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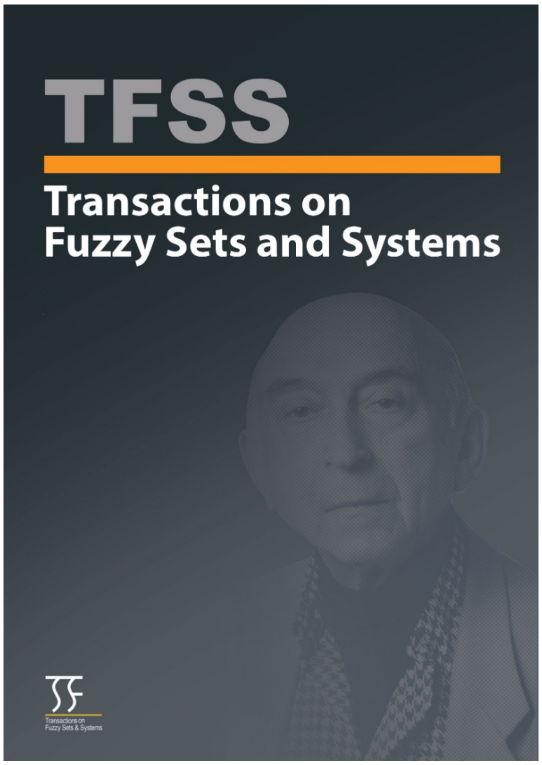

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A Novel Technique of the MARCOS Method for q-Rung Orthopair Fuzzy Information and E-Transport for Urban Mobility Explorations

Abdulgawad A.Q. Al-Qubati*, **Kifayat Ullah**, **Abrar Hussain**, **Lemnaouar Zedam**

Abstract. Due to the lack of adequate public transportation in developing countries, ride-hailing services are becoming more popular to satisfy the need for urban travel. As far as we are aware, there is a dearth of research on how passengers behave and feel about the quality of ride-hailing services, especially when it comes to studies conducted in developing countries. Ride-hailing services were introduced to accommodate the transport needs of people living in urban areas. E-transportation in urban areas can be optimized through various mathematical models and decision-making frameworks that address complex challenges like traffic flow, energy consumption, and infrastructure placement. Multi-criteria decision analysis and simulation techniques help balance costs, environmental impacts, and efficiency. Decision-makers must evaluate factors like charging station locations and vehicle routes to maximize sustainability and minimize congestion. This article articulates a novel decision-making model of the MARCOS method under the system of q-rung orthopair fuzzy (q-ROF) information. A q-ROF set (q-ROFS) is an extended and well-known mathematical model for handling uncertain human information. Additionally, we established a decision algorithm of the MARCOS method for the multi-attribute group decision-making (MAGDM) problem. This decision analysis technique ranks alternatives by computing the utility function and credibility degrees of alternatives in the MARCOS method. To prove the validity of diagnosed theories, we discuss an application related to the E-transportation system with the help of numerical examples. Furthermore, a comprehensive contracting technique is stated to verify the results of pioneering approaches with existing mathematical terminologies. At the end, concluding remarks summarize the whole article.

AMS Subject Classification 2020: 94D05; 68P30
Keywords and Phrases: q-rung orthopair fuzzy set, Aczel Alsina aggregation operators, Assessment of e-transport, and the decision analysis process.

1 Introduction

E-transport is a critical component in the shift towards more sustainable urban mobility. It offers significant environmental benefits, primarily by reducing greenhouse gas emissions and improving air quality in cities. Traditional gasoline-powered vehicles are major contributors to urban pollution, while electric vehicles (EVs) produce zero tailpipe emissions. Additionally, e-transport solutions, including electric buses, e-scooters, and e-bikes, help reduce traffic congestion and noise pollution, contributing to a healthier urban environment. Economically, e-transport can lower operational and maintenance costs for individuals and public transportation systems, as EVs generally require less maintenance and have lower fuel costs. The development of e-transport infrastructure also creates new jobs and industries, further supporting urban economies. Beyond

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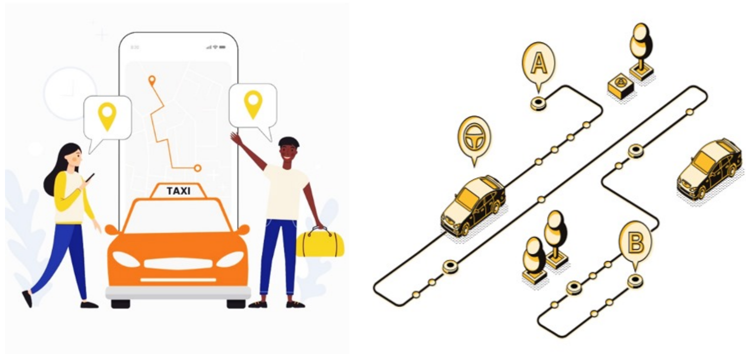

Figure 1: illustrates the features of E-transportation in urban areas

environmental and economic impacts, e-transport enhances overall mobility and the quality of life in urban settings. E-vehicles, especially shared and autonomous systems, improve traffic flow and optimize space in congested cities. Micromobility options like e-scooters and e-bikes offer convenient and affordable alternatives for short-distance travel, reducing reliance on personal cars and freeing up public spaces. This shift not only makes transportation more efficient but also supports more equitable access to mobility solutions for underserved communities. Additionally, as cities embrace e-transport, they promote healthier lifestyles by encouraging walking, cycling, and the use of public transportation, all of which contribute to cleaner, safer, and more livable urban environments. In recent years, the rise of online ride-hailing services has revolutionized urban mobility. Platforms like Uber, Lyft, Ola, and others have become indispensable for millions of people across cities globally seen in Figure 1. These services provide a seamless connection between passengers and drivers via mobile applications, simplifying transportation in ways that public transit or traditional taxis often cannot. The significance of this shift extends beyond just convenience, affecting urban transportation, economics, sustainability, and public policy. One of the primary advantages of online rides in urban areas is the convenience they offer. With just a few taps on a smartphone, users can book a ride to their destination, often within minutes. This is especially beneficial in cities where public transportation may be unreliable, slow, or absent in certain areas. Ride-hailing services have also become a lifeline for people in regions with limited access to personal vehicles, improving mobility for all socioeconomic classes. Moreover, these platforms often provide a wide range of vehicle options, from economically shared rides to luxury vehicles, catering to diverse customer needs.

The introduction of online ride-hailing has significantly disrupted traditional modes of transport such as taxis and public buses. Traditional taxi services, which once held a monopoly over urban transport, have been compelled to either adapt or suffer financial losses due to the efficiency and affordability of app-based rides. Public transport systems have also experienced a shift, as online rides often provide a more convenient option, albeit at a higher cost. However, this transition has sparked debates over issues like congestion and whether these services complement or compete with public transport. From an economic perspective, online ride-hailing platforms have contributed to job creation, offering flexible work opportunities for drivers. Many individuals, particularly in urban areas, have taken advantage of the gig economy, working part-time or full-time as drivers. However, the gig economy model has also raised concerns regarding job security, benefits, and fair compensation, as many drivers are considered independent contractors rather than employees. Despite these concerns, the economic impact of these services is evident, as they generate billions of dollars in revenue annually. While online rides have improved convenience and accessibility, their environmental impact is a subject of ongoing debate. On the one hand, these services may reduce the need for car ownership in urban areas, potentially lowering the number of vehicles on the road. On the other hand, studies have shown that the convenience of ride-hailing can increase vehicle miles travel, leading to higher emissions and congestion.

Many companies have responded by introducing electric vehicle (EV) options and promoting carpooling services, which aim to reduce the environmental footprint of their operations. The rapid growth of online ride-hailing services has posed several challenges, especially for city planners and regulators. Issues like traffic congestion, safety concerns, and the treatment of gig economy workers have led to calls for more stringent regulation. In some cities, local governments have responded by introducing caps on the number of ride-hailing vehicles, imposing stricter licensing requirements for drivers, and implementing congestion pricing to manage traffic flow. These regulations seek to balance the benefits of ride-hailing with the broader goals of urban planning and sustainability. In conclusion, online rides have already significantly influenced the structure of urban transport systems, but their long-term impact will depend on how society navigates the accompanying challenges and opportunities.

1.1 Literature Review

Zadeh [1] gave the theory of fuzzy set (FS) to cope with uncertain information about human opinions. A FS only deals with one component of the experts opinion known as membership grade, which is bounded on a closed interval $[0, 1]$. Many research scholars have applied the theory of FS to resolve different complicated real-life problems with the help of numerical examples. Afterwards, Atanassov [2] enhanced concepts of FSs and derived a new theory of an intuitionistic fuzzy set (IFS) with two components of membership grade (MG) and non-membership grade (NMG) lies on the closed interval $[0, 1]$. Yager [3] developed the theory of the pythagorean fuzzy set (PyFS) by relaxing conditions on the MGs and NMGs. Yager [4] also introduced an innovative theory of q-rung orthopair fuzzy set (q-ROFS), which is an extended version of FSs and IFSs. Ashraf et al. [5] constructed a dominant decision-making model of the EDAS method to obtain the ranking of alternatives. Darko and Liang [6] utilized properties of Hamacher aggregation operators using the decision analysis process of the EDAS method under consideration of q-ROF fields. Abbas et al. [7] proposed an innovative decision analysis process for the MAIRSCA method, considering 2-tuple linguistic q-rung orthopair fuzzy information. zer [8] enhanced the theory of complex picture fuzzy models to derive mathematical approaches of Hamacher aggregation operators with robust decision-making methods. Ahmmad [9] classified different renewable energy sources by the implementation of the theory of entropy measures and q-ROF soft sets. Bibi and Ali [10] developed Aczel Alsina aggregation operators for the analysis of crystal-based X-ray Structure with an innovative decision algorithm for the MADM problem. Dastanl. [11] discussed a novel decision-making approach of the VIKOR method to select a suitable defence industry for the investment process. Al-Barakati et al. [12] enhanced the reliability of decision-making model of the WASPAS method by applying theory of similarity measures and interval valued Pythagorean fuzzy frameworks. Qiao [13] discussed the theory of the TODIM-VIKOR method for finding the potential of the forest health tourism industry. Ali et al. [14] applied the theory of the TOPSIS method for handling the human opinions using Bonferroni mean aggregation operators considering complex spherical fuzzy environments. Zeng et al. [15] modified the concepts of the MARCOS method for resolving complicated real-life applications with the help of numerical examples. Mitra [16] investigated the ranking of suitable alternatives of cotton fiber based on their quality values and the decision analysis model of the MARCOS method. Wang et al. [17] applied the theory of the CRITIC-MARCOS method to choosing appropriate food suppliers considering concepts of pythagorean fuzzy domains and mathematical approaches. Rani et al. [18] utilized concepts of similarity measures to evaluate suitable optimal options based on the MARCOS method with picture fuzzy environments. They also discussed the drawbacks of existing similarity measures and the traditional decision analysis process. Lukic [19] applied the combined theory of LMAW and MARCOs method to check the performance of European Union and Serbian companies. Akram et al. [20] enhanced the evaluation performance of the MARCOS method with the system of 2-tuple linguistic q-rung orthopair picture fuzzy information. Badi et al. [21] used a robust decision-making model to choose Wind farm sites under different key features and characteristics. Majumder [22] integrated experts' information about water treatment plants using the combined theory of the MARCOS and GMDH method with trapezoidal fuzzy discipline.

1.2 Problem Statement of Public Transport

In urban areas, public transport faces challenges like overcrowding, unreliable schedules, and limited coverage, which hinder its efficiency and accessibility. These issues often lead to congestion, increased travel times, and pollution, especially in rapidly growing cities. Public transport may not adequately serve all areas or operate around the clock, leaving some residents with limited mobility options. Ride-hailing services have emerged as a solution, offering on-demand, flexible, and point-to-point transportation. Key features of ride-hailing include easy access via mobile apps, real-time tracking, cashless payments, and route optimization, which collectively improve convenience, reduce waiting times, and fill gaps in public transit networks. This combination of flexibility and accessibility makes ride-hailing a valuable complement to urban public transport.

1.3 Motivation and contributions to the article

The motivation behind q-ROFS stems from the need to handle complex decision-making problems that involve high levels of uncertainty and vagueness. Traditional FSs and IFSs may lack the expressive capability to handle situations where there is a high degree of hesitation or imprecision, as their MG and NMG are limited. The q-ROFS address these limitations by allowing for larger values of MGs and NMGs, which can exceed the standard boundaries. This extended flexibility is beneficial in cases where a decision involves multiple competing criteria or subjective assessments. By offering a broader range, q-ROFS enable a better representation of uncertainty, hesitation, and indeterminate information in decision scenarios. The MARCOS method is widely used in the MAGDM due to its ability to effectively rank alternatives by balancing various criteria. The methods motivation stems from the need for a flexible yet comprehensive decision-making framework that can accommodate both positive and negative ideal solutions. In many MAGDM scenarios, decision-makers deal with conflicting criteria, making it difficult to reach an optimal solution that satisfies all stakeholders. MARCOS addresses this by constructing a compromise solution that accounts for ideal and anti-ideal alternatives, thereby helping decision-makers to identify the best alternative through a systematic ranking process. This approach makes MARCOS particularly advantageous when decision-makers must assess both favorable and unfavorable criteria in a balanced way, which is essential in real-world applications where objectives often conflict. Another key motivation for the MARCOS method is its robustness in handling complex decision-making scenarios where uncertainty and varying degrees of importance exist among criteria. MARCOS incorporates a normalization process that scales each criterion according to its relative importance, enhancing the reliability and comparability of the alternatives. This normalization, coupled with the methods sensitivity to different preference structures, allows it to provide precise and reliable rankings, even in complex MAGDM problems. Additionally, MARCOS supports a participatory decision-making process, where multiple experts can contribute, thereby improving the quality and acceptance of the final decision. Its straightforward computations and structured approach also make it an appealing choice for situations where transparency and ease of interpretation are crucial for gaining consensus among decision-makers. Some important features of this presentation are articulated as follows:

1. Enhanced the reliability of the theory of q-rung orthopair fuzzy information for handling ambiguous human opinions under various flexible operations of triangular norms.

2. Formulation of different comparison rules for de-fuzzifying q-rung orthopair fuzzy information into a single term value. Based on these values, experts examine the best optimal option under the system of various criteria.

3. To modify an advanced theory of the MARCOS method for the MAGDM problem and investigate suitable optimal options using closeness coefficient indices and credibility degrees of alternatives. This

technique enables us to aggregate information on various criteria without any additional weights of criteria and experts.

4. To reveal the authenticity and credibility of diagnosed methodologies, we discuss an application related to E-transportation in urban areas based on different characteristics and key features. An experimental case study is established to evaluate suitable options for travelling from one place to other destinations.

5. To illustrate the worth and supremacy of deduced theories, a robust contrasting technique is established to compare the results of existing terminologies with pioneered mathematical approaches of Sugeno-Weber AOs and decision-making models.

1.4 Structure of the Manuscript

The successive research work is symmetrically organized: section 2 discusses some essential concepts to facilitate improvements in the proposed research work and decision-making problems. Section 3 delineates stepwise decision algorithms of the MARCOS method using Aczel Alsina aggregation operators under the system of q-ROF frameworks. In section 4, we must implement the theory of the MARCOS method to predict suitable optimal options under derived methodologies of the Aczel Alsina aggregation operator and pioneered mathematical approaches. We also discussed the applications of e-transportation systems in urban areas under consideration of different key features and diagnosed decision analysis methodologies. Section 5 presents a comprehensive discussion of the aggregated results of the proposed case study. In section 6, we contrast the results of pioneered approaches with previous methodologies stated in the literature. In section 7, some remarkable comments about proposed decision analysis methodologies and case studies are fully articulated.

2 Preliminaries

In this section, we recall basic concepts and rules used to further develop new terminologies and mathematical approaches.

Definition 2.1. [4] *Let M be any fixed set and a q-ROFS $\mathfrak{B}$ is characterized as follows:*

$$\mathfrak{B} = \{(\tau, (\mu_{\mathfrak{B}}(\tau), \nu_{\mathfrak{B}}(\tau)))|\tau \in M\}, \tag{1}$$

Where the function $\mu_{\mathfrak{B}} : M \to [0,1]$ define the membership degree (MD) and the function $\nu_{\mathfrak{B}} : M \to [0,1]$ define the non-membership degree (NMD) of the element τ in $\mathfrak{B}$ and a q-ROFS is given by: $0 \leq \mu^q_{\mathfrak{B}}(\tau) + \nu^q_{\mathfrak{B}}(\tau) \leq 1$ The hesitancy degree of the q-ROFS is given as $r_{\mathfrak{B}} = \sqrt[q]{(1 - (\mu^q_{\mathfrak{B}}(\tau) + \nu^q_{\mathfrak{B}}(\tau)))}$ and a q-ROF value (q-ROFV) is expressed as $\Gamma = (\mu, \nu)$.

Definition 2.2. [23] *Let $\Gamma = (\mu, \nu)$ be a q-ROFV and a score function $S(\Gamma)$ for a q-ROFV can be characterized as:*

$$S(\Gamma) = \mu^q(\tau) - \nu^q(\tau), S(\Gamma) \in [0,1] \tag{2}$$

Definition 2.3. [6] *Let $\Gamma_1 = (\mu_1, \nu_1)$, $\Gamma_2 = (\mu_2, \nu_2)$, and $\Gamma = (\mu, \nu)$ are three q-ROFVs, we have:*

1. $\Gamma_1 \bigoplus \Gamma_2 = (\sqrt[q]{\mu^q_1(\tau) + \mu^q_2(\tau) - \mu^q_1(\tau).\mu^q_2(\tau)}, \nu_1(\tau).\nu_2(\tau))$
2. $\Gamma_1 \bigotimes \Gamma_2 = (\mu_1(\tau).\mu_2(\tau), \sqrt[q]{\nu^q_1(\tau) + \nu^q_2(\tau) - \nu^q_1(\tau).\nu^q_2(\tau)})$
3. $\lambda.\Gamma = (\sqrt[q]{(1 - (1 - \mu^q)^\lambda)}, \nu^\lambda), \lambda > 0$

4. $\Gamma^{\lambda} = (\mu^{\lambda}, \sqrt[q]{(1-(1-\nu^{q})^{\lambda})}), \lambda > 0$
5. $\Gamma^{c} = (\nu, \mu)$

In this section, we explored the theory of Aczel-Alsina aggregation expression and expressed some necessary operations under the system of q-ROF information.

Definition 2.4. [6] *Let $\Gamma_1 = (\mu_1, \nu_1)$, $\Gamma_2 = (\mu_2, \nu_2)$, and $\Gamma = (\mu, \nu)$ are three q-ROFVs, we have:*

1. $\Gamma_1 \bigoplus \Gamma_2 = (\sqrt[q]{1 - e^{-((-\log(1-\mu_1^{q}))^{\mathfrak{P}} + (-\log(1-\mu_2^{q}))^{\mathfrak{P}})^{1}/\mathfrak{P}}}, e^{-(((-\log\nu_1))^{\mathfrak{P}} + (-\log\nu_2)^{\mathfrak{P}})^{1}/\mathfrak{P}})$
2. $\Gamma_1 \bigotimes \Gamma_2 = (e^{-(((-\log\mu_1))^{\mathfrak{P}} + (-\log\mu_2)^{\mathfrak{P}})^{1}/\mathfrak{P}}, \sqrt[q]{1 - e^{-((-\log(1-\nu_1^{q}))^{\mathfrak{P}} + (-\log(1-\nu_2^{q}))^{\mathfrak{P}})^{1}/\mathfrak{P}}})$
3. $\lambda.\Gamma = (\sqrt[q]{1 - e^{-(\lambda(-\log(1-\mu^{q}))^{\mathfrak{P}})^{1}/\mathfrak{P}}}, e^{-(\lambda(-\log\nu)^{\mathfrak{P}})^{1}/\mathfrak{P}}), \lambda > 0$
4. $\Gamma^{\lambda} = (e^{-(\lambda(-\log\mu)^{\mathfrak{P}})^{1}/\mathfrak{P}}, \sqrt[q]{1 - e^{-(\lambda(-\log(1-\nu^{q}))^{\mathfrak{P}})^{1}/\mathfrak{P}}}), \lambda > 0$

Definition 2.5. [24] *For any collection of q-ROFVs $\Gamma_{\varrho} = (\mu_{\varrho}, \nu_{\varrho})$, ($\varrho$=1,2,...,n). Then the q-ROFAAWA is a mapping $\Gamma^{n} \rightarrow \Gamma$ such that:*

$$q - ROFAAWA(\Gamma_1, \Gamma_2, ..., \Gamma_n) = \bigoplus_{\varrho=1}^{n} \Gamma_{\varrho}\varpi_{\varrho} \tag{3}$$

Theorem 2.6. [24] *For any collection of q-ROFVs $\Gamma_{\varrho} = (\mu_{\varrho}, \nu_{\varrho})$, ($\varrho$=1,2,...,n). Then, the aggregated value of the q-ROFAAWA operator also provide a q-ROFV as follows:*

$$q - ROFAAWA(\Gamma_1, \Gamma_2, ..., \Gamma_n) = (\sqrt[q]{1 - e^{-(\sum_{\varrho=1}^{n}\varpi_{\varrho}(-\log(1-\mu_{\varrho}^{q}))^{\mathfrak{P}})^{1}/\mathfrak{P}}}, e^{-(\sum_{\varrho=1}^{n}\varpi_{\varrho}(-\log\nu_{\varrho})^{\mathfrak{P}})^{1}/\mathfrak{P}}) \tag{4}$$

3 MARCOS Method for q-Rung Orthopair Fuzzy Environments

This article demonstrates a novel decision-making model for the MCGDM problem to achieve the weight of each attribute for the q-rung orthopair fuzzy scenario and q-rung orthopair fuzzy Aczel Alsina weighted averaging operators by [25]. Furthermore, linguist scales are converted into q-rung orthopair fuzzy values (q-ROFVs). The theory of the MARCOS method was established by Stevi et al. [26]. The MARCOS method is a powerful and effective decision-making model used to comprise the ranking of alternatives based on various criteria. However, this technique is more capable of handling fuzziness and ambiguous information with fuzzy extension. The description of the q-ROF MARCOS method is expressed as follows:

- A set of experts $\mathfrak{D}_i = (\mathfrak{D}_1, \mathfrak{D}_2, ..., \mathfrak{D}_n)$ with their degree of importance $\varpi_i = (\varpi_1, \varpi_2, ..., \varpi_n)$ and $\sum_{i=1}^{n}\varpi_i = 1$

$$\varpi_i = \frac{(\mu_i + r_i(\frac{\mu_i}{\mu_i+\nu_i}))}{(\sum_{i=1}^{n}(\mu_i + r_i(\frac{\mu_i}{\mu_i+\nu_i})))} \tag{5}$$

- Consider kth criterion with their degree of importance $\mathcal{C}_m$ are given by: $\mathfrak{w}_m = (\mathfrak{w}_1, \mathfrak{w}_2, ..., \mathfrak{w}_k)$ and $\sum_{m=1}^{k}\mathfrak{w}_i = 1$

Table 1: Linguistic scales for criterion and experts

Description	**q-ROFVs** (μ, ν,**r**)
Very very important (VVI)	(0.97,0.02,0.44)
Very important (VI)	(0.86,0.12,0.71)
Important (I)	(0.74,0.18,0.84)
Medium (M)	(0.55,0.26,0.93)
Bad (B)	(0.37,0.48,0.94)
Unimportant (UIM)	(0.23,0.73,0.84)
Very unimportant (VUIM)	(0.05,0.91,0.63)

Table 2: Linguistic scales for preferences or alternatives

Description	**q-ROFVs** (μ, ν,**r**)
Extreme good (EG)	(0.98,0.01,0.39)
Very very good (VVG)	(0.87,0.11,0.70)
Very good (VG)	(0.74,0.15,0.84)
Good (G)	(0.66,0.24,0.89)
Medium good (MG)	(0.53,0.31,0.94)
Fair (F)	(0.46,0.42,0.94)
Medium bad (MB)	(0.38,0.68,0.86)

Step 1: Assessment degree of importance of each criterion and expert using the linguistic scale stated in Table 1.

Step 2: Establish an aggregated decision matrix of the kth criterion.
Consider $\mathcal{R} = [\mathcal{G}_{mi}]_{k*n}, (m, i = 1, 2, ..., k, n)$ be the decision matrix of experts, where $\mathcal{G}_{mi}$ represents judgments of dth experts about kth criteria represents. $\mathcal{G}_{mi} = (\mu_{mi}, \nu_{mi}, \mathrm{r}_{mi}), (m = 1, 2k, \& \ i = 1, 2, , n)$ be the q-ROFVs, where $r_{mi} = \sqrt[q]{(1 - (\mu^q_{mi}(\tau) + \nu^q_{mi}(\tau)))}, (m = 1, 2k, \& \ i = 1, 2, , n)$, indicate the hesitancy value. Furthermore, the aggregated decision matrix is represented as $\mathcal{R} = [\mathcal{G}_{mi}]_{k*n}, (m, i = 1, 2, ..., k, n)$.

$$\mathfrak{G} = q{-}ROFAAWA(\mathcal{G}_{m1}, \mathcal{G}_{m2}, ..., \mathcal{G}_{mn}) = (\sqrt[q]{1 - e^{-(\sum_{i=1}^{n} \varpi_i (-\log(1-\mu^q_{mi}))^{\mathfrak{P}})^{1}/\mathfrak{P}}}, e^{-(\sum_{i=1}^{n} \varpi_i (-\log \nu_{mi})^{\mathfrak{P}})^{1}/\mathfrak{P}}) \quad (6)$$

Where $\mathfrak{G}_m = (\mu_{\mathfrak{G}m}, \nu_{\mathfrak{G}m}, \mathrm{r}_{\mathfrak{G}m})$ and $r_{\mathfrak{G}m} = \sqrt[q]{(1 - (\mu^q_{\mathfrak{G}m}(\tau) + \nu^q_{\mathfrak{G}m}(\tau)))}$

Step 3: In this step, determine the q-ROF ideal solutions like as q-ROF positive ideal solution (q-ROFPIS) $\rho^+ = (1, 0, 0)$ and and q-ROF negative ideal solution (q-ROFNIS) $\rho^- = (1, 0, 0)$. However, the q-ROFPIS and q-ROFNIS are expressed by max and min operations.

Step 4: Investigate the distance measures The Euclidean distance is determined by distance measures based on q-ROF information, S^+_m and S^-_m determined positive and negative solutions respectively.

$$S^+_m = \frac{1}{n}(|\mu^q_{\mathfrak{G}m}(\tau) - (\rho^+))^q| + |\nu^q_{\mathfrak{G}m}(\tau) - (\rho^+)^q| + |r^q_{\mathfrak{G}m}(\tau) + (\rho^+)^q|) \quad (7)$$

and

$$S^-_m = \frac{1}{n}(|\mu^q_{\mathfrak{G}m}(\tau) - (\rho^-))^q| + |\nu^q_{\mathfrak{G}m}(\tau) - (\rho^-)^q| + |r^q_{\mathfrak{G}m}(\tau) + (\rho^-)^q|) \quad (8)$$

Step 5: Demonstrates closeness coefficient indices DW_m be the closeness coefficient of the kth criterion and expression is defined using S_m^+ and S_m^-:

$$DW_m = \frac{S_m^-}{S_m^- + S_m^+} \tag{9}$$

Step 6: Here, we aim to collect experts judgments about the different preferences based on each criterion.

Step 7: Integrate experts opinions using the following expression.

$$q - ROFAAWA(\mathcal{G}_{m1}, \mathcal{G}_{m2}, ..., \mathcal{G}_{mn}) = (\sqrt[q]{1 - e^{-(\sum_{i=1}^{n} \varpi_i(-\log(1-\mu_{mi}^q))^{\mathfrak{P}})^1/\mathfrak{P}}}, e^{-(\sum_{i=1}^{n} \varpi_i(-\log \nu_{mi})^{\mathfrak{P}})^1/\mathfrak{P}}) \tag{10}$$

Step 8: Again, apply Equations $7 - 9$ and find out the results of DW_m using the aggregated results of different experts.

The degree of importance of each criterion is obtained using values of the closeness coefficient. The sum of the weights of all criteria is equal to 1 and the normalization process is used to find final weights.

Step 9: Established an extended decision matrix considering ideal and anti-ideal solutions as follows:

$$\begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \\ \tilde{x}_{\acute{\acute{A}}\mathcal{A}\mathcal{J}_1} & \tilde{x}_{\acute{\acute{A}}\mathcal{A}\mathcal{J}_2} & \cdots & \tilde{x}_{\acute{\acute{A}}\mathcal{A}\mathcal{J}_n} \\ \tilde{x}_{\acute{\acute{A}}\mathcal{J}_1} & \tilde{x}_{\acute{\acute{A}}\mathcal{J}_2} & \cdots & \tilde{x}_{\acute{\acute{A}}\mathcal{J}_n} \end{bmatrix}$$

Anti-ideal $\acute{\acute{A}}\mathcal{A}\mathcal{J}$ is the worst alternative or individual, whereas $\acute{\acute{A}}\mathcal{J}$ is the most preferable performance of an alternative. The $\acute{\acute{A}}\mathcal{A}\mathcal{J}$ and $\acute{\acute{A}}\mathcal{J}$ are demonstrated under the following Equations 11 and 12.

$$\acute{\acute{A}}\mathcal{A}\mathcal{J} = \{min\check{x}_{ij},\ if\ j \in B\ and\ \max \check{x}_{ij},\ if\ j \in C \tag{11}$$

$$\acute{\acute{A}}\mathcal{J} = \{max\check{x}_{ij},\ if\ j \in B\ and\ \min \check{x}_{ij},\ if\ j \in C \tag{12}$$

Step 10: This step builds a normalized q-ROF decision matrix and obtains normalized values of alternatives or individuals under the following expression:

$$F_{ij} = \begin{cases} \dfrac{\tilde{x}_{aij}}{\tilde{x}_{idj}}, & j \in B \\ \dfrac{\tilde{x}_{idj}}{\tilde{x}_{aij}}, & j \in C \end{cases} \tag{13}$$

Step 11: Construct a weighted q-ROF decision matrix The degrees of each individual or alternative are computed as Equation 14.

$$\mathcal{H}_{ij} = \mathcal{F}_{ij} \times \mathfrak{w}_j \tag{14}$$

Where $\mathfrak{w}_j$ indicate the relative importance of kth attributes.

Step 12: Investigate the $\mathcal{A}_i$ matrix, to obtain the values of $\mathcal{A}_i$ using Equation 15 and we have:

$$\mathcal{N}_i = \sum_{i=1}^{n} = \mathcal{H}_{ij} \tag{15}$$

Step 13: Obtained credibility degrees of alternatives using the Equations 16 and 17.

$$\mathcal{K}_i^- = \frac{\mathcal{N}_i}{\mathcal{N}_{ai}} \tag{16}$$

$$\mathcal{K}_i^+ = \frac{\mathcal{N}_i}{\mathcal{N}_{id}} \tag{17}$$

Step 14: Assessment of credibility degrees of alternatives utility function expressed with Equation 18.

$$\breve{f}(\mathcal{K}_i) = \frac{\mathcal{K}_i^+ + \mathcal{K}_i^-}{1 + \frac{1-\breve{f}(\mathcal{K}_i^+)}{\breve{f}(\mathcal{K}_i^+)} + \frac{1-\breve{f}(\mathcal{K}_i^-)}{\breve{f}(\mathcal{K}_i^-)}} \tag{18}$$

In Equation 18, $\breve{f}(\mathcal{K}_i^+)$ denote the utility function of an ideal solution, whereas $\breve{f}(\mathcal{K}_i^-)$ indicate the utility of the function of the anti-ideal solution. $\breve{f}(\mathcal{K}_i^+)$ and $\breve{f}(\mathcal{K}_i^-)$ obtained by Equations 19 and 20, so we have:

$$\breve{f}(\mathcal{K}_i^+) = \frac{\mathcal{K}_i^-}{\mathcal{K}_i^- + \mathcal{K}_i^+} \tag{19}$$

$$\breve{f}(\mathcal{K}_i^-) = \frac{\mathcal{K}_i^-}{\mathcal{K}_i^- + \mathcal{K}_i^+} \tag{20}$$

Step 15: Ranking of alternatives based on obtained utility functions and the highest value of utility function is known as the best alternative or individual. Therefore, obtained utility function is a preferable alternative for individuals.

4 Experimental Case Study

Due to the extraordinary rise of new technologies, consumers can now use online taxi services for their travel in real-time and through apps thanks to developments in information and communication technology. Smartphone applications have been made available to users by companies like Uber, Lift, Careem, Didi, Sidecar, and others to link commuters with local drivers. Additionally, these apps have a rating system that allows both drivers and users to grade one another after a ride [27]. Without question, these app-based services have improved commuters' travel options and had a significant impact on traditional public transportation. They may now use their cellphones to hire private taxis in a matter of minutes, eliminating the need to wait by the side of the road until their bus comes. People can now use online taxi services for their excursions in real time and through apps thanks to the phenomenal rise of new technologies and information and technology advancements. Commuters can now connect with local drivers through smartphone applications offered by companies like Uber, Lift, Careem, Didi, Sidecar, and others. Additionally, these apps have a rating system that allows both drivers and users to grade one another after a ride [28]. There is no denying that these app-based services have improved commuters' travel alternatives and had a significant impact on traditional public transportation. They may now use their cellphones to hire private taxis in a matter of minutes, eliminating the need to wait by the side of the road until their bus comes. Companies provide consumers with pick-up and drop-off locations using these applications, but users are free to select any area they like. The demand for public transit cannot be met by the current transportation networks; ride-sharing services are partially meeting customer demand. In the majority of developing nations with inadequate public transportation systems for a variety of reasons, online fees have grown common and are acknowledged as an unofficial part of public transportation [29]. App-based taxi services are revolutionizing urban transport with their many benefits [30]. Since consumers can now track their driver's whereabouts, the taxi's expected arrival time, and the cost of a certain journey, these services have given them more power. According to the literature, ride-hailing services have grown significantly over the past ten years. Approximately 2 million people used them in North America, and 5 million did so worldwide. In the five years that these services have been in place, more than 250 million people have used them [31]. In Pakistan, there are numerous problems with ride-hailing services that rely on apps. The authorities also informed the author that there is no regulatory framework in place for these services to operate in the city, and they have grave worries about the safety of passengers utilizing these services. They added that they are working with ride-hailing businesses to develop a regulatory framework. Since these services are drawing passengers from rickshaws and traditional taxi services, there have been numerous demonstrations against them by those drivers [32]. It is noteworthy to remark that these services were first heavily deregulated in San Francisco as well. However, they were eventually registered under the specific restrictions of Transportation Network Companies (TNCs) [33] and [34]. According to research, passengers' travel habits are evolving because of ride-hailing services. Studies on travelers behavioral intentions and attitudes offer crucial guidance [35]. Therefore, the purpose of the study is to ascertain how passengers feel and behave about ride-hailing services in terms of accessibility, safety, instrumentality, and service attraction features. Additionally, it will highlight the difficulties that passengers encounter when utilizing these services, the modes that they have replaced, and how these are altering consumers' perceptions of these services. To give ride-hailing services a place in the current urban transportation system, government officials, transportation planners, and policymakers will find the data useful in understanding the characteristics, perceptions, and behaviors of travelers or customers. In this experiment case study, we demonstrated different sources to fill the gap of public transport under various parameters and enhance the performance of digital technology in ride-hailing services. The ride-hailing service has already been launched in various developing countries. This number considered to evaluate different sources used to provide rides to customers. To serve this purpose, a company provides different motor cars as an online service to customers and passengers. So, there are five different motor cars under consideration as follows:

Electric Cycle $\breve{\breve{A}}_1$

Mini Car $\breve{\breve{A}}_2$

Rikshaw $\breve{\breve{A}}_3$

Scoter $\breve{\breve{A}}_4$

Electric bike $\breve{\breve{A}}_5$

There are five decision makers invited to evaluate their personal judgments about online ride and its facilitation in urban areas. Decision-makers evaluate discussed sources under the following key features:

Eco-Friendly Option $\mathcal{C}_1$:

Electric vehicles (EVs) produce zero tailpipe emissions, reducing pollution and the carbon footprint, which helps improve air quality and supports sustainability.

Convenient Access via Apps $\mathcal{C}_2$:

Booking a ride is easy with smartphone apps, allowing users to request rides from anywhere with just a few taps. Many platforms even provide real-time tracking, estimated wait times, and fare estimations.

Reduced Traffic Congestion $\mathcal{C}_3$:

The smaller size of mini cars and electric scooters allows them to navigate through traffic more smoothly,

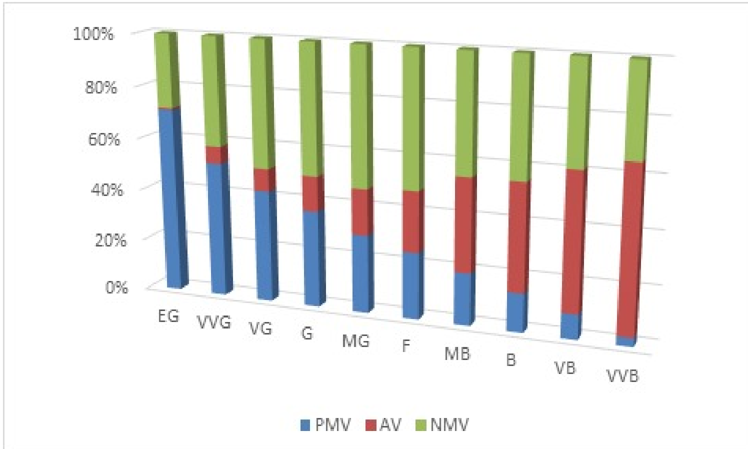

Figure 2: illustrates the features of E-transportation in urban areas

reducing congestion and often getting to destinations faster in crowded areas.

Low Noise Pollution $\mathcal{C}_4$:
Electric motors run more quietly than traditional gas engines, contributing to a quieter urban environment and making them suitable for high-density city centers.

Cost-Effective Transportation $\mathcal{C}_5$:
Mini cars and electric scooters typically have lower operational costs, and their energy efficiency leads to lower ride fares, making them affordable for short-distance commutes.

Flexible and Scalable Mobility Option $\mathcal{C}_6$**:**
The compact size of mini cars and scooters allows users to easily access tight or crowded areas. They are often parked in dedicated spots and can be used for one-way trips, making them ideal for both solo commuters and short trips.

4.1 Evaluation Procedure Using q-ROF-MARCOS method

We aim to investigate reliable optimal option of travelling sources in urban areas that fulfils the above discussed characteristics or attributes information. To serve this purpose, there are five experts hired to aggregate human judgments about the qualities of different sources. We used a questionnaire form to analyze information for the criteria and alternatives stated in Table 20. The experts illustrate six linguistic criteria based on rating scales in Table 1 and the information about each alternative or individual expressed based on linguistic scales in Table 2. Tables 4 and 7 contain linguistic information for criterion and alternatives respectively. Moreover, Figure 2 illustrates linguistic information for alternatives based on q-rung orthopair fuzzy information.

Step 1: The selection committee assigns a specific linguistic scale to each expert using defined scales in Table 1. We computed weight for each expert by using Equation 5 and aggregated weights are stated in Table 3. Figure 3 also shows the importance and worth of each expert.

Table 3: Estimated weights of experts

	Exp 1	Exp 2	Exp 3	Exp 4	Exp 5
Linguistic scale	I	VVI	M	I	VI
Index of weight	0.2049	0.2035	0.1716	0.2049	0.2152

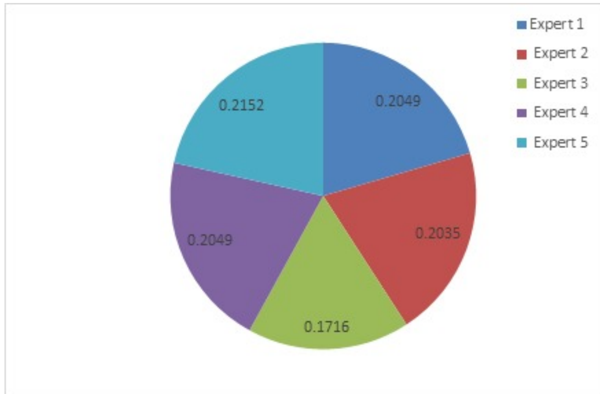

Figure 3: illustrates the features of E-transportation in urban areas

Table 4: Experts judgments for criterion in the form of linguistic scales

	Exp 1	Exp 2	Exp 3	Exp 4	Exp 5
$\mathcal{C}_1$	VVI	M	I	M	VI
$\mathcal{C}_2$	VI	VI	VVI	VVI	UIM
$\mathcal{C}_3$	I	I	M	VI	VVI
$\mathcal{C}_4$	I	VVI	VI	I	M
$\mathcal{C}_5$	VI	VI	VVI	VVI	M
$\mathcal{C}_6$	UIM	I	I	I	VVI

Step 2: Table 5 presents the q-ROF information based on linguistic scales of each criterion corresponding to each alternative or preference. The aggregated decision matrix of Table 6 is obtained by Equation 6.

Table 5: Experts opinions for criterion based on q-ROFVs

	Exp 1	Exp 2	Exp 3	Exp 4	Exp 5
$\mathcal{C}_1$	(0.97,0.02,0.44)	(0.55,0.26,0.93)	(0.74,0.18,0.84)	(0.55,0.26,0.93)	(0.86,0.12,0.71)
$\mathcal{C}_2$	(0.86,0.12,0.71)	(0.86,0.12,0.71)	(0.97,0.02,0.44)	(0.97,0.02,0.44)	(0.23,0.73,0.84)
$\mathcal{C}_3$	(0.74,0.18,0.84)	(0.74,0.18,0.84)	(0.55,0.26,0.93)	(0.86,0.12,0.71)	(0.97,0.02,0.44)
$\mathcal{C}_4$	(0.74,0.18,0.84)	(0.97,0.02,0.44)	(0.86,0.12,0.71)	(0.74,0.18,0.84)	(0.55,0.26,0.93)
$\mathcal{C}_5$	(0.86,0.12,0.71)	(0.86,0.12,0.71)	(0.97,0.02,0.44)	(0.97,0.02,0.44)	(0.55,0.26,0.93)
$\mathcal{C}_6$	(0.23,0.73,0.84)	(0.74,0.18,0.84)	(0.74,0.18,0.84)	(0.74,0.18,0.84)	(0.97,0.02,0.44)

Step 3: Investigate the value of the positive solution S^+ and negative solution S^- using Equations $7-9$ and the degree of weights are also presented in Table 6.

Step 4: In this step, experts demonstrate their judgments associated with each alternative and state them in different decision matrices of Tables 8–12

Step 5: Aggregated decision matrix obtained by the judgments of different experts using Equation 10 and integrated information is listed in Table 13.

Step 6: Obtained value of CW_m based on Equations $7-9$ and the investigated results are listed in Table 14.

Table 6: Weights of criterion based on aggregated information from different experts

		S^+	S^-	CW	
$\mathcal{C}_1$	(0.6724,0.4014,0.8516)	0.6822	0.9353	0.5782	0.1612
$\mathcal{C}_2$	(0.7603,0.3517,0.8026)	0.5605	0.9565	0.6305	0.1758
$\mathcal{C}_3$	(0.7015,0.3834,0.8427)	0.6548	0.9437	0.5904	0.1646
$\mathcal{C}_4$	(0.6909,0.3927,0.8479)	0.6702	0.9394	0.5837	0.1627
$\mathcal{C}_5$	(0.7654,0.3193,0.8037)	0.5516	0.9674	0.6369	0.1775
$\mathcal{C}_6$	(0.6711,0.4380,0.8498)	0.6978	0.9160	0.5676	0.1582

Step 7: The extended decision matrix is demonstrated in Table 15 based on the Equations 11 and 12 as follows:

$$\begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \\ \tilde{x}_{AI_1} & \tilde{x}_{AI_2} & \cdots & \tilde{x}_{AI_n} \\ \tilde{x}_{A1} & \tilde{x}_{A2} & \cdots & \tilde{x}_{An} \end{bmatrix}$$

$\acute{\acute{A}}\mathcal{AJ} = min\{0.1942, 0.2056, 0.2076, 0.1868, 0.2058\} = 0.1868$

and

$\acute{\acute{A}}\mathcal{J} = max\{0.1942, 0.2056, 0.2076, 0.1868, 0.2058\} = 0.2076$

Noted: $\{\mathcal{C}_1, \mathcal{C}_2, \mathcal{C}_3, \mathcal{C}_4\}$ and $\{\mathcal{C}_5, \mathcal{C}_6\}$ are beneficial and non-beneficial attributes.

Step 8: Based on Equation 13, a normalized matrix and integrated values are listed in Table 16.

Step 9: Compute the weight of each alternative using the values of Table 6 and Tables [16,17] considered the estimated weights of each alternative using the following expression of Equation 14:

Step 10: Using Equations $15-20$, we determined credibility degrees and utility functions of alternatives listed obtained results in Table 18.

Step 11: Based on the computed score valued of utility functions, rank discussed alternatives of E-motor cars and the highest score function is an appropriate optimal option. So, the ranking of alternatives $\breve{\breve{A}}_2 \succ \breve{\breve{A}}_4 \succ \breve{\breve{A}}_3 \succ \breve{\breve{A}}_5 \succ \breve{\breve{A}}_1$ is determined by the implementation of the MARCOS method with q-ROF information. Figure 4 depicts the ranking of alternatives based on computed score values by the MARCOS method.

5 Discussion for results

After the evaluation and aggregation process of an experimental case study, we obtained a final ranking of alternative $\breve{\breve{A}}_2 \succ \breve{\breve{A}}_4 \succ \breve{\breve{A}}_3 \succ \breve{\breve{A}}_5 \succ \breve{\breve{A}}_1$ based on appropriate characteristics and mathematical methodologies of the decision analysis process of the MARCOR method. According to the aggregation process, mini car $\breve{\breve{A}}_2$

Table 7: Experts opinion for alternatives considering different linguistic scales

		$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
Exp 1	$\breve{\breve{A}}_1$	VB	EG	VB	VVB	VVG	VB
	$\breve{\breve{A}}_2$	EG	VVB	EG	F	MB	VVG
	$\breve{\breve{A}}_3$	VG	VVG	VVG	VVG	EG	G
	$\breve{\breve{A}}_4$	VB	MG	G	G	VG	EG
	$\breve{\breve{A}}_5$	EG	MB	VG	VG	B	EG
		$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
Exp 2	$\breve{\breve{A}}_1$	VB	EG	VVG	F	VG	EG
	$\breve{\breve{A}}_2$	EG	VVB	F	VVG	B	EG
	$\breve{\breve{A}}_3$	VG	VVG	MB	EG	EG	VVG
	$\breve{\breve{A}}_4$	VB	MG	EG	F	VVG	VVB
	$\breve{\breve{A}}_5$	EG	MB	B	MB	F	G
		$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
Exp 3	$\breve{\breve{A}}_1$	EG	B	F	VVG	VG	MB
	$\breve{\breve{A}}_2$	VVB	EG	MB	B	B	MG
	$\breve{\breve{A}}_3$	VVG	VG	EG	G	EG	VVG
	$\breve{\breve{A}}_4$	EG	F	F	VB	VVG	EG
	$\breve{\breve{A}}_5$	VB	EG	G	VVG	B	VVB
		$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
Exp 4	$\breve{\breve{A}}_1$	VVG	F	EG	MB	VVG	VVG
	$\breve{\breve{A}}_2$	G	B	G	F	V	F
	$\breve{\breve{A}}_3$	VG	VVG	MG	VG	MG	G
	$\breve{\breve{A}}_4$	VB	EG	VB	EG	B	EG
	$\breve{\breve{A}}_5$	EG	B	VVG	VVG	VVG	F
		$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
Exp 5	$\breve{\breve{A}}_1$	VVG	MG	G	VVG	F	B
	$\breve{\breve{A}}_2$	VVB	B	VVG	VB	VVB	VVG
	$\breve{\breve{A}}_3$	EG	B	VVG	VG	VVG	G
	$\breve{\breve{A}}_4$	VG	EG	EG	EG	B	VG
	$\breve{\breve{A}}_5$	VB	VVG	F	VVG	G	VVG

is more comfortable for passengers at a minimum rate and the second one scooter $\breve{\breve{A}}_4$ is also a more usable resource in urban areas. The remaining travelling source is also useful for passengers in urban areas such as rikshaw $\breve{\breve{A}}_3$, electric bike $\breve{\breve{A}}_5$ and electric cycle $\breve{\breve{A}}_1$.

Table 8: Judgments of expert 1

	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$
$\breve{\breve{A}}_1$	(0.46,0.42,0.94)	(0.27,0.75,0.82)	(0.16,0.89,0.66)
$\breve{\breve{A}}_2$	(0.98,0.01,0.39)	(0.74,0.15,0.84)	(0.98,0.01,0.39)
$\breve{\breve{A}}_3$	(0.87,0.11,0.70)	(0.98,0.01,0.39)	(0.87,0.11,0.70)
$\breve{\breve{A}}_4$	(0.87,0.11,0.70)	(0.98,0.01,0.39)	(0.66,0.24,0.89)
$\breve{\breve{A}}_5$	(0.66,0.24,0.89)	(0.87,0.11,0.70)	(0.87,0.11,0.70)
	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
$\breve{\breve{A}}_1$	(0.05,0.95,0.52)	(0.87,0.11,0.70)	(0.16,0.89,0.66)
$\breve{\breve{A}}_2$	(0.46,0.42,0.94)	(0.38,0.68,0.86)	(0.87,0.11,0.70)
$\breve{\breve{A}}_3$	(0.87,0.11,0.70)	(0.98,0.01,0.39)	(0.66,0.24,0.89)
$\breve{\breve{A}}_4$	(0.66,0.24,0.89)	(0.74,0.15,0.84)	(0.98,0.01,0.39)
$\breve{\breve{A}}_5$	(0.87,0.11,0.70)	(0.27,0.75,0.82)	(0.98,0.01,0.39)

Table 9: Judgments of expert 2

	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$
$\breve{\breve{A}}_1$	(0.16,0.89 0.66)	(0.98,0.01,0.39)	(0.87,0.11,0.70)
$\breve{\breve{A}}_2$	(0.98,0.01,0.39)	(0.05,0.95,0.52)	(0.46,0.42,0.94)
$\breve{\breve{A}}_3$	(0.74,0.15,0.84)	(0.87,0.11,0.70)	(0.38,0.68,0.86)
$\breve{\breve{A}}_4$	(0.16,0.89,0.66)	(0.53,0.31,0.94)	(0.98,0.01,0.39)
$\breve{\breve{A}}_5$	(0.98,0.01,0.39)	(0.38,0.68,0.86)	(0.27,0.75,0.82)
	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
$\breve{\breve{A}}_1$	(0.46,0.42,0.94)	(0.74,0.15,0.84)	(0.98,0.01,0.39)
$\breve{\breve{A}}_2$	(0.87,0.11,0.70)	(0.27,0.75,0.82)	(0.98,0.01,0.39)
$\breve{\breve{A}}_3$	(0.98,0.01,0.39)	(0.98,0.01,0.39)	(0.87,0.11,0.70)
$\breve{\breve{A}}_4$	(0.46,0.42,0.94)	(0.87,0.11,0.70)	(0.05,0.95,0.52)
$\breve{\breve{A}}_5$	(0.38,0.68,0.86)	(0.46,0.42,0.94)	(0.66,0.24,0.89)

6 Comparison method

In this section, we conducted a comprehensive contrasting technique to prove the validation and compatibility of discussed decision-making methodologies and aggregation operators. There are many mathematical approaches and optimization techniques presented in the literature. However, each decision-making model has a lot of advantages to aggregate fuzzy information of human opinions. However, many decision analysis techniques have limited features and are unable to handle incomplete human information. To achieve the main goal of this section, we applied different existing mathematical approaches to organize information by experts in Tables 8-12. For instance, Cheng et al. [36] modified the theory of the VIKOR method for investigating the weights of experts and criteria to evaluate suitable optimal options under consideration of various characteristics. Riaz et al. [37] combined theories of two different decision-making methodologies

Table 10: Judgments of expert 3

	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$
$\breve{A}_1$	(0.98,0.01,0.39)	(0.27,0.75,0.82)	(0.46,0.42,0.94)
$\breve{A}_2$	(0.05,0.95,0.52)	(0.98,0.01,0.39)	(0.38,0.68,0.86)
$\breve{A}_3$	(0.87,0.11,0.70)	(0.74,0.15,0.84)	(0.98,0.01,0.39)
$\breve{A}_4$	(0.98,0.01,0.39)	(0.46,0.42,0.94)	(0.46,0.42,0.94)
$\breve{A}_5$	(0.16,0.89,0.66)	(0.98,0.01,0.39)	(0.66,0.24,0.89)
	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
$\breve{A}_1$	(0.87,0.11,0.70)	(0.74,0.15,0.84)	(0.38,0.68,0.86)
$\breve{A}_2$	(0.27,0.75,0.82)	(0.27,0.75,0.82)	(0.53,0.31,0.94)
$\breve{A}_3$	(0.66,0.24,0.89)	(0.98,0.01,0.39)	(0.87,0.11,0.70)
$\breve{A}_4$	(0.16,0.89,0.66)	(0.87,0.11,0.70)	(0.98,0.01,0.39)
$\breve{A}_5$	(0.87,0.11,0.70)	(0.27,0.75,0.82)	(0.05,0.95,0.52)

Table 11: Judgments of expert 4

	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$
$\breve{A}_1$	(0.87,0.11,0.70)	(0.46,0.42,0.94)	(0.98,0.01,0.39)
$\breve{A}_2$	(0.66,0.24,0.89)	(0.27,0.75,0.82)	(0.66,0.24,0.89)
$\breve{A}_3$	(0.74,0.15,0.84)	(0.87,0.11,0.70)	(0.53,0.31,0.94)
$\breve{A}_4$	(0.16,0.89,0.66)	(0.98,0.01,0.39)	(0.16,0.89,0.66)
$\breve{A}_5$	(0.98,0.01,0.39)	(0.27,0.75,0.82)	(0.87,0.11,0.70)
	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
$\breve{A}_1$	(0.38,0.68,0.86)	(0.87,0.11,0.70)	(0.87,0.11,0.70)
$\breve{A}_2$	(0.46,0.42,0.94)	(0.27,0.75,0.82)	(0.46,0.42,0.94)
$\breve{A}_3$	(0.74,0.15,0.84)	(0.53,0.31,0.94)	(0.66,0.24,0.89)
$\breve{A}_4$	(0.98,0.01,0.39)	(0.27,0.75,0.82)	(0.98,0.01,0.39)
$\breve{A}_5$	(0.87,0.11,0.70)	(0.87,0.11,0.70)	(0.46,0.42,0.94)

of TOPSIS and VIKOR methods by incorporating the q-ROF information. Li et al. [38] characterized an advanced decision analysis process of the EDAS method for the MAGDM problem. Recently, new mathematical approaches to Sugeno-Weber aggregation operators were developed by Wang et al. [39]. Hussain et al. [40] derived Aczel Alsina aggregation operators to compute the unknown degree of weights and appropriate optimal options. Akram et al. [41] enhanced the theoretical concepts of the MABAC method to aggregate various types of information. Zhao et al. [42] developed aggregation approaches of Hamy mean models based on bipolar complex fuzzy domains. After applying existing approaches to the given information in Tables 8-12, the obtained ranking of alternatives is shown in Table 19. Figure 5 illustrates the aggregated results of existing mathematical approaches.

From Table 19, readers can examine the ranking of alternatives deduced by existing approaches. Some of

Table 12: Judgments of expert 5

	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$
$\breve{A}_1$	(0.87,0.11,0.70)	(0.53,0.31,0.94)	(0.66,0.24,0.89)
$\breve{A}_2$	(0.05,0.95,0.52)	(0.27,0.75,0.82)	(0.87,0.11,0.70)
$\breve{A}_3$	(0.98,0.01,0.39)	(0.27,0.75,0.82)	(0.87,0.11,0.70)
$\breve{A}_4$	(0.74,0.15,0.84)	(0.98,0.01,0.39)	(0.98,0.01,0.39)
$\breve{A}_5$	(0.16,0.89,0.66)	(0.87,0.11,0.70)	(0.46,0.42,0.94)
	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
$\breve{A}_1$	(0.87,0.11,0.70)	(0.46,0.42,0.94)	(0.27,0.75,0.82)
$\breve{A}_2$	(0.16,0.89,0.66)	(0.05,0.95,0.52)	(0.87,0.11,0.70)
$\breve{A}_3$	(0.74,0.15,0.84)	(0.87,0.11,0.70)	(0.66,0.24,0.89)
$\breve{A}_4$	(0.98,0.01,0.39)	(0.27,0.75,0.82)	(0.74,0.15,0.84)
$\breve{A}_5$	(0.87,0.11,0.70)	(0.66,0.24,0.89)	(0.87,0.11,0.70)

Table 13: Aggregated decision matrix by experts judgments

	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$
$\breve{A}_1$	(0.6985,0.4346,0.8326)	(0.6237,0.5270,0.8486)	(0.6845,0.4434,0.8397)
$\breve{A}_2$	(0.7447,0.3859,0.8091)	(0.6125,0.5661,0.8382)	(0.6889,0.4281,0.8409)
$\breve{A}_3$	(0.7447,0.3238,0.8209)	(0.7263,0.3793,0.8253)	(0.7028,0.4131,0.8351)
$\breve{A}_4$	(0.6691,0.4783,0.8392)	(0.8176,0.2422,0.7601)	(0.7518,0.3537,0.8097)
$\breve{A}_5$	(0.7449,0.3817,0.8098)	(0.6972,0.4468,0.8300)	(0.5884,0.5457,0.8590)
	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
$\breve{A}_1$	(0.5613,0.6149,0.8391)	(0.6285,0.4571,0.8690)	(0.6672,0.5120,0.8285)
$\breve{A}_2$	(0.4772,0.6827,0.8307)	(0.2154,0.8944,0.6499)	(0.7201,0.3775,0.8305)
$\breve{A}_3$	(0.7195,0.3479,0.8365)	(0.8259,0.2298,0.7516)	(0.6165,0.4738,0.8703)
$\breve{A}_4$	(0.7529,0.3491,0.8096)	(0.5861,0.5594,0.8543)	(0.8114,0.2607,0.7652)
$\breve{A}_5$	(0.6796,0.4504,0.8410)	(0.5069,0.6354,0.8496)	(0.6868,0.4391,0.8394)

the previous mathematical terminologies are unable to handle expert judgments due to the limited structures of discussed approaches. The MARCOS method is an appropriate decision-making model and has various dominant features like investigating weights of criteria and experts and investigating credibility degrees of alternatives based on closeness coefficient indices. This decision analysis technique aggregates large amounts of human information without any loss of information during aggregation processes. Based on the significance of the discussed methodologies, we conclude that pioneered methodologies are superior to other existing methods.

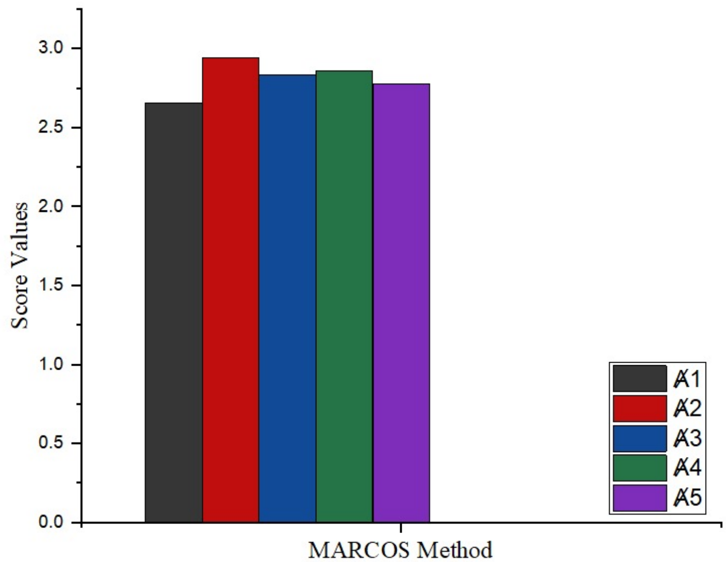

Figure 4: Geometrical representation to explore aggregated results by the MARCOS method

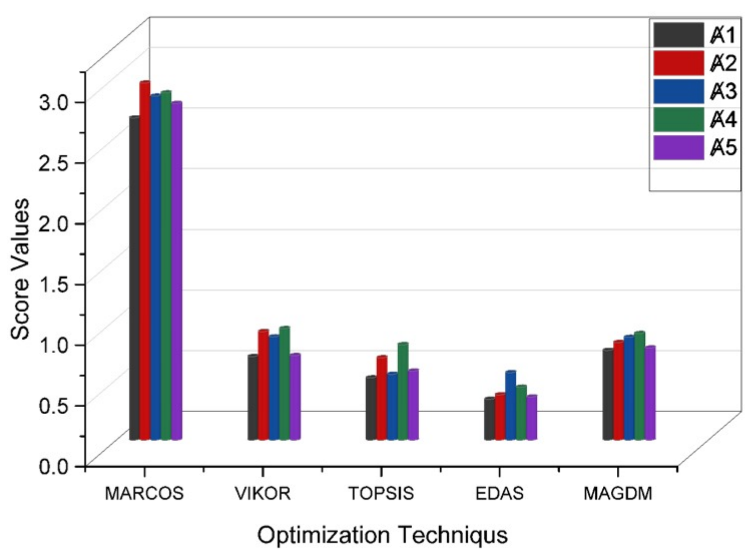

Figure 5: Aggregated results by existing optimization techniques

Table 14: Computed positive and negative solutions for the alternatives

	$S^+_{(\mathcal{C}_1)}$	$S^-_{(\mathcal{C}_1)}$	$CW_{(C_1)}$	$S^+_{(\mathcal{C}_2)}$	$S^-_{(\mathcal{C}_2)}$	$CW_{(C_2)}$	$S^+_{(\mathcal{C}_3)}$	$S^-_{(\mathcal{C}_3)}$	$CW_{(C_3)}$
$\breve{A}_1$	0.6593	0.9179	0.5820	0.7574	0.8537	0.5299	0.6793	0.9128	0.5733
$\breve{A}_2$	0.5870	0.9426	0.6162	0.7703	0.8186	0.5152	0.6731	0.9215	0.5779
$\breve{A}_3$	0.5871	0.9661	0.6220	0.6168	0.9454	0.6052	0.6528	0.9295	0.5874
$\breve{A}_4$	0.7004	0.8906	0.5598	0.4534	0.9858	0.6849	0.5750	0.9558	0.6244
$\breve{A}_5$	0.5866	0.9444	0.6168	0.6611	0.9108	0.5794	0.7963	0.8375	0.5126
	$S^+_{(\mathcal{C}_4)}$	$S^-_{(\mathcal{C}_4)}$	$CW_{(C_4)}$	$S^+_{(\mathcal{C}_5)}$	$S^-_{(\mathcal{C}_5)}$	$CW_{(C_5)}$	$S^+_{(\mathcal{C}_6)}$	$S^-_{(\mathcal{C}_6)}$	$CW_{(C_6)}$
$\breve{A}_1$	0.8232	0.7675	0.4825	0.7517	0.9045	0.5461	0.7030	0.8657	0.5519
$\breve{A}_2$	0.8913	0.6819	0.4334	0.9900	0.2844	0.2232	0.6265	0.9462	0.6016
$\breve{A}_3$	0.6275	0.9579	0.6042	0.4367	0.9879	0.6934	0.7657	0.8936	0.5386
$\breve{A}_4$	0.5733	0.9575	0.6255	0.7986	0.8249	0.5081	0.4658	0.9823	0.6783
$\breve{A}_5$	0.6862	0.9086	0.5698	0.8697	0.7434	0.4609	0.6760	0.9154	0.5752

Table 15: Extended decision matrix for all individuals

	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
$\breve{A}_1$	0.1942	0.1818	0.1994	0.1777	0.2246	0.18736
$\breve{A}_2$	0.2056	0.1768	0.2010	0.1596	0.0918	0.20425
$\breve{A}_3$	0.2076	0.2076	0.2043	0.2225	0.2852	0.18283
$\breve{A}_4$	0.1868	0.2350	0.2171	0.2304	0.2089	0.23028
$\breve{A}_5$	0.2058	0.1988	0.1783	0.2098	0.1895	0.1953
	0.2076	0.2350	0.2171	0.2304	0.0918	0.1828
	0.1868	0.1768	0.1783	0.1596	0.2852	0.2303

Table 16: Normalized decision matrix

	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
$\breve{A}_1$	0.9357	0.7736	0.9183	0.7714	0.4087	0.9759
$\breve{A}_2$	0.9907	0.7522	0.9256	0.6929	1.0000	0.8952
$\breve{A}_3$	1.0000	0.8836	0.9409	0.9660	0.3219	1.0000
$\breve{A}_4$	0.8999	1.0000	1.0000	1.0000	0.4393	0.7940
$\breve{A}_5$	0.9917	0.8460	0.8210	0.9109	0.4843	0.9363
	0.0335	0.0413	0.0357	0.0375	0.0163	0.0289
	0.0301	0.0311	0.0293	0.0260	0.0506	0.0364

7 Conclusion

This presentation articulated a novel decision-making model for investigating some dominant optimal options under considering appropriate characteristics or attributes information. To achieve the aims of this article,

Table 17: Weighted decision matrix based on alternatives

	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$
$\breve{\breve{A}}_1$	0.1508	0.1360	0.1511	0.1255	0.0726	0.1544
$\breve{\breve{A}}_2$	0.1597	0.1322	0.1523	0.1127	0.1775	0.1416
$\breve{\breve{A}}_3$	0.1612	0.1553	0.1548	0.1572	0.0571	0.1582
$\breve{\breve{A}}_4$	0.1451	0.1758	0.1646	0.1627	0.0780	0.1256
$\breve{\breve{A}}_5$	0.1599	0.1487	0.1351	0.1482	0.0860	0.1481
	0.0335	0.0413	0.0357	0.0375	0.0163	0.0289
	0.0301	0.0311	0.0293	0.0260	0.0506	0.0364

Table 18: Utility indices and utility functions for all individuals

	S_i^+	$\breve{\breve{A}}^-$	$\breve{\breve{A}}^+$	$f(\breve{\breve{A}}^+)$	$f(\breve{\breve{A}}^-)$	$f(\breve{\breve{A}}_i)$	**Rank**
$\breve{\breve{A}}_1$	0.7904	3.8831	4.0911	0.4870	0.5130	2.6556	5
$\breve{\breve{A}}_2$	0.8761	4.3044	4.5350	0.4870	0.5130	2.9438	1
$\breve{\breve{A}}_3$	0.8439	4.1458	4.3679	0.4870	0.5130	2.8353	3
$\breve{\breve{A}}_4$	0.8517	4.1844	4.4085	0.4870	0.5130	2.8617	2
$\breve{\breve{A}}_5$	0.8260	4.0579	4.2753	0.4870	0.5130	2.7752	4

Table 19: Ranking of preferences by existing approaches

Methodologies	**Ranking of preferences**
MARCOS method (Dicussed approach)	$\breve{\breve{A}}_2 \succ \breve{\breve{A}}_4 \succ \breve{\breve{A}}_3 \succ \breve{\breve{A}}_5 \succ \breve{\breve{A}}_1$
Cheng et al. [36]	$\breve{\breve{A}}_4 \succ \breve{\breve{A}}_2 \succ \breve{\breve{A}}_3 \succ \breve{\breve{A}}_5 \succ \breve{\breve{A}}_1$
Riaz et al. [37]	$\breve{\breve{A}}_4 \succ \breve{\breve{A}}_2 \succ \breve{\breve{A}}_5 \succ \breve{\breve{A}}_3 \succ \breve{\breve{A}}_1$
Li et al. [38]	$\breve{\breve{A}}_3 \succ \breve{\breve{A}}_4 \succ \breve{\breve{A}}_2 \succ \breve{\breve{A}}_5 \succ \breve{\breve{A}}_1$
Wang et al.[39]	$\breve{\breve{A}}_4 \succ \breve{\breve{A}}_3 \succ \breve{\breve{A}}_2 \succ \breve{\breve{A}}_5 \succ \breve{\breve{A}}_1$
Hussain et al. [40]	Limited structure
Akram et al. [41]	Limited structure
Zhao et al. [42]	Limited structure

we discussed an innovative theory of the MARCOS method under the system of q-ROF environment. However, the q-ROFS is an efficient and reliable mathematical terminology of fuzzy set theory used to handle ambiguous information accurately. In this article, five E-motor cars are evaluated by five experts under consideration of six criteria by the extensive literature review and expert's judgments through the q-ROF MARCOS method. After aggregating experts judgements, investigate the ranking of alternatives $\breve{\breve{A}}_2 \succ \breve{\breve{A}}_4 \succ \breve{\breve{A}}_3 \succ \breve{\breve{A}}_5 \succ \breve{\breve{A}}_1$ based on specific criteria or attribute information. So, mini car $\breve{\breve{A}}_2$ is the most comfortable motor car for passengers and their online booking rate is maximum as compared to other ones. So, the discussed decision-making methodology of the MARCOS method can aggregate human judgments in all aspects accurately. Moreover, a comparison method is conducted to reveal the supremacy and effectiveness of deduced theories with previous mathematical approaches.

In the coming future, discussed theory and decision-making terminologies can be used to resolve many other complicated real-life problems such as artificial intelligence, medical diagnosis, graph theories and computational mathematics. Furthermore, we will expand the discussed methodologies in different optimization techniques to resolve different real-life applications.

Table 20: Utility indices and utility functions for all individuals

Criteria	**(VVI)**	**(VI)**	**(I)**	**(M)**	**(B)**	**(UIM)**	**(VUIM)**
Eco-Friendly Option $\mathcal{C}_1$							
Convenient Access via Apps $\mathcal{C}_2$							
Reduced Traffic Congestion $\mathcal{C}_3$							
Low Noise Pollution $\mathcal{C}_4$							
Cost-Effective Transportation $\mathcal{C}_5$							
Flexible and Scalable Mobility Option $\mathcal{C}_6$							
Alternatives	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$(\mathcal{C}_5)$	$\mathcal{C}_6$	—
$\breve{\breve{A}}_1$							$\times$
$\breve{\breve{A}}_2$							$\times$
$\breve{\breve{A}}_3$							$\times$
$\breve{\breve{A}}_4$							$\times$
$\breve{\breve{A}}_5$							$\times$

Abbreviation:
For experts and criteria: Very very important (VVI) Very important (VI) Important (I) Medium (M) Bad (B) Unimportant (UIM) Very unimportant (VUIM).
Information for the preferences: Extreme good (EG); Very very good (VVG); Very good (VG); Good (G); Medium good (MG); Fair (F); Medium bad (MB); Bad (B); Very bad (VB); Very very bad (VVB).

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