the classical SWARA approach. Owing to these improvements, the impact relation map of the criteria is generated. The main performance indicators of the knowledge-based innovative business investments in electric vehicle industry can have an influence on each other. Because of this issue, for the purpose of finding the most critical items, the causal direction among these items should be considered. Hence, using M-SWARA methodology in this process increases the appropriateness of the analysis results. (ii) Using collaborative filtering technique in the analysis process provides an opportunity for the experts not to answer the questions when they are not sure. In the decision-making models where, collaborative filtering is not used, the decision makers are forced to give answers to all questions. Therefore, it is seen that collaborative filtering methodology helps to increase the effectiveness of the proposed model. (iii) Integration of the AI technique into the fuzzy decision-making methodology is one of the most essential contributions of this proposed model to literature. With the help of this issue, it can be possible to reach more effective findings.

The second part reviews similar studies from literature. The methodology of articles is explained in the following section. The fourth section consists of the analysis results. The final parts give information about the discussion and conclusion.

2. Literature Review

Global competition is one of the most important criteria in the development of innovative solutions for electric vehicle investments. Global competition can be expressed as increasing the efficiency of production, discovering new technologies and developing products that can better respond to consumer demands [9]. Similarly, vehicle production and sales, charging network services and construction, facility standards and vehicle management can be given as examples for this situation [10]. Innovations in business models in these fields can also have a positive impact on the global development and spread of electric vehicles [11]. In other words, the increasing trend of transportation electrification also gives investors the opportunity to provide charging services to electric vehicle owners and offers competitive prices compared to regulated service usage rates [12]. Shao *et al.* [13] made evaluation for the competition among lithium importers because lithium is widely used in the electric vehicle industry. As a result, with the competition getting tougher, the competition between lithium importing countries has gradually transformed from regional competition to global competition. Zavvos *et al.* [14] proposed a new sequential, game theory model for firm competition and algorithms to solve this situation. They made a model for rival station investors who aim to maximize the expected profit by charging stations along the road, which is essential to ensure the adoption of electric vehicles.

Research and development incentives are another factor that is effective in developing innovative solutions for electric vehicle investments. For this purpose, discounts and charging infrastructure investments are designed to encourage the adoption of electric vehicles [15]. In this process, it is aimed to achieve emission reduction goals by offering tax credits, subsidies, and charging station installation [16]. Moreover, the government also plays an important role in supporting the electric vehicle industry by providing the research and development funding necessary to motivate scientists and engineers to enter new areas of innovation [17, 18]. Veza *et al.* [19] and Guo and Zhang [20] addressed some critical issues in the implementation of electric vehicles in Malaysia and Indonesia. In this study, they provided a summary of the adoption scenario of electric vehicles in each country and then described the types of electric vehicles and battery capacities available in both countries. Xia *et al.* [21] and Deng *et al.* [22] considered electric vehicles as innovative products that are different from conventional fuel vehicles and proposed a research model in which several factors affecting the adoption of electric vehicles are identified.

Intersectoral technology transfer is another criterion that plays an important role in the development of innovative solutions for electric vehicle investments. While technology transfer refers to an active process in which advanced technologies are transferred between two different actors, in a competitive environment, the development and commercialization of new technologies such as battery electric vehicles increasingly depend on technology transfer [23]. The main drivers of technology transfer are the innovation capacity of countries and the scale of the countries' market demand for battery electric vehicle technology [24]. In other words, technology transfer brings together knowledge and experience in different industries and contributes to the development of electric vehicles in a more efficient, competitive, and sustainable way [25]. Trying to include more details about knowledge and technology transfer, Qu and Zhang [26] measured patent assignments as well as citations to academic studies in global electric vehicle pricing patent documents. They provided a broad assessment of the relationship between knowledge obtained from the business sector and inventions that are subsequently patented. According to Esmaili *et al.* [27] and Wu and Xu [28], since the electric vehicle industry includes various technological collaborative innovations, it needs to cooperate with businesses and research institutions in the sector. The structure and evolution characteristics of the research institution are evaluated in this study.

Organizational competencies are another effective criterion in the development of innovative solutions for electric vehicle investments. The resources, knowledge and skills of an organization can be decisive for the development and marketing of electric vehicle technologies [29, 30]. In addition, organizational capabilities that influence a firm's decision and its ability to pursue modular innovation to varying degrees can undoubtedly be considered an important success factor [31, 32]. Carlton and Sultana [33] and Cabigiosu [34] described the process for open innovation for the supply and development of electric batteries. They reached the conclusion that coordination of different departments in electrical vehicle companies plays a critical role in achieving this objective. Huang *et al.* [35] and Berhorst *et al.* [36] formulated a plan to expand the competency set for electric vehicles by leveraging the skills developed by developed economies. They aimed to achieve the goals of minimizing learning time, reducing learning costs and maximizing the quality of learning.

The results of the literature review explain that the popularity of electrical vehicles has increased especially in the lats years mainly because of the negative effects of the carbon emission problem. Therefore, significant innovative solutions should be identified for the improvements of these investments. In other words, the knowledge-based innovative business investments in electric vehicle industry should be determined. However, there are lots of indicators for the performance improvements of this process. Because making improvements for these indicators increases the costs of the companies. Therefore, it is not possible for the companies to focus on lots of improvements. Due to this condition, companies should mainly focus on the most important determinants to manage the budget constraint problem. Thus, most critical performance indicators of this process should be identified. Nevertheless, the number of the studies in the literature related to this issue are quite limited. Thus, there is a need for a new study that evaluates the most critical indicators of these projects. To satisfy this situation, a priority analysis has been conducted in this study with respect to the performance indicators of the knowledge-based innovative business investments in electric vehicle industry.

3. Methodology

Effective criteria for innovative solutions in electric vehicles are defined. In the analysis of the study, hybrid multi-criteria decision-making techniques are used. The criteria set obtained by literature analysis is weighted with the M-SWARA method. Thus, the criteria that should be prioritized for the electric vehicle industry are determined. In the continuation of the study, business alternatives for the electric vehicle industry are investigated. The VIKOR method is used to determine the optimal business alternative. For computing of the criteria weights in the VIKOR method, the values obtained from the previous method are considered.

The hybrid model used in the analysis of the article analyzes decision makers (DMs) opinions. Using direct evaluations has been criticized due to its use of linguistic expressions and the different levels of knowledge of DMs. In the study, fuzzy set theory is used to analyze ambiguity in linguistic expressions. Quantum picture fuzzy rough sets (QPFRS) with golden ratio are preferred to evaluate uncertainty in linguistic expressions. In addition, the sociodemographic structures of the DMs and the artificial intelligence-based DMs prioritization algorithm are used. In this way, DMs selection and weighting are achieved. Finally, missing data in DMs opinions are completed with the Collaborative Filtering method. Details of the methods used in the four stages of the article are presented under subheadings in this section.

3.1. DMs Prioritization Using AI-based Decision-Making

Computing unweighted arithmetic mean of opinions of DMs is a situation that has been criticized in recent years. For this criticism, an artificial intelligence model based the k-means clustering algorithm is suggested in the article. Within-Cluster Sum of Squares (WCSS) is computed to find the optimal number of the cluster (k). The steps of the DMs prioritization model are introduced below [37]. WCSS with different values of k is defined using Equations (1)-(3).

$$WCSS = \sum_{j=1}^{k} \sum_{x_i \in C_j} d(x_i, c_j)^2 \tag{1}$$

$$d(x_i, x_j) = \sqrt{\sum_{l=1}^{n} (x_{il} - x_{jl})^2} \tag{2}$$

$$c_j = \frac{1}{|C_j|} \sum_{x_i \in C_j} x_i \tag{3}$$

The weights of DMs are calculated with DMs' cluster weights. The mean standard deviations (s_j) are found by Equations (4)-(8).

$$s_j = \frac{1}{n} \sum_{l=1}^{n} \sigma_{jl} \tag{4}$$

$$\sigma_{jl} = \sqrt{\frac{1}{|C_j|} \sum_{x_i \in C_j} (x_{il} - \bar{x}_{jl})^2} \tag{5}$$

$$\bar{x}_{jl} = \frac{1}{|C_j|} \sum_{x_i \in C_j} x_{il} \tag{6}$$

$$w_j = |\, C_j \,| \times s_j \tag{7}$$

$$w_{tj} = \frac{1}{|C_j|} \frac{w_j}{\sum_{w_j \in C_j} w_j} \tag{8}$$

3.2. Recommender System with Collaborative Filtering

In models where the evaluations of DMs are taken into account, DMs may sometimes not want to express their opinion or make incomplete evaluations. In both conditions, Asking DMs again negatively impact the validity of the analysis. In other words, requiring opinions of DMs can be misleading. Therefore, the following method steps (Equations (9) and (10)) are recommended to complete the missing opinions [38].

$$sim(u,v) = \frac{\sum_{i\in I}(r_{u,i}-\overline{r_u})(r_{v,i}-\overline{r_v})}{\sqrt{\sum_{i\in I}(r_{u,i}-\overline{r_u})^2}\sqrt{\sum_{i\in I}(r_{v,i}-\overline{r_v})^2}} \quad (9)$$

$$p_{u,i} = \frac{\sum_{j\in S} sim(u,v) r_{u,j}}{\sum_{j\in S}|sim(u,v)|} \quad (10)$$

3.3. Handling Uncertainties in the Process

Linguistic opinion has an ambiguity. In analyzing with ambiguous terms, fuzzy set theory is used which one discipline of mathematics. Fuzzy set theory is one of theories recommended to measure types of uncertainty. Fuzzy set theory was first put forward by Zadeh and continues to be developed today. The proposed paradigm combines quantum physics with fuzzy set theory. According to quantum physics, the square of ϕ represents the probability of a massless particle. These functions detailed in Equations (11) and (55) consist of a complex structure containing amplitude and phase angle (θ) [39].

$$Q(|u>) = \varphi e^{j\theta} \quad (11)$$

$$|C> = \{|u_1>, |u_2>, \dots, |u_n>\} \quad (12)$$

$$\sum_{|u>\subseteq|C>}|Q(|u>)| = 1 \quad (13)$$

$$A = \{\langle x, \mu_A(x)\rangle | x \in X\} \quad (14)$$

$$A = \{\langle x, \mu_A(x), v_A(x)\rangle | x \in X\} \quad (15)$$

$$A = \{\langle x, \mu_A(x), n_A(x), v_A(x), h_A(x)\rangle | x \in X\} \quad (16)$$

$$A \subseteq B \text{ if } \mu_A(x) \le \mu_B(x) \text{ and } n_A(x) \le n_B(x) \text{ and } v_A(x) \ge v_B(x), \forall x \in X\ ) \quad (17)$$

$$A = B \text{ if } A \subseteq B \text{ and } B \subseteq A \quad (18)$$

$$A \cup B = \left\{\left(x, max\left(\mu_A(x), \mu_B(x)\right), min\left(n_A(x), n_B(x)\right), min\left(v_A(x), v_B(x)\right)\right) | x \in X\right\} \quad (19)$$

$$A \cap B = \left\{\left(x, min\left(\mu_A(x), \mu_B(x)\right), min\left(n_A(x), n_B(x)\right), max\left(v_A(x), v_B(x)\right)\right) | x \in X\right\} \quad (20)$$

$$coA = \bar{A} = \left\{\left(x, v_A(x), n_A(x), \mu_A(x)\right) | x \in X\right\} \quad (21)$$

$$\underline{Apr}(C_i) = \cup\left\{Y \in \frac{X}{R(Y)} \le C_i\right\} \quad (22)$$

$$\overline{Apr}(C_i) = \cup\left\{Y \in \frac{X}{R(Y)} \ge C_i\right\} \quad (23)$$

$$Bnd(C_i) = \cup\left\{Y \in \frac{X}{R(Y)} \ne C_i\right\} \quad (24)$$

$$\underline{Lim}(C_i) = \sqrt[N_L]{\prod_{i=1}^{N_L} Y \in \underline{Apr}(C_i)} \quad (25)$$

$$\overline{Lim}(C_i) = \sqrt[N_U]{\prod_{i=1}^{N_U} Y \in \overline{Apr}(C_i)} \quad (26)$$

$$RN(C_i) = \left[\underline{Lim}(C_i), \overline{Lim}(C_i)\right] \quad (27)$$

$$|C_A> = \left\{ \begin{matrix} \langle u, ([\underline{Lim}(C_{i\mu_A}), \overline{Lim}(C_{i\mu_A})]\,(u), [\underline{Lim}(C_{in_A}), \overline{Lim}(C_{in_A})](u), \\ [\underline{Lim}(C_{iv_A}), \overline{Lim}(C_{iv_A})](u), [\underline{Lim}(C_{ih_A}), \overline{Lim}(C_{ih_A})](u)) | u \in 2^{|C_A>} \end{matrix} \right\} \quad (28)$$

$$\underline{Lim}(C_{i\mu_A}) = \frac{1}{N_{L\mu_A}} \sum_{i=1}^{N_{L\mu_A}} Y \in \underline{Apr}(C_{i\mu_A}) \quad (29)$$

$$\underline{Lim}(C_{in_A}) = \frac{1}{N_{Ln_A}} \sum_{i=1}^{N_{Ln_A}} Y \in \underline{Apr}(C_{in_A}) \quad (30)$$

$$\underline{Lim}(C_{iv_A}) = \frac{1}{N_{Lv_A}} \sum_{i=1}^{N_{Lv_A}} Y \in \underline{Apr}(C_{iv_A}) \quad (31)$$

$$\underline{Lim}(C_{ih_A}) = \frac{1}{N_{L\pi_A}} \sum_{i=1}^{N_{L\pi_A}} Y \in \underline{Apr}(C_{ih_A}) \quad (32)$$

$$\overline{Lim}(C_{i\mu_A}) = \frac{1}{N_{U\mu_A}} \sum_{i=1}^{N_{U\mu_A}} Y \in \overline{Apr}(C_{i\mu_A}) \quad (33)$$

$$\overline{Lim}(C_{in_A}) = \frac{1}{N_{Un_A}} \sum_{i=1}^{N_{Un_A}} Y \in \overline{Apr}(C_{in_A}) \quad (34)$$

$$\overline{Lim}(C_{iv_A}) = \frac{1}{N_{Uv_A}} \sum_{i=1}^{N_{Uv_A}} Y \in \overline{Apr}(C_{iv_A}) \quad (35)$$

$$\overline{Lim}(C_{ih_A}) = \frac{1}{N_{U\pi_A}} \sum_{i=1}^{N_{U\pi_A}} Y \in \overline{Apr}(C_{ih_A}) \quad (36)$$

$$\underline{Apr}(C_{i\mu_A}) = \cup \left\{ Y \in \frac{X}{\tilde{R}(Y)} \leq C_{i\mu_A} \right\} \quad (37)$$

$$\underline{Apr}(C_{in_A}) = \cup \left\{ Y \in \frac{X}{\tilde{R}(Y)} \leq C_{in_A} \right\} \quad (38)$$

$$\underline{Apr}(C_{iv_A}) = \cup \left\{ Y \in \frac{X}{\tilde{R}(Y)} \leq C_{iv_A} \right\} \quad (39)$$

$$\underline{Apr}(C_{ih_A}) = \cup \left\{ Y \in \frac{X}{\tilde{R}(Y)} \leq C_{ih_A} \right\} \quad (40)$$

$$\overline{Apr}(C_{i\mu_A}) = \cup \left\{ Y \in \frac{X}{\tilde{R}(Y)} \leq C_{i\mu_A} \right\} \quad (41)$$

$$\overline{Apr}(C_{in_A}) = \cup \left\{ Y \in \frac{X}{\tilde{R}(Y)} \leq C_{in_A} \right\} \quad (42)$$

$$\overline{Apr}(C_{iv_A}) = \cup \left\{ Y \in \frac{X}{\tilde{R}(Y)} \leq C_{iv_A} \right\} \quad (43)$$

$$\overline{Apr}(C_{ih_A}) = \cup \left\{ Y \in \frac{X}{\tilde{R}(Y)} \leq C_{ih_A} \right\} \quad (44)$$

$$C = [C_\mu . e^{j2\pi.\alpha}, C_n . e^{j2\pi.\gamma}, C_v . e^{j2\pi.\beta}, C_h . e^{j2\pi.T}] \quad (45)$$

$$\varphi^2 = |C_\mu(|u_i>)| \quad (46)$$

$$C_n = \frac{C_\mu}{G} \quad (47)$$

$$C_h = \frac{C_v}{G} \quad (48)$$

$$\alpha = |C_\mu(|u_i>)| \quad (49)$$

$$\gamma = \frac{\alpha}{G} \quad (50)$$

$$T = \frac{\beta}{G} \quad (51)$$

$$\lambda * \tilde{A}_c = \left\{ \begin{matrix} \left[\underline{Lim}(C_{\mu_{\tilde{A}}})\lambda, \overline{Lim}(C_{\mu_{\tilde{A}}})\lambda\right] e^{j2\pi.\left[\left(\frac{\underline{\alpha}_{\tilde{A}}}{2\pi}\right)\lambda, \left(\frac{\overline{\alpha}_{\tilde{A}}}{2\pi}\right)\lambda\right]}, \left[\underline{Lim}(C_{n_{\tilde{A}}})\lambda, \overline{Lim}(C_{n_{\tilde{A}}})\lambda\right] e^{j2\pi.\left[\left(\frac{\underline{\gamma}_{\tilde{A}}}{2\pi}\right)\lambda, \left(\frac{\overline{\gamma}_{\tilde{A}}}{2\pi}\right)\lambda\right]}, \\ \left[\underline{Lim}(C_{v_{\tilde{A}}})\lambda, \overline{Lim}(C_{v_{\tilde{A}}})\lambda\right] e^{j2\pi.\left[\left(\frac{\underline{\beta}_{\tilde{A}}}{2\pi}\right)\lambda, \left(\frac{\overline{\beta}_{\tilde{A}}}{2\pi}\right)\lambda\right]}, \left[\underline{Lim}(C_{h_{\tilde{A}}})\lambda, \overline{Lim}(C_{h_{\tilde{A}}})\lambda\right] e^{j2\pi.\left[\left(\frac{\underline{T}_{\tilde{A}}}{2\pi}\right)\lambda, \left(\frac{\overline{T}_{\tilde{A}}}{2\pi}\right)\lambda\right]} \end{matrix} \right\} \quad (52)$$

$$\tilde{A}_c^{\ \lambda} = \left\{ \begin{matrix} \left[\underline{Lim}(C_{\mu_{\tilde{A}}})^{\lambda}, \overline{Lim}(C_{\mu_{\tilde{A}}})^{\lambda}\right] e^{j2\pi.\left[\left(\frac{\underline{\alpha}_{\tilde{A}}}{2\pi}\right)^{\lambda}, \left(\frac{\overline{\alpha}_{\tilde{A}}}{2\pi}\right)^{\lambda}\right]}, \left[\underline{Lim}(C_{n_{\tilde{A}}})^{\lambda}, \overline{Lim}(C_{n_{\tilde{A}}})^{\lambda}\right] e^{j2\pi.\left[\left(\frac{\underline{\gamma}_{\tilde{A}}}{2\pi}\right)^{\lambda}, \left(\frac{\overline{\gamma}_{\tilde{A}}}{2\pi}\right)^{\lambda}\right]}, \\ \left[\underline{Lim}(C_{v_{\tilde{A}}})^{\lambda}, \overline{Lim}(C_{v_{\tilde{A}}})^{\lambda}\right] e^{j2\pi.\left[\left(\frac{\underline{\beta}_{\tilde{A}}}{2\pi}\right)^{\lambda}, \left(\frac{\overline{\beta}_{\tilde{A}}}{2\pi}\right)^{\lambda}\right]}, \left[\underline{Lim}(C_{h_{\tilde{A}}})^{\lambda}, \overline{Lim}(C_{h_{\tilde{A}}})^{\lambda}\right] e^{j2\pi.\left[\left(\frac{\underline{T}_{\tilde{A}}}{2\pi}\right)^{\lambda}, \left(\frac{\overline{T}_{\tilde{A}}}{2\pi}\right)^{\lambda}\right]}, \end{matrix} \right\} \quad (53)$$

$$\tilde{A}_c \cup \tilde{B}_c = \left\{ \begin{matrix} \left[min\left(\underline{Lim}(C_{\mu_{\tilde{A}}})e^{j2\pi.\left(\frac{\underline{\alpha}_{\tilde{A}}}{2\pi}\right)}, \underline{Lim}(C_{\mu_{\tilde{B}}})e^{j2\pi.\left(\frac{\underline{\alpha}_{\tilde{B}}}{2\pi}\right)}\right), max\left(\overline{Lim}(C_{\mu_{\tilde{A}}})e^{j2\pi.\left(\frac{\overline{\alpha}_{\tilde{A}}}{2\pi}\right)}, \overline{Lim}(C_{\mu_{\tilde{B}}})e^{j2\pi.\left(\frac{\overline{\alpha}_{\tilde{B}}}{2\pi}\right)}\right)\right], \\ \left[min\left(\underline{Lim}(C_{n_{\tilde{A}}})e^{j2\pi.\left(\frac{\underline{\gamma}_{\tilde{A}}}{2\pi}\right)}, \underline{Lim}(C_{n_{\tilde{B}}})e^{j2\pi.\left(\frac{\underline{\gamma}_{\tilde{B}}}{2\pi}\right)}\right), max\left(\overline{Lim}(C_{n_{\tilde{A}}})e^{j2\pi.\left(\frac{\overline{\gamma}_{\tilde{A}}}{2\pi}\right)}, \overline{Lim}(C_{n_{\tilde{B}}})e^{j2\pi.\left(\frac{\overline{\gamma}_{\tilde{B}}}{2\pi}\right)}\right)\right], \\ \left[min\left(\underline{Lim}(C_{v_{\tilde{A}}})e^{j2\pi.\left(\frac{\underline{\beta}_{\tilde{A}}}{2\pi}\right)}, \underline{Lim}(C_{v_{\tilde{B}}})e^{j2\pi.\left(\frac{\underline{\beta}_{\tilde{B}}}{2\pi}\right)}\right), max\left(\overline{Lim}(C_{v_{\tilde{A}}})e^{j2\pi.\left(\frac{\overline{\beta}_{\tilde{A}}}{2\pi}\right)}, \overline{Lim}(C_{v_{\tilde{B}}})e^{j2\pi.\left(\frac{\overline{\beta}_{\tilde{B}}}{2\pi}\right)}\right)\right], \\ \left[min\left(\underline{Lim}(C_{h_{\tilde{A}}})e^{j2\pi.\left(\frac{\underline{T}_{\tilde{A}}}{2\pi}\right)}, \underline{Lim}(C_{h_{\tilde{B}}})e^{j2\pi.\left(\frac{\underline{T}_{\tilde{B}}}{2\pi}\right)}\right), max\left(\overline{Lim}(C_{h_{\tilde{A}}})e^{j2\pi.\left(\frac{\overline{T}_{\tilde{A}}}{2\pi}\right)}, \overline{Lim}(C_{h_{\tilde{B}}})e^{j2\pi.\left(\frac{\overline{T}_{\tilde{B}}}{2\pi}\right)}\right)\right] \end{matrix} \right\} \quad (54)$$

$$\tilde{A}_c \cap \tilde{B}_c = \left\{ \begin{matrix} \left[max\left(\underline{Lim}(C_{\mu_{\tilde{A}}})e^{j2\pi.\left(\frac{\underline{\alpha}_{\tilde{A}}}{2\pi}\right)}, \underline{Lim}(C_{\mu_{\tilde{B}}})e^{j2\pi.\left(\frac{\underline{\alpha}_{\tilde{B}}}{2\pi}\right)}\right), min\left(\overline{Lim}(C_{\mu_{\tilde{A}}})e^{j2\pi.\left(\frac{\overline{\alpha}_{\tilde{A}}}{2\pi}\right)}, \overline{Lim}(C_{\mu_{\tilde{B}}})e^{j2\pi.\left(\frac{\overline{\alpha}_{\tilde{B}}}{2\pi}\right)}\right)\right], \\ \left[max\left(\underline{Lim}(C_{n_{\tilde{A}}})e^{j2\pi.\left(\frac{\underline{\gamma}_{\tilde{A}}}{2\pi}\right)}, \underline{Lim}(C_{n_{\tilde{B}}})e^{j2\pi.\left(\frac{\underline{\gamma}_{\tilde{B}}}{2\pi}\right)}\right), min\left(\overline{Lim}(C_{n_{\tilde{A}}})e^{j2\pi.\left(\frac{\overline{\gamma}_{\tilde{A}}}{2\pi}\right)}, \overline{Lim}(C_{n_{\tilde{B}}})e^{j2\pi.\left(\frac{\overline{\gamma}_{\tilde{B}}}{2\pi}\right)}\right)\right], \\ \left[max\left(\underline{Lim}(C_{v_{\tilde{A}}})e^{j2\pi.\left(\frac{\underline{\beta}_{\tilde{A}}}{2\pi}\right)}, \underline{Lim}(C_{v_{\tilde{B}}})e^{j2\pi.\left(\frac{\underline{\beta}_{\tilde{B}}}{2\pi}\right)}\right), min\left(\overline{Lim}(C_{v_{\tilde{A}}})e^{j2\pi.\left(\frac{\overline{\beta}_{\tilde{A}}}{2\pi}\right)}, \overline{Lim}(C_{v_{\tilde{B}}})e^{j2\pi.\left(\frac{\overline{\beta}_{\tilde{B}}}{2\pi}\right)}\right)\right], \\ \left[max\left(\underline{Lim}(C_{h_{\tilde{A}}})e^{j2\pi.\left(\frac{\underline{T}_{\tilde{A}}}{2\pi}\right)}, \underline{Lim}(C_{h_{\tilde{B}}})e^{j2\pi.\left(\frac{\underline{T}_{\tilde{B}}}{2\pi}\right)}\right), min\left(\overline{Lim}(C_{h_{\tilde{A}}})e^{j2\pi.\left(\frac{\overline{T}_{\tilde{A}}}{2\pi}\right)}, \overline{Lim}(C_{h_{\tilde{B}}})e^{j2\pi.\left(\frac{\overline{T}_{\tilde{B}}}{2\pi}\right)}\right)\right] \end{matrix} \right\} \quad (55)$$

3.4. M-SWARA with QPFRS

The set of criteria for innovative solutions in electric vehicles is determined via Equations (56)-(62) [40].

$$C_k = \begin{bmatrix} 0 & C_{12} & \cdots & \cdots & C_{1n} \\ C_{21} & 0 & \cdots & \cdots & C_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ C_{n1} & C_{n2} & \cdots & \cdots & 0 \end{bmatrix} \quad (56)$$

$$w_k \times \mathrm{C} \quad (57)$$

$$C = \begin{pmatrix} \left[min_{i=1}^{k}\left(\underline{Lim}\left(C_{\mu_{ij}}\right)\right), max_{i=1}^{k}\left(\overline{Lim}\left(C_{\mu_{ij}}\right)\right)\right] e^{j2\pi.\left[min_{i=1}^{k}\left(\frac{\underline{\alpha}_{ij}}{2\pi}\right), max_{i=1}^{k}\left(\frac{\overline{\alpha}_{ij}}{2\pi}\right)\right]}, \\ \left[min_{i=1}^{k}\left(\underline{Lim}\left(C_{n_{ij}}\right)\right), max_{i=1}^{k}\left(\overline{Lim}\left(C_{n_{ij}}\right)\right)\right] e^{j2\pi.\left[min_{i=1}^{k}\left(\frac{\underline{\gamma}_{ij}}{2\pi}\right), max_{i=1}^{k}\left(\frac{\overline{\gamma}_{ij}}{2\pi}\right)\right]}, \\ \left[min_{i=1}^{k}\left(\underline{Lim}\left(C_{v_{ij}}\right)\right), max_{i=1}^{k}\left(\overline{Lim}\left(C_{v_{ij}}\right)\right)\right] e^{j2\pi.\left[min_{i=1}^{k}\left(\frac{\underline{\beta}_{ij}}{2\pi}\right), max_{i=1}^{k}\left(\frac{\overline{\beta}_{ij}}{2\pi}\right)\right]}, \\ \left[min_{i=1}^{k}\left(\underline{Lim}\left(C_{h_{ij}}\right)\right), max_{i=1}^{k}\left(\overline{Lim}\left(C_{h_{ij}}\right)\right)\right] e^{j2\pi.\left[min_{i=1}^{k}\left(\frac{\underline{T}_{ij}}{2\pi}\right), max_{i=1}^{k}\left(\frac{\overline{T}_{ij}}{2\pi}\right)\right]} \end{pmatrix} \quad (58)$$

$$Defc_i = \frac{\begin{pmatrix} \underline{Lim}(C_{\mu_i}) - \underline{Lim}(C_{n_i}) + \underline{Lim}(C_{\mu_i}).\left(\underline{Lim}(C_{v_i}) - \underline{Lim}(C_{h_i})\right) + \left(\frac{\underline{\alpha}_{ij}}{2\pi}\right) - \left(\frac{\underline{\gamma}_{ij}}{2\pi}\right) + \left(\frac{\underline{\alpha}_{ij}}{2\pi}\right).\left(\left(\frac{\underline{\beta}_{ij}}{2\pi}\right) - \left(\frac{\underline{T}_{ij}}{2\pi}\right)\right) + \\ \overline{Lim}(C_{\mu_i}) - \overline{Lim}(C_{n_i}) + \overline{Lim}(C_{\mu_i}).\left(\overline{Lim}(C_{v_i}) - \overline{Lim}(C_{h_i})\right) + \left(\frac{\overline{\alpha}_{ij}}{2\pi}\right) - \left(\frac{\overline{\gamma}_{ij}}{2\pi}\right) + \left(\frac{\overline{\alpha}_{ij}}{2\pi}\right).\left(\left(\frac{\overline{\beta}_{ij}}{2\pi}\right) - \left(\frac{\overline{T}_{ij}}{2\pi}\right)\right) \end{pmatrix}}{2} \quad (59)$$

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases} \quad (60)$$

$$q_j = \begin{cases} 1 & j = 1 \\ \frac{q_{j-1}}{k_j} & j > 1 \end{cases} \quad If\ s_{j-1} = s_j,\ q_{j-1} = q_j \quad If\ s_j = 0,\ k_{j-1} = k_j \quad (61)$$

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \quad (62)$$

3.5. VIKOR with QPFRS

The details of the VIKOR are defined by Equations (63)-(68) [41].

$$X_k = \begin{bmatrix} 0 & X_{12} & \cdots & \cdots & X_{1m} \\ X_{21} & 0 & \cdots & \cdots & X_{2m} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_{n1} & X_{n2} & \cdots & \cdots & 0 \end{bmatrix} \quad (63)$$

$$\tilde{f}_J^* = \max_i \tilde{x}_{ij}, \text{ and } \tilde{f}_j^- = \min_i \tilde{x}_{ij} \quad (64)$$

$$\tilde{S}_i = \sum_{i=1}^{n} \widetilde{w}_j \frac{\left(\left|\tilde{f}_j^{\,*} - \tilde{x}_{ij}\right|\right)}{\left(\left|\tilde{f}_j^{\,*} - \tilde{f}_j^{\,-}\right|\right)} \quad (65)$$

$$\tilde{R}_i = max_j \left[\widetilde{w}_j \frac{\left(\left|\tilde{f}_j^{\,*} - \tilde{x}_{ij}\right|\right)}{\left(\left|\tilde{f}_j^{\,*} - \tilde{f}_j^{\,-}\right|\right)}\right] \quad (66)$$

$$\tilde{Q}_i = v\left(\tilde{S}_i - \tilde{S}^*\right)/\left(\tilde{S}^- - \tilde{S}^*\right) + (1 - v)\left(\tilde{R}_i - \tilde{R}^*\right)/\left(\tilde{R}^- - \tilde{R}^*\right) \quad (67)$$

$$Q\left(A^{(2)}\right) - Q\left(A^{(1)}\right) \geq \frac{1}{(j-1)} \quad (68)$$

4. Empirical Findings

4.1. Weighting the Experts

The demographic information of the experts is denoted in Table A1. Figure 1 denotes that optimal value equals 3 for k.

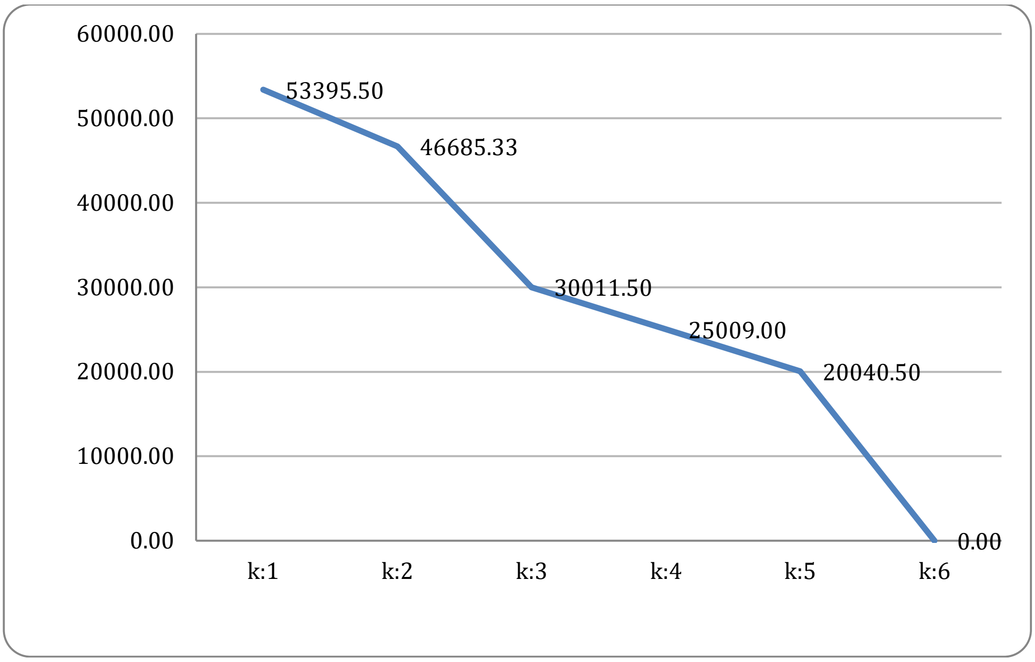

Fig. 1. The plot of the WCSS values and k numbers

In the end of Step 3, the algorithm for clustering DMs is applied by Equations (2) and (3). The analysis results of optimal cluster value are shown in Table A2. When Table A2 is examined, the cluster of the DMs is considered as DM1 is considered in cluster 1; DM2, DM3 and DM6 are located in cluster 2; DM4 and DM5 are together in cluster 3. As result of Step 4, DMs' weights are computed using Equation (4)-(7). The mean standard deviations are detailed in Table A3. Linguistic scales in Table A4 are used in this evaluation process. Tables A5 and A6 give information about the expert evaluations. The DMs' weights calculated by Equation (8) are illustrated with Table 1.

Table 1
The weights of DMs with pareto principle

DMs	Weights	Normalized weights with pareto principle
DM1	0.00	0.00
DM2	0.14	0.07
DM3	0.14	0.07
DM4	0.29	0.40
DM5	0.29	0.40
DM6	0.14	0.07

According to Table 1, DM4 and DM5 have the best priorities because of the value is 0.29.

4.2. Completing the Missing Values

The criteria are demonstrated in Table 2.

Table 2
Criteria set for innovative solutions in electric vehicles

Criteria	Codes
Global competition	GLCOM
Incentives for research and development	INREDE
Technology transfer among the industries	TECHTRA
Organizational competencies	ORGCOM

Selected business alternatives for electric vehicle industry are given in Table 3.

Table 3
Business alternatives for electric vehicle industry

Alternatives	Codes
Advanced battery technologies	ADBATTECH
Smart charging solutions	SMARTCHASOL
Efficient material selection with recycling process	EFFMATSELRE
Flexible transportation using data-driven services	FLETRADASER

4.3. Examining the indicators and alternatives

Similarity index matrixes for criteria and alternatives are denoted in Tables A7 and A8. Tables A9 and A10 give information about the completion of the missing data. Completed opinions are demonstrated in Tabe A11. Moreover, Table A12 highlights the decision matrix. Expert weighted matrix and normalized values are shown in Tables A13 and A14. Table A15 emphasizes the normalized matrix. Relationship degrees are indicated in Table A16. The impacts are given in Table A17. The stable matrix is indicated in Table 4.

Table 4
Stable Matrix

	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM	0.244	0.244	0.244	0.244
INREDE	0.249	0.249	0.249	0.249
TECHTRA	0.277	0.277	0.278	0.277
ORGCOM	0.230	0.230	0.230	0.230

According to Table 4, the most important criterion for innovative solutions in electric vehicles is technology transfer among the industries because of high value. The weight of incentives for research and development is 0.249. Organizational competencies are least important criteria with a weight of 0.23. The evaluations are shown in Table 5.

Table 5
Completed linguistic evaluations of DMs for alternatives

	DM2			
	GLCOM	INREDE	TECHTRA	ORGCOM
ADBATTECH	B	G	F	G
SMARTCHASOL	B	G	G	B
EFFMATSELRE	F	G	G	G
FLETRADASER	P	G	F	B
	DM3			
	GLCOM	INREDE	TECHTRA	ORGCOM
ADBATTECH	G	B	F	B
SMARTCHASOL	G	G	G	B
EFFMATSELRE	G	B	G	B
FLETRADASER	G	G	B	B
	DM4			
	GLCOM	INREDE	TECHTRA	ORGCOM
ADBATTECH	G	G	F	B
SMARTCHASOL	F	G	F	B
EFFMATSELRE	G	G	G	B
FLETRADASER	B	G	B	B

Table 5
Continued

	DM5			
	GLCOM	INREDE	TECHTRA	ORGCOM
ADBATTECH	G	G	P	F
SMARTCHASOL	B	G	F	G
EFFMATSELRE	B	F	G	B
FLETRADASER	B	F	G	G
	DM6			
	GLCOM	INREDE	TECHTRA	ORGCOM
ADBATTECH	G	G	G	G
SMARTCHASOL	G	G	G	G
EFFMATSELRE	F	G	G	G
FLETRADASER	G	F	F	G

Table A18 explains the decision matrix. Expert weighted matrix is constructed in Table A19. On the other side, Table A20 denotes the defuzzified matrix. The ranking results are defined in Table 6.

Table 6
Comparative ranking values with sensitivity analysis

Extended VIKOR (*v*: 0.5)	Case1	Case2	Case3	Case4
ADBATTECH	4	4	4	4
SMARTCHASOL	3	3	3	3
EFFMATSELRE	1	1	1	1
FLETRADASER	2	2	2	2
Extended TOPSIS	Case1	Case2	Case3	Case4
ADBATTECH	4	4	4	4
SMARTCHASOL	3	3	3	3
EFFMATSELRE	1	1	1	1
FLETRADASER	2	2	2	2

The most optimal business alternative for electric vehicle industry is efficient material selection with recycling process. The second optimal alternative is flexible transportation using data-driven services. Moreover, the results obtained are consistent in both methods. Therefore, it can be stated that the results are valid.

5. Discussion

It is important that technology transfer between sectors is effective to obtain innovative solutions for electric vehicles. In the design of electric vehicles, different sciences such as automotive engineering and energy storage technologies need to work together in an integrated manner. Therefore, transferring technology between these different sectors helps increase the effectiveness of these projects. Moreover, this also supports increasing the efficiency of electric vehicle investments. Rauf *et al.* [42] discussed that by transferring technology from different sectors, it can help reduce the costs of electric vehicle investors. Gicha *et al.* [43] stated that improvements in energy storage technologies enable the charging systems of electric vehicles to operate more effectively. On the other hand, Liu *et al.* [44] identified that successful technology transfer also allows businesses to increase their competitiveness. According to Tao [45], it is possible to increase the efficiency of the operational processes of electric vehicles by applying advanced technologies in different sectors. In this way, investors can significantly increase their competitiveness compared to their competitors.

Current technologies must be applied in electric vehicle investments. In this context, more advanced technologies are needed to ensure the effectiveness of both charging infrastructure and energy storage processes. To achieve this goal, it is vital to provide government incentives. Naresh *et al.* [46] highlighted that providing low-interest loans and tax exemptions contribute to reducing the costs of businesses. In this way, businesses will be able to prioritize research and development studies on electric vehicles. According to Niri *et al.* [47], to increase research and development studies on electric vehicles, it is important for industry and universities to work effectively with each other. Owing to the cooperation of these institutions, more effective technological research can be carried out. Wang *et al.* [48] discussed that more accurate policy recommendations for the sector can be offered through academic studies carried out at universities. On the other hand, Chaianong *et al.* [7] stated that research funds and incentives can be created to support research projects related to electric vehicles. Thanks to these funds, it is possible to develop more innovative technologies.

6. Conclusion

It is aimed at examining the knowledge-based innovative business investments in electric vehicle industry. In this scope, a new fuzzy decision-making model is proposed. The first stage includes prioritization of the decision makers by AI methodology. Next, the missing evaluations of knowledge-based innovative business investments in electric vehicle industry are estimated with expert recommender system. In the following stage, the criteria for innovative solutions in electric vehicles are weighed via QPFR Multi-SWARA. The business alternatives for electric vehicle industry are ranked with the help of QPFR VIKOR in the final stage. It is identified that the most important criteria for innovative solutions in electric vehicles are technology transfer among the industries and incentives for research and development. On the other hand, the ranking results indicate that efficient material selection with recycling process and flexible transportation using data-driven services are the most significant business alternatives for electric vehicle industry.

The main contribution of this study to literature is the integration of the AI technique into the fuzzy decision-making methodology. This situation creates an opportunity to compute the weights of the decision makers. With the help of this issue, it can be possible to reach more effective findings. Using collaborative filtering technique in the analysis process provides an opportunity to the experts not to answer the questions when they are not sure. This situation helps to increase the effectiveness of the proposed model. Making a general application for the performance analysis of electric vehicles is the most important theoretical limitation of this article. In this context, it is also important to carry out a more specific analysis to increase the performance of electric vehicles. In this context, a more comprehensive analysis of charging technologies of electric vehicles can be carried out in future studies. On the other hand, the biggest limitation of the proposed model is the use of the VIKOR technique in the ranking process. Both VIKOR and other ranking techniques have been criticized in many studies in literature. Therefore, it is important to develop an original ranking model that takes these criticisms into account in the following studies.

Appendix

Table A1
The details of the Experts

DMs	Level of Education	Periods of Experience	$	Age
DM1	PhD	15	2600	44
DM2	PhD	17	2500	47
DM3	Master	18	2500	48
DM4	Master	16	2400	45
DM5	Bachelor	20	2300	51
DM6	Master	16	2500	43

Table A2
Clustering for DMs

Iteration 1 (DM 1 is in Cluster 1; DM2 is in Cluster 2; DM 3 is in Cluster 3)				
Initial Cluster Centers				
DMs	Distance to C1	Distance to C2	Distance to C3	Cluster Assignment
DM1	.00	10.06	10.13	1
DM2	10.06	.00	1.73	2
DM3	10.13	1.73	.00	3
DM4	20.01	10.03	10.06	2
DM5	30.13	20.07	20.03	3
DM6	10.01	4.24	5.39	2
Average of Data Points				
DMs	Distance to C1	Distance to C2	Distance to C3	Cluster Assignment
DM1	.00	133.35	20.12	1
DM2	10.06	33.41	10.06	2
DM3	10.13	33.51	10.02	2
DM4	20.01	66.67	5.43	3
DM5	30.13	166.82	10.02	3
DM6	10.01	33.40	10.26	2
Iteration 2 (DM 1 is in Cluster 1; DM2 is in Cluster 2; DM 4 is in Cluster 3)				
Initial Cluster Centers				
DMs	Distance to C1	Distance to C2	Distance to C3	Cluster Assignment
DM1	.00	10.06	20.01	1
DM2	10.06	.00	10.03	2
DM3	10.13	1.73	10.06	2
DM4	20.01	10.03	.00	3
DM5	30.13	20.07	10.26	3
DM6	10.01	4.24	10.02	2
Average of Data Points				
DMs	Distance to C1	Distance to C2	Distance to C3	Cluster Assignment
DM1	.00	10.04	25.05	1
DM2	10.06	1.20	15.01	2
DM3	10.13	2.26	15.00	2
DM4	20.01	10.01	5.13	3
DM5	30.13	20.09	5.13	3
DM6	10.01	3.18	15.10	2

Table A3
The standard deviations and Weights

Cluster center	Size	Education	Experience	Salary	Age	Mean SD	Weight
C1	1	0	0	0	0	.00	.00
C2	3	.47	1.05	33.33	2.38	9.31	27.93
C3	2	.50	2.24	7.71	3.35	19.20	38.40

Table A4
Linguistic scales and quantum picture fuzzy numbers for evaluation

Linguistic Scales for Criteria	Linguistic Scales for Alternatives	Recommender Degrees	Possibility Degrees	QPFNs
No influence (n)	Weakest (w)	1	.40	$\begin{bmatrix}\sqrt{.16}e^{j2\pi..4},\\ \sqrt{.10}e^{j2\pi..25},\\ \sqrt{.46}e^{j2\pi..22},\\ \sqrt{.28}e^{j2\pi..13}\end{bmatrix}$
somewhat influence (s)	Poor (p)	2	.45	$\begin{bmatrix}\sqrt{.20}e^{j2\pi..45},\\ \sqrt{.13}e^{j2\pi..28},\\ \sqrt{.42}e^{j2\pi..17},\\ \sqrt{.25}e^{j2\pi..10}\end{bmatrix}$
medium influence (m)	Fair (f)	3	.50	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$
high influence (h)	Good (g)	4	.55	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$
very high influence (vh)	Best (b)	5	.60	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$

Table A5
Linguistic evaluations of the decision makers for the relation matrix

	DM 1	DM 2	DM 3	DM 4	DM 5
GLCOM- INREDE	5	4	4	3	4
GLCOM- TECHTRA	5	3	5	5	5
GLCOM- ORGCOM	4	2	5	5	5
INREDE- GLCOM	4	n/a	4	5	4
INREDE- TECHTRA	n/a	4	3	4	5
INREDE- ORGCOM	n/a	3	4	n/a	4
TECHTRA- GLCOM	n/a	5	3	4	4
TECHTRA- INREDE	4	n/a	2	4	4
TECHTRA- ORGCOM	3	4	2	4	5
ORGCOM- GLCOM	3	5	3	n/a	4
ORGCOM- INREDE	n/a	5	4	3	3
ORGCOM- TECHTRA	3	n/a	5	2	4

Table A6
Linguistic evaluations of the decision makers for the decision matrix

	DM 1	DM 2	DM 3	DM 4	DM 5
GLCOM-ADBATTECH	5	4	n/a	4	4
GLCOM-SMARTCHASOL	5	4	3	5	4
GLCOM-EFFMATSELRE	3	n/a	4	5	3
GLCOM-FLETRADASER	2	4	5	5	4
INREDE-ADBATTECH	4	5	4	4	n/a
INREDE-SMARTCHASOL	n/a	4	4	4	4
INREDE-EFFMATSELRE	n/a	5	4	3	4
INREDE-FLETRADASER	4	4	n/a	3	3
TECHTRA-ADBATTECH	3	3	n/a	2	4
TECHTRA-SMARTCHASOL	4	4	3	3	4
TECHTRA-EFFMATSELRE	n/a	4	4	4	4
TECHTRA-FLETRADASER	3	5	5	4	n/a
ORGCOM-ADBATTECH	4	5	5	3	4
ORGCOM-SMARTCHASOL	5	n/a	5	4	4
ORGCOM-EFFMATSELRE	n/a	5	5	5	4
ORGCOM-FLETRADASER	5	5	n/a	4	4

Table A7
Similarity index matrix of the decision makers for the criteria

	DM 1	DM 2	DM 3	DM 4	DM 5
DM 1	10.00	-0.33	0.35	0.32	0.08
DM 2	-0.33	10.00	-0.50	-0.45	-0.60
DM 3	0.35	-0.50	10.00	-0.03	0.00
DM 4	0.32	-0.45	-0.03	10.00	0.54
DM 5	0.08	-0.60	0.00	0.54	10.00

Table A8
Similarity index matrix of the decision makers for the alternatives

	DM 1	DM 2	DM 3	DM 4	DM 5
DM 1	1.00	0.17	-0.30	-0.01	0.22
DM 2	0.17	1.00	0.34	0.26	0.06
DM 3	-0.30	0.34	1.00	0.09	0.05
DM 4	-0.01	0.26	0.09	1.00	-0.06
DM 5	0.22	0.06	0.05	-0.06	1.00

Table A9
Iterative completion of missing expressions for the criteria

	DM 1	DM 3	DM 4	DM 5	DM 6
GLCOM- INREDE	5	4	4	3	4
GLCOM- TECHTRA	5	3	5	5	5
GLCOM- ORGCOM	4	2	5	5	5
INREDE- GLCOM	4	4 (Iteration 1)	4	5	4
INREDE- TECHTRA	3 (Iteration 1)	4	3	4	5
INREDE- ORGCOM	4 (Iteration 1)	3	4	4 (Iteration 1)	4
TECHTRA- GLCOM	3 (Iteration 1)	5	3	4	4
TECHTRA- INREDE	4	4 (Iteration 1)	2	4	4
TECHTRA- ORGCOM	3	4	2	4	5
ORGCOM- GLCOM	3	5	3	4 (Iteration 1)	4
ORGCOM- INREDE	4 (Iteration 1)	5	4	3	3
ORGCOM- TECHTRA	3	3 (Iteration 1)	5	2	4

Table A10
Iterative completion of missing expressions for the alternatives

	DM 1	DM 3	DM 4	DM 5	DM 6
GLCOM-ADBATTECH	5	4	4 (Iteration 1)	4	4
GLCOM-SMARTCHASOL	5	4	3	5	4
GLCOM-EFFMATSELRE	3	4 (Iteration 1)	4	5	3
GLCOM-FLETRADASER	2	4	5	5	4
INREDE-ADBATTECH	4	5	4	4	4 (Iteration 1)
INREDE-SMARTCHASOL	4 (Iteration 1)	4	4	4	4
INREDE-EFFMATSELRE	4 (Iteration 1)	5	4	3	4
INREDE-FLETRADASER	4	4	4 (Iteration 1)	3	3
TECHTRA-ADBATTECH	3	3	3 (Iteration 1)	2	4
TECHTRA-SMARTCHASOL	4	4	3	3	4
TECHTRA-EFFMATSELRE	4 (Iteration 1)	4	4	4	4
TECHTRA-FLETRADASER	3	5	5	4	3 (Iteration 1)
ORGCOM-ADBATTECH	4	5	5	3	4
ORGCOM-SMARTCHASOL	5	5 (Iteration 1)	5	4	4
ORGCOM-EFFMATSELRE	4 (Iteration 1)	5	5	5	4
ORGCOM-FLETRADASER	5	5	5 (Iteration 1)	4	4

Table A11
Completed opinions of DMs for the criteria

		DM2		
	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM		VH	VH	H
INREDE	H		M	H
TECHTRA	M	H		M
ORGCOM	M	H	M	
		DM3		
	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM		H	M	S
INREDE	H		H	M
TECHTRA	VH	H		H
ORGCOM	VH	VH	M	
		DM4		
	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM		H	VH	VH
INREDE	H		M	H
TECHTRA	M	S		S
ORGCOM	M	H	VH	
		DM5		
	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM		M	VH	VH
INREDE	VH		H	H
TECHTRA	H	H		H
ORGCOM	H	M	S	
		DM6		
	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM		H	VH	VH
INREDE	H		VH	H
TECHTRA	H	H		VH
ORGCOM	H	M	H	

Table A12
Quantum picture fuzzy numbers for the relation matrix

	DM2			
	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM		$\left[\sqrt{.36}e^{j2\pi..6}, \sqrt{.22}e^{j2\pi..37}, \sqrt{.26}e^{j2\pi..02}, \sqrt{.16}e^{j2\pi..01}\right]$	$\left[\sqrt{.36}e^{j2\pi..6}, \sqrt{.22}e^{j2\pi..37}, \sqrt{.26}e^{j2\pi..02}, \sqrt{.16}e^{j2\pi..01}\right]$	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.32}e^{j2\pi..07}, \sqrt{.19}e^{j2\pi..04}\right]$
INREDE	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.32}e^{j2\pi..07}, \sqrt{.19}e^{j2\pi..04}\right]$		$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.37}e^{j2\pi..12}, \sqrt{.23}e^{j2\pi..07}\right]$	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.32}e^{j2\pi..07}, \sqrt{.19}e^{j2\pi..04}\right]$
TECHTRA	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.37}e^{j2\pi..12}, \sqrt{.23}e^{j2\pi..07}\right]$	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.32}e^{j2\pi..07}, \sqrt{.19}e^{j2\pi..04}\right]$		$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.37}e^{j2\pi..12}, \sqrt{.23}e^{j2\pi..07}\right]$
ORGCOM	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.37}e^{j2\pi..12}, \sqrt{.23}e^{j2\pi..07}\right]$	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.32}e^{j2\pi..07}, \sqrt{.19}e^{j2\pi..04}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.37}e^{j2\pi..12}, \sqrt{.23}e^{j2\pi..07}\right]$	
	DM3			
	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM		$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.32}e^{j2\pi..07}, \sqrt{.19}e^{j2\pi..04}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.37}e^{j2\pi..12}, \sqrt{.23}e^{j2\pi..07}\right]$	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.32}e^{j2\pi..07}, \sqrt{.19}e^{j2\pi..04}\right]$
INREDE	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.32}e^{j2\pi..07}, \sqrt{.19}e^{j2\pi..04}\right]$		$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.32}e^{j2\pi..07}, \sqrt{.19}e^{j2\pi..04}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.37}e^{j2\pi..12}, \sqrt{.23}e^{j2\pi..07}\right]$
TECHTRA	$\left[\sqrt{.36}e^{j2\pi..6}, \sqrt{.22}e^{j2\pi..37}, \sqrt{.26}e^{j2\pi..02}, \sqrt{.16}e^{j2\pi..01}\right]$	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.32}e^{j2\pi..07}, \sqrt{.19}e^{j2\pi..04}\right]$		$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.32}e^{j2\pi..07}, \sqrt{.19}e^{j2\pi..04}\right]$
ORGCOM	$\left[\sqrt{.36}e^{j2\pi..6}, \sqrt{.22}e^{j2\pi..37}, \sqrt{.26}e^{j2\pi..02}, \sqrt{.16}e^{j2\pi..01}\right]$	$\left[\sqrt{.36}e^{j2\pi..6}, \sqrt{.22}e^{j2\pi..37}, \sqrt{.26}e^{j2\pi..02}, \sqrt{.16}e^{j2\pi..01}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.37}e^{j2\pi..12}, \sqrt{.23}e^{j2\pi..07}\right]$	

Table A12
Continued

		DM4		
	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM		$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55}, \\ \sqrt{.19}e^{j2\pi..34}, \\ \sqrt{.32}e^{j2\pi..07}, \\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6}, \\ \sqrt{.22}e^{j2\pi..37}, \\ \sqrt{.26}e^{j2\pi..02}, \\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6}, \\ \sqrt{.22}e^{j2\pi..37}, \\ \sqrt{.26}e^{j2\pi..02}, \\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
INREDE	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55}, \\ \sqrt{.19}e^{j2\pi..34}, \\ \sqrt{.32}e^{j2\pi..07}, \\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$		$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50}, \\ \sqrt{.15}e^{j2\pi..31}, \\ \sqrt{.37}e^{j2\pi..12}, \\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55}, \\ \sqrt{.19}e^{j2\pi..34}, \\ \sqrt{.32}e^{j2\pi..07}, \\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$
TECHTRA	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50}, \\ \sqrt{.15}e^{j2\pi..31}, \\ \sqrt{.37}e^{j2\pi..12}, \\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.20}e^{j2\pi..45}, \\ \sqrt{.13}e^{j2\pi..28}, \\ \sqrt{.42}e^{j2\pi..17}, \\ \sqrt{.25}e^{j2\pi..10}\end{bmatrix}$		$\begin{bmatrix}\sqrt{.20}e^{j2\pi..45}, \\ \sqrt{.13}e^{j2\pi..28}, \\ \sqrt{.42}e^{j2\pi..17}, \\ \sqrt{.25}e^{j2\pi..10}\end{bmatrix}$
ORGCOM	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50}, \\ \sqrt{.15}e^{j2\pi..31}, \\ \sqrt{.37}e^{j2\pi..12}, \\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55}, \\ \sqrt{.19}e^{j2\pi..34}, \\ \sqrt{.32}e^{j2\pi..07}, \\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6}, \\ \sqrt{.22}e^{j2\pi..37}, \\ \sqrt{.26}e^{j2\pi..02}, \\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	
		DM5		
	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM		$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50}, \\ \sqrt{.15}e^{j2\pi..31}, \\ \sqrt{.37}e^{j2\pi..12}, \\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6}, \\ \sqrt{.22}e^{j2\pi..37}, \\ \sqrt{.26}e^{j2\pi..02}, \\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6}, \\ \sqrt{.22}e^{j2\pi..37}, \\ \sqrt{.26}e^{j2\pi..02}, \\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
INREDE	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6}, \\ \sqrt{.22}e^{j2\pi..37}, \\ \sqrt{.26}e^{j2\pi..02}, \\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$		$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55}, \\ \sqrt{.19}e^{j2\pi..34}, \\ \sqrt{.32}e^{j2\pi..07}, \\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55}, \\ \sqrt{.19}e^{j2\pi..34}, \\ \sqrt{.32}e^{j2\pi..07}, \\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$
TECHTRA	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55}, \\ \sqrt{.19}e^{j2\pi..34}, \\ \sqrt{.32}e^{j2\pi..07}, \\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55}, \\ \sqrt{.19}e^{j2\pi..34}, \\ \sqrt{.32}e^{j2\pi..07}, \\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$		$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55}, \\ \sqrt{.19}e^{j2\pi..34}, \\ \sqrt{.32}e^{j2\pi..07}, \\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$
ORGCOM	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55}, \\ \sqrt{.19}e^{j2\pi..34}, \\ \sqrt{.32}e^{j2\pi..07}, \\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50}, \\ \sqrt{.15}e^{j2\pi..31}, \\ \sqrt{.37}e^{j2\pi..12}, \\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.20}e^{j2\pi..45}, \\ \sqrt{.13}e^{j2\pi..28}, \\ \sqrt{.42}e^{j2\pi..17}, \\ \sqrt{.25}e^{j2\pi..10}\end{bmatrix}$	

Table A12
Continued

	DM6			
	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM		$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
INREDE	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$		$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$
TECHTRA	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$		$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
ORGCOM	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	

Table A13
Expert weighed QPFRS for the direct relation matrix

	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM		$\left[\sqrt{.02},\sqrt{.12}\right] e^{j2\pi.[.04,.22]}$, $\left[\sqrt{.01},\sqrt{.07}\right] e^{j2\pi.[.02,.14]}$, $\left[\sqrt{.02},\sqrt{.15}\right] 0^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right] e^{j2\pi.[.00,.03]}$	$\left[\sqrt{.02},\sqrt{.14}\right] e^{j2\pi.[.04,.24]}$, $\left[\sqrt{.01},\sqrt{.09}\right] e^{j2\pi.[.02,.15]}$, $\left[\sqrt{.02},\sqrt{.13}\right] 0^{j2\pi.[.00,.03]}$, $\left[\sqrt{.01},\sqrt{.08}\right] e^{j2\pi.[.00,.02]}$	$\left[\sqrt{.01},\sqrt{.14}\right] e^{j2\pi.[.03,.24]}$, $\left[\sqrt{.01},\sqrt{.09}\right] e^{j2\pi.[.02,.15]}$, $\left[\sqrt{.02},\sqrt{.13}\right] 0^{j2\pi.[.00,.03]}$, $\left[\sqrt{.01},\sqrt{.08}\right] e^{j2\pi.[.00,.02]}$
INREDE	$\left[\sqrt{.02},\sqrt{.14}\right] e^{j2\pi.[.04,.24]}$, $\left[\sqrt{.01},\sqrt{.09}\right] e^{j2\pi.[.02,.15]}$, $\left[\sqrt{.02},\sqrt{.13}\right] 0^{j2\pi.[.00,.03]}$, $\left[\sqrt{.01},\sqrt{.08}\right] e^{j2\pi.[.00,.02]}$		$\left[\sqrt{.02},\sqrt{.12}\right] e^{j2\pi.[.04,.22]}$, $\left[\sqrt{.01},\sqrt{.07}\right] e^{j2\pi.[.02,.14]}$, $\left[\sqrt{.02},\sqrt{.15}\right] 0^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right] e^{j2\pi.[.00,.03]}$	$\left[\sqrt{.02},\sqrt{.12}\right] e^{j2\pi.[.04,.22]}$, $\left[\sqrt{.01},\sqrt{.07}\right] e^{j2\pi.[.02,.14]}$, $\left[\sqrt{.02},\sqrt{.15}\right] 0^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right] e^{j2\pi.[.00,.03]}$
TECHTRA	$\left[\sqrt{.02},\sqrt{.12}\right] e^{j2\pi.[.04,.22]}$, $\left[\sqrt{.01},\sqrt{.07}\right] e^{j2\pi.[.02,.14]}$, $\left[\sqrt{.02},\sqrt{.15}\right] 0^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right] e^{j2\pi.[.00,.03]}$	$\left[\sqrt{.02},\sqrt{.12}\right] e^{j2\pi.[.04,.22]}$, $\left[\sqrt{.01},\sqrt{.07}\right] e^{j2\pi.[.02,.14]}$, $\left[\sqrt{.02},\sqrt{.15}\right] 0^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right] e^{j2\pi.[.00,.03]}$		$\left[\sqrt{.02},\sqrt{.12}\right] e^{j2\pi.[.04,.22]}$, $\left[\sqrt{.01},\sqrt{.07}\right] e^{j2\pi.[.02,.14]}$, $\left[\sqrt{.02},\sqrt{.15}\right] 0^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right] e^{j2\pi.[.00,.03]}$
ORGCOM	$\left[\sqrt{.02},\sqrt{.12}\right] e^{j2\pi.[.04,.22]}$, $\left[\sqrt{.01},\sqrt{.07}\right] e^{j2\pi.[.02,.14]}$, $\left[\sqrt{.02},\sqrt{.15}\right] 0^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right] e^{j2\pi.[.00,.03]}$	$\left[\sqrt{.02},\sqrt{.12}\right] e^{j2\pi.[.04,.22]}$, $\left[\sqrt{.01},\sqrt{.07}\right] e^{j2\pi.[.02,.14]}$, $\left[\sqrt{.02},\sqrt{.15}\right] 0^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right] e^{j2\pi.[.00,.03]}$	$\left[\sqrt{.02},\sqrt{.14}\right] e^{j2\pi.[.04,.24]}$, $\left[\sqrt{.01},\sqrt{.09}\right] e^{j2\pi.[.02,.15]}$, $\left[\sqrt{.02},\sqrt{.13}\right] 0^{j2\pi.[.00,.03]}$, $\left[\sqrt{.01},\sqrt{.08}\right] e^{j2\pi.[.00,.02]}$	

Table A14
The defuzzified values of QPFRSs

	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM	0.000	0.082	0.086	0.085
INREDE	0.089	0.000	0.080	0.079
TECHTRA	0.080	0.083	0.000	0.082
ORGCOM	0.080	0.080	0.091	0.000

Table A15
The normalized relation matrix

	GLCOM	INREDE	TECHTRA	ORGCOM
GLCOM	0.000	0.323	0.341	0.336
INREDE	0.359	0.000	0.323	0.318
TECHTRA	0.327	0.339	0.000	0.334
ORGCOM	0.319	0.319	0.362	0.000

Table A16
S, K, Q and W for the relationship degrees of each criterion

GLCOM	Sj	kj	qj	Wj	INREDE	Sj	Kj	qj	Wj
TECHTRA	0.341	10.000	10.000	0.432	GLCOM	0.359	10.000	10.000	0.429
ORGCOM	0.336	10.336	0.748	0.323	TECHTRA	0.323	10.323	0.756	0.325
INREDE	0.323	10.323	0.566	0.244	ORGCOM	0.318	10.318	0.574	0.246
TECHTRA	Sj	kj	qj	wj	ORGCOM	Sj	Kj	qj	Wj
INREDE	0.339	10.000	10.000	0.432	TECHTRA	0.362	10.000	10.000	0.397
ORGCOM	0.334	10.334	0.750	0.324	INREDE	0.319	10.319	0.758	0.301
GLCOM	0.327	10.327	0.565	0.244	GLCOM	0.319	10.000	0.758	0.301

Table A17
Relation matrix and impacts

	GLCOM	INREDE	TECHTRA	ORGCOM	Impact directions
GLCOM		0.244	0.432	0.323	GLCOM→TECHTRA
INREDE	0.429		0.325	0.246	INREDE→GLCOM
TECHTRA	0.244	0.432		0.324	TECHTRA→INREDE
ORGCOM	0.301	0.301	0.397		ORGCOM→TECHTRA

Table A18
QPFN for the decision matrix

	DM2			
	GLCOM	INREDE	TECHTRA	ORGCOM
ADBATTECH	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$
SMARTCHASOL	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
EFFMATSELRE	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$
FLETRADASER	$\begin{bmatrix}\sqrt{.20}e^{j2\pi..45},\\ \sqrt{.13}e^{j2\pi..28},\\ \sqrt{.42}e^{j2\pi..17},\\ \sqrt{.25}e^{j2\pi..10}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$

Table A18
Continued

	GLCOM	INREDE	TECHTRA	ORGCOM
DM3				
	GLCOM	INREDE	TECHTRA	ORGCOM
ADBATTECH	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
SMARTCHASOL	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
EFFMATSELRE	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
FLETRADASER	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
DM4				
	GLCOM	INREDE	TECHTRA	ORGCOM
ADBATTECH	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
SMARTCHASOL	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
EFFMATSELRE	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
FLETRADASER	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
DM5				
	GLCOM	INREDE	TECHTRA	ORGCOM
ADBATTECH	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.20}e^{j2\pi..45},\\ \sqrt{.13}e^{j2\pi..28},\\ \sqrt{.42}e^{j2\pi..17},\\ \sqrt{.25}e^{j2\pi..10}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$
SMARTCHASOL	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$

Table A18
Continued

		DM5		
	GLCOM	INREDE	TECHTRA	ORGCOM
EFFMATSELRE	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$
FLETRADASER	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..6},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.26}e^{j2\pi..02},\\ \sqrt{.16}e^{j2\pi..01}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$
		DM6		
	GLCOM	INREDE	TECHTRA	ORGCOM
ADBATTECH	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$
SMARTCHASOL	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$
EFFMATSELRE	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$
FLETRADASER	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.37}e^{j2\pi..12},\\ \sqrt{.23}e^{j2\pi..07}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.32}e^{j2\pi..07},\\ \sqrt{.19}e^{j2\pi..04}\end{bmatrix}$

Table A19
Expert weighted QPFRS for the decision matrix

	GLCOM	INREDE	TECHTRA	ORGCOM
ADBATTECH	$\left[\sqrt{.02},\sqrt{.14}\right]e^{j2\pi.[.04,.24]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.02,.15]}$, $\left[\sqrt{.02},\sqrt{.13}\right]0^{j2\pi.[.00,.03]}$, $\left[\sqrt{.01},\sqrt{.08}\right]e^{j2\pi.[.00,.02]}$	$\left[\sqrt{.02},\sqrt{.12}\right]e^{j2\pi.[.04,.22]}$, $\left[\sqrt{.01},\sqrt{.07}\right]e^{j2\pi.[.02,.14]}$, $\left[\sqrt{.02},\sqrt{.15}\right]0^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.00,.03]}$	$\left[\sqrt{.02},\sqrt{.10}\right]e^{j2\pi.[.04,.20]}$, $\left[\sqrt{.01},\sqrt{.06}\right]e^{j2\pi.[.02,.12]}$, $\left[\sqrt{.02},\sqrt{.15}\right]e^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.00,.03]}$	$\left[\sqrt{.02},\sqrt{.14}\right]e^{j2\pi.[.04,.24]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.02,.15]}$, $\left[\sqrt{.02},\sqrt{.13}\right]0^{j2\pi.[.00,.03]}$, $\left[\sqrt{.01},\sqrt{.08}\right]e^{j2\pi.[.00,.02]}$
SMARTCHASOL	$\left[\sqrt{.02},\sqrt{.14}\right]e^{j2\pi.[.04,.24]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.02,.15]}$, $\left[\sqrt{.02},\sqrt{.13}\right]0^{j2\pi.[.00,.03]}$, $\left[\sqrt{.01},\sqrt{.08}\right]e^{j2\pi.[.00,.02]}$	$\left[\sqrt{.02},\sqrt{.12}\right]e^{j2\pi.[.04,.22]}$, $\left[\sqrt{.01},\sqrt{.07}\right]e^{j2\pi.[.02,.14]}$, $\left[\sqrt{.02},\sqrt{.15}\right]0^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.00,.03]}$	$\left[\sqrt{.02},\sqrt{.10}\right]e^{j2\pi.[.04,.20]}$, $\left[\sqrt{.01},\sqrt{.06}\right]e^{j2\pi.[.02,.12]}$, $\left[\sqrt{.02},\sqrt{.15}\right]e^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.00,.03]}$	$\left[\sqrt{.02},\sqrt{.14}\right]e^{j2\pi.[.04,.24]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.02,.15]}$, $\left[\sqrt{.02},\sqrt{.13}\right]0^{j2\pi.[.00,.03]}$, $\left[\sqrt{.01},\sqrt{.08}\right]e^{j2\pi.[.00,.02]}$
EFFMATSELRE	$\left[\sqrt{.02},\sqrt{.14}\right]e^{j2\pi.[.04,.24]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.02,.15]}$, $\left[\sqrt{.02},\sqrt{.13}\right]0^{j2\pi.[.00,.03]}$, $\left[\sqrt{.01},\sqrt{.08}\right]e^{j2\pi.[.00,.02]}$	$\left[\sqrt{.02},\sqrt{.12}\right]e^{j2\pi.[.04,.22]}$, $\left[\sqrt{.01},\sqrt{.07}\right]e^{j2\pi.[.02,.14]}$, $\left[\sqrt{.02},\sqrt{.15}\right]0^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.00,.03]}$	$\left[\sqrt{.02},\sqrt{.12}\right]e^{j2\pi.[.04,.22]}$, $\left[\sqrt{.01},\sqrt{.07}\right]e^{j2\pi.[.02,.14]}$, $\left[\sqrt{.02},\sqrt{.15}\right]0^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.00,.03]}$	$\left[\sqrt{.02},\sqrt{.14}\right]e^{j2\pi.[.04,.24]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.02,.15]}$, $\left[\sqrt{.02},\sqrt{.13}\right]0^{j2\pi.[.00,.03]}$, $\left[\sqrt{.01},\sqrt{.08}\right]e^{j2\pi.[.00,.02]}$
FLETRADASER	$\left[\sqrt{.01},\sqrt{.14}\right]e^{j2\pi.[.03,.24]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.02,.15]}$, $\left[\sqrt{.02},\sqrt{.13}\right]0^{j2\pi.[.00,.03]}$, $\left[\sqrt{.01},\sqrt{.08}\right]e^{j2\pi.[.00,.02]}$	$\left[\sqrt{.02},\sqrt{.12}\right]e^{j2\pi.[.04,.22]}$, $\left[\sqrt{.01},\sqrt{.07}\right]e^{j2\pi.[.02,.14]}$, $\left[\sqrt{.02},\sqrt{.15}\right]0^{j2\pi.[.00,.05]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.00,.03]}$	$\left[\sqrt{.02},\sqrt{.14}\right]e^{j2\pi.[.04,.24]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.02,.15]}$, $\left[\sqrt{.02},\sqrt{.13}\right]0^{j2\pi.[.00,.03]}$, $\left[\sqrt{.01},\sqrt{.08}\right]e^{j2\pi.[.00,.02]}$	$\left[\sqrt{.02},\sqrt{.14}\right]e^{j2\pi.[.04,.24]}$, $\left[\sqrt{.01},\sqrt{.09}\right]e^{j2\pi.[.02,.15]}$, $\left[\sqrt{.02},\sqrt{.13}\right]0^{j2\pi.[.00,.03]}$, $\left[\sqrt{.01},\sqrt{.08}\right]e^{j2\pi.[.00,.02]}$

Table A20

The defuzzified decision values

Criteria/Alternatives	GLCOM	INREDE	TECHTRA	ORGCOM
ADBATTECH	0.081	0.081	0.073	0.091
SMARTCHASOL	0.091	0.081	0.073	0.089
EFFMATSELRE	0.088	0.082	0.081	0.088
FLETRADASER	0.085	0.080	0.088	0.089

Acknowledgement

This research was not funded by any grant.

Conflicts of Interest

The authors declare no conflicts of interest.

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