SUPPLIER SELECTION PROBLEM UNDER UNCERTAINTY: A CASE STUDY OF PICKUP TRUCK FLEET PURCHASE

BY

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AN INDEPENDENT STUDY SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING (LOGISTICS AND SUPPLY CHAIN SYSTEMS ENGINEERING)

SIRINDHORN INTERNATIONAL INSTITUTE OF TECHNOLOGY

THAMMASAT UNIVERSITY

ACADEMIC YEAR 2023

THAMMASAT UNIVERSITY

SIRINDHORN INTERNATIONAL INSTITUTE OF TECHNOLOGY

INDEPENDENT STUDY

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ENTITLED

SUPPLIER SELECTION PROBLEM

UNDER UNCERTAINTY:

A CASE STUDY OF PICKUP TRUCK FLEET PURCHASE

was approved as partial fulfillment of the requirements for

the degree of Master of Engineering (Logistics and Supply Chain Systems Engineering)

on June 15, 2024

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Independent Study Title	SUPPLIER SELECTION PROBLEM UNDER UNCERTAINTY: A CASE STUDY OF PICKUP TRUCK FLEET PURCHASE
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Academic Years	2023

ABSTRACT

Supplier selection plays a pivotal role in organizational procurement, impacting material costs and overall competitiveness. However, navigating the complexities of this process, especially in the context of conflicting criteria and uncertain parameters, poses significant challenges. This study focuses on aiding decision-makers in a state enterprise tasked with selecting a diesel-powered 2WD pickup from seven available options in the Thai market. By employing fuzzy multi-criteria decision-making methods including Fuzzy Analytic Hierarchy Process (F-AHP), Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (F-TOPSIS), a combination of Fuzzy AHP and TOPSIS, and The Best-Worst Method (BWM), this research aims to provide insights into effective decision-making strategies. The results highlight FORD Ranger XLT Open Cab XLT 2.0L Turbo HR 6MT as the preferred choice across multiple methods, underscoring the reliability and robustness of certain approaches. For future research, we suggest exploring hybrid methodologies and considering diverse datasets to enhance decision-making processes in procurement contexts.

Keywords: Car selection criteria, Supplier selection, Fuzzy AHP, Fuzzy TOPSIS, Best-Worst Method

ACKNOWLEDGEMENTS

I would like to express my heartfelt thanks to Jirachai Buddhakulsomsiri. My dedicated mentor, his constant encouragement, and expert guidance played a key role in shaping the direction of this independent research. Without him to give advice, independent research this time would be difficult.

I am immensely grateful to my family for their unfailing support and understanding during the challenging moments of this academic pursuit. Their belief in my abilities and steadfast encouragement provided a solid foundation, enabling me to persevere and stay motivated even during the most demanding times.

In conclusion, I would like to acknowledge my own efforts for the determination and perseverance demonstrated throughout this research journey. Balancing the rigors of academic work with personal commitments required significant dedication and resilience. Recognizing my own contributions is essential, as it underscores the hard work, late nights, and moments of self-doubt that were overcome to achieve this accomplishment.

Pawena Fukfon

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Symbols/Abbreviations	**Terms**
BWM	The Best-Worst Method
F-AHP	The Fuzzy Analytical Hierarchy Process Method
F-AHP&TOPSIS	The Method is Based on The Combination of F-AHP and F-TOPSIS
F-TOPSIS	The Fuzzy Technique for Order Performance by Similarity to Ideal Solution

CHAPTER 1
INTRODUCTION

The strategic task of selecting vehicles for organizational operations goes beyond the mere acquisition of transportation assets—it is a decision that intricately shapes operational efficiency, corporate identity, and long-term sustainability. In this process, a delicate equilibrium must be struck among various considerations, encompassing the intended purpose of the vehicles, financial parameters, reliability, adherence to environmental standards, and regulatory compliance. As highlighted by M. Khurrum and S. Bhutta (2003) in the context of supplier selection, analogous criteria, such as pricing structure, delivery efficiency, product quality, and service capabilities, come to the forefront in the vehicle selection process. Whether constructing a delivery fleet or choosing executive vehicles, decisions in this domain carry profound implications for organizational functionality and perception within the competitive business landscape.

1.1 Vehicle selection

The significance of vehicle selection transcends the operational realm. These vehicles serve as indispensable tools influencing supply chain logistics, employee mobility, and customer interactions. In an era characterized by heightened environmental consciousness and an increasing emphasis on corporate responsibility, the choice of vehicles assumes additional gravity. Beyond addressing immediate operational requirements and budgetary constraints, the selected fleet becomes a tangible manifestation of the organization's commitment to sustainability, contributing to a positive brand image and advancing long-term environmental goals.

Effectively navigating the challenges inherent in vehicle selection demands a comprehensive evaluation process that extends beyond mere functional utility. It necessitates a profound understanding of the organization's operational needs and a strategic alignment with long-term objectives. Striking a delicate balance between practical considerations and strategic goals is imperative to ensure that the chosen vehicles not only meet immediate demands but also seamlessly integrate with the evolving business landscape.

The study will continue in the next chapters, delving into complex decision-making approaches meant to meet these nuanced difficulties. my goal is to provide organizations with the tools and insights needed to navigate the complexities of vehicle selection by focusing on frameworks such as the Fuzzy Analytic Hierarchy Process, Fuzzy Technique for Order of Preference by Similarity to Ideal Solution, the synergistic application of Fuzzy AHP and TOPSIS, and The Best-Worst Method.

CHAPTER 2
REVIEW OF LITERATURE

2.1 Multi-criteria decision-making methods in supplier selection

The selection of vendors for vehicle procurement has become a complicated procedure that necessitates a careful balance of operational, financial, and environmental goals. Several research on the role of multi-criteria decision-making approaches in this sector have been conducted. For example, Wei and Zhou (2023) emphasized the importance of frameworks such as AHP, BWM, and TOPSIS in the context of Chinese government agencies and public organizations, highlighting the necessity to connect preferences for electric vehicle procurement with sustainability and efficiency. Similarly, research by Jamil, Besar, and Sim (2013) highlighted the instrumental role of these methodologies in meeting the distinct operational and budgetary requirements of the automotive industry. Gupta, Soni, and Kumar (2019) investigated the integration of environmental issues, highlighting the need of multi-criteria decision-making in addressing sustainability in unpredictable contexts. These studies together highlight the critical significance of decision-making models in aligning varied aims within car supplier selection procedures, showing their critical importance in the dynamic environment of automotive procurement.

2.1.1 Fuzzy AHP

Veisi et al.(2022)employ the Analytic Hierarchy Process (AHP) in the multi-criteria selection of agricultural irrigation systems. This study showcases how AHP can support decision-makers in the agricultural sector by considering factors such as efficiency, cost-effectiveness, and environmental impact. The use of AHP contributes to sustainable and data-driven irrigation system selection.

In a 2017 study by Shahidan and Suâ, the research delves into the discerning car-buying habits of Malaysians who consider multiple criteria when making a purchasing decision. The study not only determines the preferred choice between domestic and imported cars in Malaysia but also compares and ranks the key criteria influencing buyers. Utilizing a structured questionnaire and the Fuzzy Analytical

Hierarchy Process (FAHP) method, the study serves as a practical guide for implementing FAHP in other multiple criteria decision-making scenarios.

2.1.2 Fuzzy TOPSIS

TOPSIS compares alternatives by calculating weights for each criterion, normalizing scores for each criterion, and finding the geometric distance between each alternative and the ideal choice. In this strategy, the optimal alternative is the one with the shortest geometric distance from the positive ideal solution and the largest geometric distance from the negative ideal solution. (Mahsa Oroojeni Mohammad Javad et al., 2020)

Nor-Al-Din et al. (2021) use TOPSIS to identify the best cars in Malaysia, emphasizing criteria like cost and performance. The study suggests potential variations with alternative methods, offering practical insights for those selecting cars based on specific criteria in the Malaysian market.

Azizi, Aikhuele, and Souleman (2015) focus on automotive supplier selection, identifying key criteria and sub-criteria. They introduce a Fuzzy Technique for Order Performance by Similarity to Ideal Solution (FTOPSIS) model, utilizing Triangular Fuzzy sets to handle vagueness and considering interdependencies between criteria. The FTOPSIS model proves successful in determining the best supplier, showing stability in rankings across different criteria weights and multiple sub-criteria. The study advocates for the applicability of this methodology in addressing vague multiple criteria decision-making problems and suggests potential expansion to different fields or industries in future research.

2.1.3 Fuzzy AHP and TOPSIS

Ball and Korukolu offer a fuzzy decision model in their 2009 study to facilitate the selection of a suitable operating system for computer systems inside enterprises, while taking into consideration decision makers' subjective views. The method is based on the combination of the F-AHP and the TOPSIS. The F-AHP approach is used to calculate criterion weights based on the decision-maker's preferences, whereas the TOPSIS method is used to rank operating systems. An empirical investigation validates the model's usefulness, highlighting its practical relevance in the complicated decision-making environment of operating system selection for enterprises (Ball & Korukolu, 2009).

In their 2020 study, Yousaf and colleagues address the overwhelming choices in the competitive automobile industry by proposing a novel Full Consistency Fuzzy TOPSIS method for car selection. This hybrid approach combines the Full Consistency method for criteria weight calculation with the Fuzzy TOPSIS approach for alternative ranking. The study evaluates seven alternatives based on criteria from Pak wheels, including style, fuel economy, price, comfort, and performance. Results demonstrate superior accuracy in alternative ranking compared to traditional TOPSIS and Analytical Hierarchy Process methods. The novelty of the approach lies in its application to alternative selection scenarios, offering a versatile solution for multi-criteria decision-making challenges in various industries (Yousaf et al., 2020).

2.1.4 Best-Worst Method

The Best-Worst Method (BWM) to handle problems with MCDM. The objective of that is to choose the best alternative or alternatives from a pool of options depending on various criteria. Beginning with the decision-maker's preferred criteria, BWM first identifies the best (most desirable) and worst (least desirable) options. Following that, it compares these two criteria with all other criteria in pairs. (Jafar Rezaei, 2015)

Mohtashami (2021), a novel Fuzzy Best-Worst Method (FBWM) is introduced as an extension of the Best-Worst Method for multi-criteria decision-making. The FBWM addresses uncertainties in comparisons involving linguistic variables. Unlike previous methods, it directly generates crisp weights from a fuzzy pairwise comparison matrix, eliminating the need for additional aggregation and ranking procedures. The proposed method ensures consistent rankings and outperforms established methods by better satisfying initial judgments, as demonstrated through numerical examples.

2.2 Environmental considerations in supplier and vehicle selection

Khan & Ali (2020) concentrate on selecting sustainable hybrid electric vehicles within the framework of a developing nation. Their study provides insights into the specific challenges and opportunities in achieving environmental sustainability in vehicle selection in developing regions. Atofarati (2021) presents a case study of Scania, emphasizing sustainable supplier selection and product design to achieve environmental sustainability goals. This case study likely showcases the integration of environmental criteria in supplier selection processes within a renowned automotive company. Hadian, Chahardoli, Golmohammadi, & Mostafaeipour (2020) propose a practical framework for supplier selection decisions, particularly within the automotive sector. Their framework likely addresses environmental sustainability concerns and could offer a structured approach towards selecting suppliers aligned with such objectives. Glock & Kim (2015) explore coordinating a supply chain with a heterogeneous vehicle fleet, considering greenhouse gas emissions. This study might offer insights into the environmental implications of vehicle fleet management within the supply chain, specifically addressing greenhouse gas emissions

Yousaf et al.'s 2020 study addresses the need for efficient transportation in Pakistan, using a hybrid FUCOM-Fuzzy TOPSIS approach to endorse the Toyota Mira as the optimal choice. The research introduces a novel Multi-Criteria Decision-Making technique, outperforming traditional methods. Despite benefiting potential car buyers, the study contributes a pioneering hybrid method for future decision-making research, recognizing limitations in data sources and response numbers.

Al Mohamed (2023) use F-TOPSIS, F-VIKOR, and F-GRA for green supplier selection. Notably, F-GRA and F-TOPSIS show the highest similarity in fuzzy weight calculation and alternative ranking, offering insights for selecting a green supplier in natural laurel soap production.

2.3 Operational and budgetary alignment in vehicle procurement

The automotive industry's procurement processes are intricate, demanding a careful harmony between operational needs and financial constraints. Several studies have delved into decision-making frameworks and methodologies that aim to align these operational requirements with budgetary considerations in vehicle procurement. Rhoden, Ball, Grajewski, Vögele, and Kuckshinrichs (2023) conducted an extensive assessment of the German passenger car sector, focusing on deciphering stakeholder preferences to understand the diverse factors influencing vehicle procurement within this sector. Their study illuminated the crucial nature of aligning stakeholder needs with both operational requisites and budgetary limitations in the process of selecting vehicles. Additionally, Jaller and Otay (2020) explored sustainable vehicle technologies for freight transportation, using spherical fuzzy AHP and TOPSIS methodologies. Their research emphasized the importance of evaluating and selecting sustainable vehicle technologies, striking a balance between operational efficiency and sustainability within the boundaries of budgetary constraints. Collectively, these studies contribute significantly to understanding the delicate balance needed between operational demands and financial limitations in the automotive industry's procurement processes, offering insights into strategies for efficient and sustainable vehicle selections within budgetary limitations.

2.4 Research gap and study contribution

The literary review comprises 14 academic works divided into two sections. Table 2.1, Research gap, presents these sections. Part 1 (Entries 1-4) investigates challenges in supplier selection, encompassing diverse topics such as the selection of mobile phones, supplier selection based on environmentally friendly innovation capabilities (e.g., Khouzestan Steel Company), and supplier selection in the chemical and process industries. Part 2 (Entries 5-14) focuses on vehicle selection, including considerations for choosing hybrid cars and various aspects related to car selection.

Specifically, the review emphasizes research related to vehicle selection, encompassing 10 studies. A summary of these diverse findings is detailed in Table 2.2 Illustrating the principles used in deciding on vehicle selection.

Each research study's selected criteria for decision-making are considered at 100%. The research under review predominantly highlights the "Cost of Purchase" criterion, as depicted in Table 2.3 Outlining the criteria used in deciding vehicle selection.

Table 2.1 Research gap.

Order	Year	Relate journals	Application area
1	2013	Modeling and development of a decision support system for supplier selection in the process industry	Selecting suppliers in the chemical processing industry.
2	2015	Best-worst multi-criteria decision-making method	choosing mobile phone
3	2020	Green supplier selection for the steel industry using BWM and fuzzy TOPSIS: A case study of Khouzestan steel company	Selecting suppliers of Khouzestan Steel Company (KSC) based on their green innovation ability.
4	2023	Application of fuzzy group decision-making selecting green supplier: a case study of the manufacture of natural laurel soap	Selecting suppliers in the process industry
5	2011	Choosing a hybrid car using a hierarchical decision model	Choosing a hybrid car
6	2017	Applying Fuzzy Analytical Hierarchy Process to Evaluate and Select the Best Car between Domestic and Imported Cars in Malaysia	Choosing Vehicle
7	2017	A novel modified fuzzy best-worst multi-criteria decision-making method	Choosing Vehicle
8	2018	Combining the AHP and TOPSIS to Evaluate Car Selection	Choosing Vehicle
9	2019	Selection of Electric Vehicles for Public Use Using AHP	Choosing Vehicle

Table 2.1 Research gap (Cont.)

Order	Year	Relate journals	Application area
10	2020	Development of a new hybrid multi criteria decision-making Method for a car selection scenario	Choosing Vehicle
11	2021	Application of TOPSIS Method for Decision Making in Selecting the Best New Car in Malaysia	Choosing Vehicle
12	2022	Decision making for car selection in Vietnam	Choosing Vehicle
13	2023	Decision support system for electric car selection using AHP and SAW Methods	Choosing Vehicle
14	2023	Selection of a vehicle for Brazilian Navy using the multi-criteria method to support decision-making TOPSIS-M	Choosing Vehicle

Table 2.2 Illustrating the principles used in deciding on vehicle selection.

Order	Relate journals	Use	Fuzzy	Number of Alternative	The best method
1	David Fenwick and Tugrul U. Daim(2011)	AHP		3	AHP
2	Wan Nurshazelin WanShahidan.,etc.(2017)	F-AHP	√	4	F-AHP
3	Qazvin Branch.,etc.(2017)	F-BWM	√	4	F-BWM
4	M. Mujiya Ulkhaq.,etc.(2018)	AHP, TOPSIS		2	AHP, TOPSIS
5	Nader A.,etc.(2019)	AHP		5	AHP
6	Yousaf A.,etc.(2020)	FCF-TOPSIS, AHP-F-TOPSIS, F-TOPSIS	√	7	FUCOM-Fuzzy TOPSIS
7	S M Nor-Al-Din.,etc.(2021)	TOPSIS		7	TOPSIS
8	Do Duc Trung.,etc.(2022)	R method, CURLT method	√	3	R and CURLT method
9	Yudhistira.,etc.(2023)	AHP ,SAW		3	AHP ,SAW
10	Jonathas V.,etc.(2023)	TOPSIS, TOPSIS-M	√	3	TOPSIS-M

Table 2.3 Outlining the criteria used in deciding vehicle selection.

Criteria		The Order of Related Journals										% of
		1	2	3	4	5	6	7	8	9	10	journals
Economic	Cost of Purchase	√	√	√	√	√	√	√	√	√	√	100%
	Resale Value				√							10%
	Maintenance Costs					√						10%
	Fuel Consumption Rate	√	√				√		√			50%
	Spare part warranty				√							10%
	Dealer				√							10%
Environment	Performance	√	√		√		√	√		√	√	70%
	Battery									√		10%
	Electric vehicle		√									10%
Features	Safety Features		√	√	√			√	√			50%
	Accessibility & Inclusivity				√			√	√			30%
	Community Impact		√						√			20%
	Technology & Connectivity								√			10%
	Space & Comfort	√	√	√			√		√			50%
	Aesthetics & Brand Image						√					10%
	Fuel tank capacity							√			√	20%
	Design			√	√					√	√	40%
	Made in									√		10%

CHAPTER 3
METHODOLOGY

3.1 The conceptual framework

Figure 3.1 shows the conceptual framework that guided this research. To obtain the study results, the research objectives focused on methods such as F-AHP, F-TOPSIS, the combined use of Fuzzy AHP&TOPSIS, and the BWM method, followed by a comparison of the results of each method. The aim is to provide organizations with the tools and insights needed to efficiently navigate the complex selection of pickup trucks.

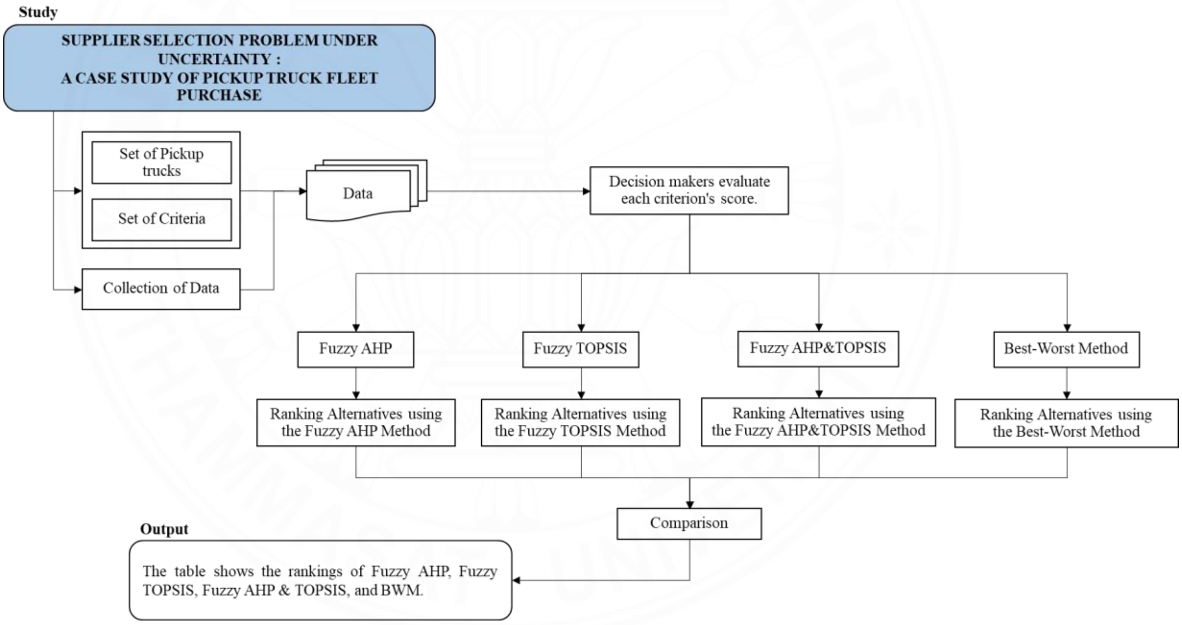

Figure 3.1 The conceptual framework.

3.2 Data collection

Data collection is essential for methods like the Fuzzy AHP, Fuzzy TOPSIS, and Fuzzy Best-Worst Method as it forms the bedrock of decision-making. The accuracy and relevance of decisions made using these methods heavily depend on the quality and reliability of the data collected. Without comprehensive and reliable data, it becomes challenging to conduct meaningful analysis, evaluate alternatives, and derive actionable insights. Thus, effective data collection is fundamental in ensuring the success and validity of the decision-making process.

The following are the steps taken to collect relevant data and information for supplier selection using these fuzzy decision-making techniques.

a. Identify Criteria: Identify the criteria relevant to supplier selection based on literature review and consultation with industry experts. These criteria may include cost, quality, brand reputation etc.

b. Data Sources: Gather data from various sources including procurement records, supplier performance reports, cost data, quality metrics, supplier profiles. Conduct interviews or surveys with procurement managers and subject matter experts to gather insights and preferences regarding supplier selection criteria.

c. Measurement Scales: Define measurement scales for each criterion. Determine whether criteria will be measured quantitatively (e.g., cost, number of airbags) or qualitatively (e.g., warranty coverage, quality rated on a scale from low to high).

d. Quantify Data: Convert qualitative data into quantitative form whenever possible. Assign numerical values to qualitative assessments or use fuzzy numbers to represent subjective judgments.

3.3 The consistency check

The Consistency Check concept and the Consistency Ratio (CR) are crucial for ensuring the reliability of the pairwise comparison judgments. According to Thomas L. Saaty, the developer of AHP, the CR must be less than 10% (or 0.10) to be considered acceptably consistent. Both the AHP and AHP-TOPSIS methods necessitate a consistency check to ensure the reliability of pairwise comparison judgments. Performing this consistency check validates that the comparisons are logically coherent and that the derived weights are accurate. This step is crucial for ensuring that the decision-making outcomes in both methods are dependable and credible.

The Consistency Index (CI) is calculated using the following formula:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{3.1}$$

where n is the number of criteria, and λ_{max} is the maximum eigenvalue of the pairwise comparison matrix.

Subsequently, the Consistency Ratio (CR) is determined by:

$$CR = \frac{CI}{RI} \tag{3.2}$$

Here, RI (Random Index) is the average consistency index of a randomly generated pairwise comparison matrix of the same size. The values of RI for different matrix sizes are taken from Saaty's established tables.

Table 3.1 The RI for different size matrices.

Number of elements	3	4	5	6	7	8	9	10	11	12	13
R.I.	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49	1.51	1.54	1.56

For cases where n is greater than 13, the RI values can be obtained from extended tables or interpolated from existing values. Saaty’s research provides RI values for larger matrices, ensuring that the consistency measure remains reliable for extensive criteria sets. For example, the RI value for $n = 18$ is approximately 1.56. If the CR is found to be less than 0.10, the pairwise comparisons are deemed to be consistent. If the CR exceeds 0.10, the judgments need to be re-evaluated and revised to improve consistency.

3.4 The TFNs

Triangular fuzzy numbers (TFNs), characterized by their three elements (lower bound, median, and upper bound denoted as l, m, u respectively) (Karimi, Sadeghi-Dastaki, & Javan, 2020), are pivotal in methods like AHP, Fuzzy TOPSIS, and Fuzzy Best-Worst Method for supplier selection involving multiple decision-makers. TFNs enable decision-makers to express their preferences and uncertainties, providing a flexible framework to capture the subjective assessments of various criteria and supplier alternatives. By leveraging TFNs, these methods accommodate the inherent vagueness and imprecision in decision-making, facilitating more accurate and realistic evaluations in the supplier selection process.

Table 3.2 Showing the importance of weights and ratings for the Fuzzy method.

Linguistic Terms	Fuzzy number
Equally Important (EI)	(1, 1, 2)
Little More Important (LI)	(2, 3, 4)
Much More Important (MI)	(4, 5, 6)
So Much More Important (SI)	(6, 7, 8)
Absolutely More Important (AI)	(8, 9, 9)
The intermittent values	
ELI	(1, 2, 3)
LMI	(3, 4, 5)
MSI	(5, 6, 7)
SAI	(7, 8, 9)

3.5 Fuzzy AHP (F-AHP)

F-AHP is a method in MCDM used for selecting the optimal pickup truck. It serves as a fuzzy of AHP, specifically designed to address hierarchical fuzzy problems. Recognized as one of the best methods, F-AHP proves convenient for assessing selection problems. (Nurshazelin, 2017) The selection or decision point entails various criteria, often with sub-criteria. In this scenario, a multitude of criteria must be considered, whether they involve objective or subjective considerations and quantitative and qualitative data.

Below is a systematic procedure detailing how to solve a problem utilizing the Fuzzy AHP approach.

Step 1: Decision makers $\{D_1, D_2, D_3, \dots, D_k\}$ evaluate criteria by scoring each criterion $\{C_1, C_2, C_3, \dots, C_j\}$.

Step 2: Perform pairwise comparisons and evaluate alternatives based on each criterion and Assign weights to criteria and alternatives $\{A_1, A_2, A_3, \dots, A_i\}$ based on proper linguistic terms.

$$\widetilde{A}^k = \begin{bmatrix} \frac{\tilde{a}_{1k}}{\tilde{a}_{1k}} & \frac{\tilde{a}_{1k}}{\tilde{a}_{2k}} & \cdots & \frac{\tilde{a}_{1k}}{\tilde{a}_{jk}} \\ \frac{\tilde{a}_{2k}}{\tilde{a}_{1k}} & \frac{\tilde{a}_{2k}}{\tilde{a}_{2k}} & \cdots & \frac{\tilde{a}_{2k}}{\tilde{a}_{jk}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\tilde{a}_{jk}}{\tilde{a}_{1k}} & \frac{\tilde{a}_{jk}}{\tilde{a}_{2k}} & \cdots & \frac{\tilde{a}_{jk}}{\tilde{a}_{jk}} \end{bmatrix} \tag{3.3}$$

Where $\tilde{a}_{jk}$ indicates the Decision-makers k preference of criterion j over another criterion j.

$$\widetilde{V}^k = \begin{bmatrix} \frac{\tilde{a}^j_{1k}}{\tilde{a}^j_{1k}} & \frac{\tilde{a}^j_{1k}}{\tilde{a}^j_{2k}} & \cdots & \frac{\tilde{a}^j_{1k}}{\tilde{a}^j_{ik}} \\ \frac{\tilde{a}^j_{2k}}{\tilde{a}^j_{1k}} & \frac{\tilde{a}^j_{2k}}{\tilde{a}^j_{2k}} & \cdots & \frac{\tilde{a}^j_{2k}}{\tilde{a}^j_{ik}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\tilde{a}^j_{ik}}{\tilde{a}^j_{1k}} & \frac{\tilde{a}^j_{ik}}{\tilde{a}^j_{2k}} & \cdots & \frac{\tilde{a}^j_{ik}}{\tilde{a}^j_{ik}} \end{bmatrix} \tag{3.4}$$

Where $\tilde{a}^j_{ik}$ indicates the Decision-makers k preference of alternative i over another alternative i with respect to criterion j.

Step 3: When multiple decision-makers are involved, the preferences of each individual are typically averaged.

$$\tilde{a}_{jj} = \frac{\sum_{k=1}^{K} \tilde{a}_{jjk}}{K} \tag{3.5}$$

$$\tilde{a}_{ii} = \frac{\sum_{k=1}^{K} \tilde{a}_{iik}}{K} \tag{3.6}$$

Step 4: Normalize the weights of the criteria. And Normalize the rating scores of alternatives.

The geometric mean of fuzzy comparison values is calculated:

$$\tilde{r}_j = \left(\prod_{j=1}^{n} \tilde{a}_{jj}\right)^{1/n}, \text{ for } j = 1, 2, 3, \ldots, n \tag{3.7}$$

The fuzzy weights of each criterion, denoted as w_j, can be determined as follows

$$\widetilde{w}_j = \tilde{r}_j \left(\sum_{j=1}^{n} \tilde{r}_j\right)^{-1} \tag{3.9}$$

Where

$$\left(\sum_{j=1}^{n} \tilde{r}_j\right)^{-1} = \left(\frac{1}{\sum_{j=1}^{n} r_{ju}}, \frac{1}{\sum_{j=1}^{n} r_{jm}}, \frac{1}{\sum_{j=1}^{n} r_{jl}}\right) \tag{3.10}$$

The geometric mean of fuzzy comparison values is calculated:

$$\tilde{r}_i = \left(\prod_{i=1}^{m} \tilde{a}_{ii}\right)^{1/m}, \text{ for } i = 1, 2, 3, \ldots, m \tag{3.11}$$

The fuzzy rating score of each alternative x_i can be find:

$$\tilde{x}_i = \tilde{r}_i \left(\sum_{i=1}^{m} \tilde{r}_i\right)^{-1} \tag{3.12}$$

Where

$$\left(\sum_{i=1}^{m} \tilde{r}_i\right)^{-1} = \left(\frac{1}{\sum_{i=1}^{m} r_{iu}}, \frac{1}{\sum_{i=1}^{m} r_{im}}, \frac{1}{\sum_{i=1}^{m} r_{il}}\right) \quad (3.13)$$

Step 5: Normalize de-fuzzified numbers.

$$Mc_j = \frac{w_{jl}+w_{jm}+w_{ju}}{3} \quad (3.14)$$

Normalize the defuzzified weight:

$$Nc_j = \frac{Mc_j}{\sum_{j=1}^{n} Mc_j} \quad (3.15)$$

The same computational process is applied for alternatives to each criterion.

$$Ma_i = \frac{w_{il}+w_{im}+w_{iu}}{3} \quad (3.16)$$

$$Na_j = \frac{Ma_i}{\sum_{i=1}^{m} Ma_i} \quad (3.17)$$

Step 6: Compute a weighted standardized decision matrix Normalized values and Compute the total weighted standardized value of each alternative.

$$V = \begin{bmatrix} Na_1Nc_1 & Na_1Nc_2 & \cdots & Na_1Nc_n \\ Na_2Nc_1 & Na_2Nc_2 & \cdots & Na_2Nc_n \\ \vdots & \vdots & \ddots & \vdots \\ Na_mNc_1 & Na_mNc_2 & \cdots & Na_mNc_n \end{bmatrix} \quad (3.18)$$

Step 7: Compute the total weighted standardized value of each alternative. A rank alternative based on total weighted standardized.

$$S_i = \sum_{j}^{n} V_{ij} \qquad \text{for } i \in m, j \in n \quad (3.19)$$

3.6 Fuzzy TOPSIS (F-TOPSIS)

F-TOPSIS was developed by Huang and Yoon as a mathematical framework for addressing Multi Criteria Decision Making. This method revolves around ranking available alternatives based on their similarity to positive and negative ideal solutions. Here are the steps for implementing the F-TOPSIS technique.

Step 1: Begin by listing all possible alternatives $\{A_1, A_2, A_3, \ldots, A_i\}$ for i=1,2,3,..,m and identifying various evaluation criteria $\{C_1, C_2, C_3, \ldots, C_j\}$ for j=1,2,3,..,n. Additionally, designate a group of decision-makers $\{D_1, D_2, D_3, \ldots, D_k\}$.

Decision makers then assess the ratings of alternatives in relation to each criterion. For quantitative criteria, ratings are determined based on the values associated with each alternative.

Moving forward, decision-makers proceed to evaluate the ratings of alternatives, taking into account the significance or weight assigned to each criterion

Step 2: Determine appropriate linguistic terms and linguistic weights for both criteria and alternatives, represented as triangular fuzzy numbers.

Quantitative rating has no triangular fuzzy numbers $(l_{ijk}, m_{ijk}, u_{ijk})$. $\widetilde{X}_{ijk}$ is exactly equal to the rating value.

Step 3: Compute the combined fuzzy weights for criteria $\widetilde{w}_{jk}$ and obtain aggregated fuzzy ratings for alternatives $\tilde{x}_{ijk}$.

$$\tilde{x}_{ij}=(l_{ijk},m_{ijk},u_{ijk}) \tag{3.20}$$

$$l_{ij}= \frac{1}{K}\sum_{k=1}^{K} l_{ijk} \tag{3.21}$$

$$m_{ij}= \frac{1}{K}\sum_{k=1}^{K} m_{ijk} \tag{3.22}$$

$$u_{ij}= \frac{1}{K}\sum_{k=1}^{K} u_{ijk} \tag{3.23}$$

$$\widetilde{w}_{ij}=(w_{j1},w_{j2},w_{j3}) \tag{3.24}$$

$$w_{j1}= \frac{1}{K}\sum_{k=1}^{K} l_{jk1} \tag{3.25}$$

$$w_{j2}= \frac{1}{K}\sum_{k=1}^{K} m_{jk2} \tag{3.26}$$

$$w_{j3}= \frac{1}{K}\sum_{k=1}^{K} u_{jk3} \tag{3.27}$$

Where K is the number of decision-makers.

Step 4: Normalize fuzzy decision matrix.

$$\widetilde{R} = \begin{bmatrix} \tilde{r}_{11} & \tilde{r}_{12} & \dots & \tilde{r}_{1j} & \dots & \tilde{r}_{1n} \\ \tilde{r}_{21} & \tilde{r}_{22} & \cdots & \tilde{r}_{2j} & \cdots & \tilde{r}_{2n} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ \tilde{r}_{i1} & \tilde{r}_{i2} & \cdots & \tilde{r}_{ij} & \cdots & \tilde{r}_{in} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ \tilde{r}_{m1} & \tilde{r}_{m2} & \cdots & \tilde{r}_{mj} & \cdots & \tilde{r}_{mn} \end{bmatrix} \tag{3.28}$$

Assumption B is a set of benefit criteria and C is a set of cost criteria.

$$\tilde{r}_{ij}=\left(\frac{l_{ij}}{u_j^+},\frac{m_{ij}}{u_j^+},\frac{u_{ij}}{u_j^+}\right),\ u_j^+=\max_i u_{ij}\ ,\ j\in B \tag{3.29}$$

$$\tilde{r}_{ij}=\left(\frac{l_j^-}{u_{ij}},\frac{l_j^-}{m_{ij}},\frac{l_j^-}{l_{ij}}\right),\ l_j^-=\ \min_i l_{ij}\ ,\ j\in C \tag{3.30}$$

Step 5: Create a weighted normalized matrix. Multiplying the normalized fuzzy decision matrix $\tilde{r}_{ij}$ and the weights $\widetilde{w}_j$ of the evaluating criteria, to get weighted normalized matrix $\widetilde{V}$.

$$\widetilde{V}=\begin{bmatrix} \widetilde{w}_1\tilde{r}_{11} & \widetilde{w}_2\tilde{r}_{12} & \dots & \widetilde{w}_j\tilde{r}_{1j} & \dots & \widetilde{w}_n\tilde{r}_{1n} \\ \widetilde{w}_1\tilde{r}_{21} & \widetilde{w}_2\tilde{r}_{22} & \cdots & \widetilde{w}_j\tilde{r}_{2j} & \cdots & \widetilde{w}_n\tilde{r}_{2n} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ \widetilde{w}_1\tilde{r}_{i1} & \widetilde{w}_2\tilde{r}_{i2} & \cdots & \widetilde{w}_j\tilde{r}_{ij} & \cdots & \widetilde{w}_n\tilde{r}_{in} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ \widetilde{w}_1\tilde{r}_{m1} & \widetilde{w}_2\tilde{r}_{m2} & \cdots & \widetilde{w}_j\tilde{r}_{mj} & \cdots & \widetilde{w}_n\tilde{r}_{mn} \end{bmatrix} \tag{3.31}$$

Step 6: Compute fuzzy PIS A^{+} and fuzzy NIS A^{-}.

$$A^{+}=\left(\tilde{v}_1^{+},\tilde{v}_2^{+},\ldots,\tilde{v}_n^{+}\right),\text{ where }\tilde{v}_j^{+}=\max_i\left\{v_{iju}\right\},\text{ for } i=1,2,\ldots,m \text{ and } j=1,2,\ldots,n \quad (3.32)$$

$$A^{-}=\left(\tilde{v}_1^{-},\tilde{v}_2^{-},\ldots,\tilde{v}_n^{-}\right),\text{ where }\tilde{v}_j^{-}=\min_i\left\{v_{ijl}\right\},\text{ for } i=1,2,\ldots,m \text{ and } j=1,2,\ldots,n \quad (3.33)$$

Step 7: Find the distance of each alternative from fuzzy NIS and fuzzy PIS using Euclidean distance.

$$d_i^{+}=\sqrt{\sum_{j=1}^{n}\left(\tilde{v}_j^{+}-\tilde{v}_{ij}\right)^2}\text{ , for } i=1,2,\ldots,m \quad (3.34)$$

$$d_i^{-}=\sqrt{\sum_{j=1}^{n}\left(\tilde{v}_j^{-}-\tilde{v}_{ij}\right)^2}\text{ , for } i=1,2,\ldots,m \quad (3.35)$$

Step 8: Calculate the closeness coefficients and rank the alternatives accordingly.

$$CC_i=\frac{d_i^{-}}{d_i^{-}+d_i^{+}} \quad (3.36)$$

3.7 Fuzzy AHP and TOPSIS (F-AHP& TOPSIS)

In the initial phase, a qualitative performance evaluation is conducted through the application of fuzzy AHP to determine criteria weights. Subsequently, fuzzy TOPSIS is employed to establish the ranking of suppliers (Mithat & Cüneyt, 2011). The integration of AHP and TOPSIS methodologies has demonstrated greater effectiveness compared to their individual use, particularly in fuzzy conditions when addressing intricate Multiple Criteria Decision Making problems (Zeydan & Çolpan, 2009).Below is a sequential guide outlining the steps to solve a problem using the Fuzzy AHP approach.

Step 1: Begin by listing all possible alternatives $\{A_1, A_2, A_3, \dots, A_i\}$ for i=1,2,3,..,m and identifying various evaluation criteria $\{C_1, C_2, C_3, \dots, C_j\}$ for j=1,2,3,..,n. Additionally, designate a group of decision-makers $\{D_1, D_2, D_3, \dots, D_k\}$.

Step 2: Perform pairwise comparisons and evaluate alternatives based on each criterion and Assign weights to criteria and to alternatives based on proper linguistic terms.

$$\widetilde{A}^k = \begin{bmatrix} \tilde{a}_{1k}/\tilde{a}_{1k} & \tilde{a}_{1k}/\tilde{a}_{2k} & \cdots & \tilde{a}_{1k}/\tilde{a}_{jk} \\ \tilde{a}_{2k}/\tilde{a}_{1k} & \tilde{a}_{2k}/\tilde{a}_{2k} & \cdots & \tilde{a}_{2k}/\tilde{a}_{jk} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{jk}/\tilde{a}_{1k} & \tilde{a}_{jk}/\tilde{a}_{2k} & \cdots & \tilde{a}_{jk}/\tilde{a}_{jk} \end{bmatrix} \tag{3.37}$$

Where $\tilde{a}_{jk}$ indicates the Decision makers k preference of criterion j over another criterion j.

Step 3: Calculate the importance degrees for each criterion. The normalization of the geometric mean method is used to determine the importance degrees for each criterion. Let w_j denote the importance degree for the i criterion, then

$$w_i = \frac{\left[\prod_{j=1}^{n} a_{ij}\right]^{1/n}}{\sum_{i=1}^{m}\left[\prod_{j=1}^{n} a_{ij}\right]^{1/n}}, \text{ for } i = 1, 2, 3, \dots, m \text{ , for } j = 1, 2, 3, \dots, n \tag{3.38}$$

Step 4: Normalize fuzzy decision matrix.

$$\tilde{R}=\begin{bmatrix}\tilde{r}_{11} & \tilde{r}_{12} & \cdots & \tilde{r}_{1j} & \cdots & \tilde{r}_{1n}\\ \tilde{r}_{21} & \tilde{r}_{22} & \cdots & \tilde{r}_{2j} & \cdots & \tilde{r}_{2n}\\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots\\ \tilde{r}_{i1} & \tilde{r}_{i2} & \cdots & \tilde{r}_{ij} & \cdots & \tilde{r}_{in}\\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots\\ \tilde{r}_{m1} & \tilde{r}_{m2} & \cdots & \tilde{r}_{mj} & \cdots & \tilde{r}_{mn}\end{bmatrix} \tag{3.39}$$

Assumption B is a set of benefit criteria and C is a set of cost criteria.

$$\tilde{r}_{ij}=\left(\frac{l_{ij}}{u_j^+},\frac{m_{ij}}{u_j^+},\frac{u_{ij}}{u_j^+}\right),\ u_j^+=\max_i u_{ij},\ j\in B \tag{3.40}$$

$$\tilde{r}_{ij}=\left(\frac{l_j^-}{u_{ij}},\frac{l_j^-}{m_{ij}},\frac{l_j^-}{l_{ij}}\right),\ l_j^-=\min_i l_{ij},\ j\in C \tag{3.41}$$

Step 5: Create a weighted normalized matrix. Multiplying the normalized fuzzy decision matrix $\tilde{r}_{ij}$ and the weights $\tilde{w}_j$ of the evaluating criteria, to get weighted normalized matrix $\tilde{V}$.

$$\tilde{V}=\begin{bmatrix}\tilde{w}_1\tilde{r}_{11} & \tilde{w}_2\tilde{r}_{12} & \cdots & \tilde{w}_j\tilde{r}_{1j} & \cdots & \tilde{w}_n\tilde{r}_{1n}\\ \tilde{w}_1\tilde{r}_{21} & \tilde{w}_2\tilde{r}_{22} & \cdots & \tilde{w}_j\tilde{r}_{2j} & \cdots & \tilde{w}_n\tilde{r}_{2n}\\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots\\ \tilde{w}_1\tilde{r}_{i1} & \tilde{w}_2\tilde{r}_{i2} & \cdots & \tilde{w}_j\tilde{r}_{ij} & \cdots & \tilde{w}_n\tilde{r}_{in}\\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots\\ \tilde{w}_1\tilde{r}_{m1} & \tilde{w}_2\tilde{r}_{m2} & \cdots & \tilde{w}_j\tilde{r}_{mj} & \cdots & \tilde{w}_n\tilde{r}_{mn}\end{bmatrix} \tag{3.41}$$

Step 6: Identify the positive ideal solutions and negative ideal solutions.

$$A^+=\left(\tilde{v}_1^+,\tilde{v}_2^+,\ldots,\tilde{v}_n^+\right),\ \text{where } \tilde{v}_j^+=\max_i\left\{v_{iju}\right\},\ \text{for } i=1,2,\ldots,m \text{ and } j=1,2,\ldots,n \tag{3.42}$$

$$A^-=\left(\tilde{v}_1^-,\tilde{v}_2^-,\ldots,\tilde{v}_n^-\right),\ \text{where } \tilde{v}_j^-=\min_i\left\{v_{ijl}\right\},\ \text{for } i=1,2,\ldots,m \text{ and } j=1,2,\ldots,n \tag{3.43}$$

Step 7: Calculate the distance from alternatives to the fuzzy Positive Ideal Solution (PIS) and fuzzy Negative Ideal Solution (NIS).

$$d_i^{+}=\sqrt{\sum_{j=1}^{n}\left(\tilde{v}_j^{+}-\tilde{v}_{ij}\right)^2}\text{, for } i=1, 2, \ldots, m \tag{3.44}$$

$$d_i^{-}=\sqrt{\sum_{j=1}^{n}\left(\tilde{v}_j^{-}-\tilde{v}_{ij}\right)^2}\text{, for } i=1, 2, \ldots, m \tag{3.45}$$

Step 8: Determine the closeness coefficient and rank the alternatives accordingly.

$$CC_i=\frac{d_i^{-}}{d_i^{-}+d_i^{+}} \tag{3.46}$$

3.8 Best-Worst Method (BWM)

Best-Worst Method enhances traditional BWM by incorporating fuzzy set theory, allowing for nuanced representation of preferences amidst uncertainty. It replaces rigid numerical scales with fuzzy sets, providing flexibility in decision-making. This adaptation acknowledges real-world ambiguity, offering more accurate results in situations where preferences are not clearly defined. Here's a step-by-step guide on solving a problem using the -BWM approach:

Step 1: Establish the decision criteria defined by the Decision maker as $\{C_1, C_2, C_3, ..., C_j\}$ for j=1,2,3,..,n.

Step 2: Decision makers $\{D_1, D_2, D_3, ..., D_k\}$ evaluate criteria by scoring each criterion. If there are multiple decision-makers, they will find the average. The highest score represents the best criterion, and the lowest score represents the worst criterion, as determined by the decision maker.

Step 3: The priority of the best criterion over other criteria (BO) is calculated by the decision maker, who evaluates the scores of each criterion and compares them. The resulting number represents a comparison between the best criterion and the other criteria, denoted as $A_{Bj} = (a_{B1}, a_{B2}, \cdots, a_{Bn})$.

Step 4: The priority of other criteria over the worst criterion (OW) is calculated as the decision maker evaluates the scores of each criterion and compares them. The numbers obtained represent a comparison between the other criteria and the worst criterion, denoted as $A_{jW} = (a_{1W}, a_{2W}, \cdots, a_{nW})$.

Step 5: Calculating the weights of the criteria, $W^* \in \{w_1^*, w_2^*, \cdots, w_n^*\}$ The mathematical model of BWM is based on the BO and OW priority vectors.

Optimal weights of the criteria must satisfy the following equations: $w_j/w_W = a_{jW}$, $w_B/w_j = a_{Bj}$. To satisfy these conditions, a solution must be found for each j, maximizes $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $|w_j/w_W - a_{jW}|$. ξ represents the maximum deviation between experts' comparison vectors. Please be aware that we are currently optimizing the ξ, indicating that our linear programming model is designed to minimize inconsistencies.

Optimal weights of the criteria in BWM are obtained using the equation.

$$\text{Min } \xi \tag{3.47}$$

$$w_B - a_{Bj} w_j - \xi \leq 0, \forall j \tag{3.48}$$

$$w_B - a_{Bj} w_j + \xi \geq 0, \forall j \tag{3.49}$$

$$w_j - a_{jW} w_W - \xi \leq 0, \quad \forall j \tag{3.50}$$

$$w_j - a_{jW} w_W + \xi \geq 0, \quad \forall j \tag{3.51}$$

$$\sum_{j=1}^{n} w_j = 1 \tag{3.52}$$

$$W_j \geq 0 \tag{3.53}$$

Step 6: Normalized values

If the data comes from evaluations by decision-makers, it implies qualitative data, and we can skip this step. However, in cases where there are quantitative data, normalization should be performed using the following equation:

$$X_{ij}=X_{normalized} = \frac{x-x_{min}}{x_{max}-x_{min}} \tag{3.54}$$

Step 7: Generalized Pairwise Comparison Method implementation under each alternative.

$$
\text{GPM} = \begin{bmatrix} X_{11} & X_{12} & \ldots & X_{1j} & \ldots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2j} & \cdots & X_{2n} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ X_{i1} & X_{i2} & \cdots & X_{ij} & \cdots & X_{in} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mj} & \cdots & X_{mn} \end{bmatrix} \tag{3.55}
$$

Step 8: Priority calculation and Ranking.

$$
\text{GMP} \times W^{*} = \begin{bmatrix} X_{11} & X_{12} & \ldots & X_{1j} & \ldots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2j} & \cdots & X_{2n} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ X_{i1} & X_{i2} & \cdots & X_{ij} & \cdots & X_{in} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mj} & \cdots & X_{mn} \end{bmatrix} \times \left[w_1^*, w_2^*, \ldots, w_j^*, w_n^*\right]
$$

$$
= \begin{bmatrix} X_{11}\times w_1^* & X_{12}\times w_2^* & \ldots & X_{1j}\times w_j^* & \ldots & X_{1n}\times w_n^* \\ X_{21}\times w_1^* & X_{22}\times w_2^* & \cdots & X_{2j}\times w_j^* & \cdots & X_{2n}\times w_n^* \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ X_{i1}\times w_1^* & X_{i2}\times w_2^* & \cdots & X_{ij}\times w_j^* & \cdots & X_{in}\times w_n^* \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ X_{m1}\times w_1^* & X_{m2}\times w_2^* & \cdots & X_{mj}\times w_j^* & \cdots & X_{mn}\times w_n^* \end{bmatrix} \tag{3.56}
$$

Afterward, the scores for each alternative are as follows:

$$
\text{Overall} = \begin{bmatrix} (X_{11}\times w_1^*)+(X_{12}\times w_2^*)+\ldots+(X_{1j}\times w_j^*)+(X_{1n}\times w_n^*) \\ (X_{21}\times w_1^*)+(X_{22}\times w_2^*)+\ldots+(X_{2j}\times w_j^*)+(X_{2n}\times w_n^*) \\ \vdots \\ (X_{i1}\times w_1^*)+(X_{i2}\times w_2^*)+\ldots+(X_{ij}\times w_j^*)+(X_{in}\times w_n^*) \\ \vdots \\ (X_{m1}\times w_1^*)+(X_{m2}\times w_2^*)+\ldots+(X_{mj}\times w_j^*)+(X_{mn}\times w_n^*) \end{bmatrix} \tag{3.57}
$$

CHAPTER 4
COMPUTATIONAL STUDY

4.1 Data collection of case study

The state enterprise, one company is in the process of selecting a diesel-powered 2WD pickup with a manual 6-speed transmission and two doors. Therefore, the company needs to decide on the purchase of a company vehicle based on 18 criteria, with six decision-makers. There are a total of seven options for pickup trucks from seven different brands available in the pickup truck market in Thailand, as follows:

a. MITSUBISHI (Triton Mega Cab Plus 2WD 2.4 GLX 6MT)
b. ISUZU (Spark 1.9 Ddi B)
c. FORD (Ranger XLT Open Cab XLT 2.0L Turbo HR 6MT)
d. TOYOTA (Hilux Revo Standard Cab 4x2 2.4 Entry)
e. NISSAN (KC Calibre E 6MT)
f. MG (EXTENDER 2.0 GRAND D 6MT)
g. MAZDA (BT-50 STANDARD CAB 1.9E)

4.1.1 List of criteria

The data utilized in this study emanates from the comprehensive literature review presented in Chapter Two, serving as a foundational source for extracting information about the criteria considered paramount by decision-makers in the reception and assessment of recommendations. Predominantly discussed factors include price, fuel costs, and repair expenses, with a total of 18 distinct criteria, as delineated in Table 4.1 C_j refers to criteria j, where j is the set of criteria 1,2,3,...,18 and has determined that there are 9 quantitative decision criteria. The others are qualitative evaluation criteria. Subsequently, six decision-makers were engaged in the evaluation process, assigning ratings to each criterion based on their perspectives. It is essential to note that the data in this segment represents a simulated scoring system, employing a scale from 1 to 9. In this context, a score of 1 signifies the least significance, while a score of 9 denotes the utmost importance as depicted in Table 4.2.

Table 4.1 List of criteria.

Criteria category	Initial	Criteria	Type	Cost/ Benefit
Powertrain	C_1	Engine Size (L)	Quantitative	Benefit
	C_2	Maximum Power (PS/ 3500 rpm)	Quantitative	Benefit
Financial	C_3	Cost (฿)	Quantitative	Cost
	C_4	Resale Value 5-year (%)	Quantitative	Benefit
	C_5	Maintenance&repair 5 Year Cost (฿)	Quantitative	Cost
	C_6	Fuel Consumption Rate (L/km)	Quantitative	Cost
Payload Capacity	C_7	Maximum Payload Rating (m^3)	Quantitative	Benefit
	C_8	Distribution of Payload (Pounds)	Quantitative	Benefit
Warranty Coverage	C_9	Warranty Coverage (1-9)	Qualitative	Benefit
Technology and Connectivity	C_{10}	Infotainment System Features (1:Touchable,0:Not Touchable)	Qualitative	Benefit
	C_{11}	Connectivity Options (1-9)	Qualitative	Benefit
Safety Features	C_{12}	Number of Airbags (airbags)	Quantitative	Benefit
	C_{13}	Traction Control System (1:Yes, 0:No)	Qualitative	Benefit
	C_{14}	Collision Avoidance Systems (1:Yes, 0:No)	Qualitative	Benefit
	C_{15}	Backup Cameras and Parking Sensors (1:Yes, 0:No)	Qualitative	Benefit
Service	C_{16}	Brand Reputation (1-9)	Qualitative	Benefit
	C_{17}	Dealer Network Accessibility (1-9)	Qualitative	Benefit
	C_{18}	Service quality (1-9)	Qualitative	Benefit

4.1.2 Score of decision-makers evaluate each criterion

Six decision-makers are involved in the evaluation process, where D_k refers to decision-maker k, with k ranging from 1 to 6, utilizing the scale depicted in Table 4.2 Weightage preference. Scores are allocated to each criterion based on their respective perspectives, as illustrated in Table 4.3.

Table 4.2 Weightage preference.

Scale	Initial	Weightage preference
Extremely low	EI	1
Very low	ELI	2
Low	LI	3
Low to Medium	LMI	4
Medium	MI	5
Medium to high	MSI	6
Hight	SI	7
Very high	SAI	8
Extremely high	AI	9

Table 4.3 Rankings of the criteria used by various decision-makers.

Evaluate the criteria by	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
D_1	MI	MI	SAI	MSI	MSI	MI	SI	SI	LMI
D_2	LI	LI	AI	SAI	SI	SAI	MSI	MSI	MI
D_3	MSI	MI	SAI	MSI	MSI	AI	SI	SI	MSI
D_4	LMI	MI	SI	MI	MI	MSI	MI	MI	SI
D_5	LMI	MI	MSI	SAI	SAI	AI	SI	SI	MI
D_6	SI	SAI	MI	MSI	SI	SAI	SI	SI	MI

Table 4.3 Rankings of the criteria used by various decision-makers (Cont.)

Evaluate the criteria by	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
D_1	ELI	LI	MI	MI	MSI	LI	MSI	MI	MSI
D_2	EI	ELI	SI	SI	SI	LMI	SI	SI	MSI
D_3	LI	LMI	MSI	MSI	MSI	LMI	MSI	SI	SI
D_4	MI	MI	MSI	SI	SI	EI	MI	SI	SAI
D_5	ELI	MI	MSI	MSI	MSI	MI	LI	SI	SAI
D_6	EI	LI	MSI	MSI	SI	LI	ELI	SI	SAI

4.1.3 Quantitative information about pickup trucks

Out of the 18 criteria, 9 are quantitative criteria. This information can be sourced from the respective websites of each pickup truck. It's important to note that this research focused on pickup truck data starting from the beginning of 2024 as presented in Table 4.4. Let A_i represent alternative pickup truck i, where i ranges from 1 to 7, A_1-MITSUBISHI Triton Mega Cab Plus 2WD 2.4 GLX 6MT, A_2-ISUZU Spark 1.9 Ddi B, A_3-FORD Ranger XLT Open Cab XLT 2.0L Turbo HR 6MT, A_4-TOYOTA Hilux Revo Standard Cab 4x2 2.4 Entry, A_5-NISSAN KC Caliber E 6MT, A_6-MG EXTENDER 2.0 GRAND D 6MT, and A_7-MAZDA BT-50 STANDARD CAB 1.9E

Table 4.4 Data of each alternative for quantitative criteria.

Criteria	Alternative						
	A_1	A_2	A_3	A_4	A_5	A_6	A_7
C_1	2.4	1.9	2	2.4	2.5	2	1.9
C_2	181	150	170	150	163	161	150
C_3	697,000	577,000	809,000	604,000	765,000	769,000	553,000
C_4	50%	55%	55%	65%	50%	50%	55%
C_5	70,407	51,269	91,517	55,998	73,867	64,939	73,867
C_6	0.085	0.069	0.093	0.071	0.067	0.075	0.098
C_7	1.582	1.723	1.399	1.75	1.268	1.188	1.588
C_8	1100	1200	1600	1350	1250	1150	1250
C_{12}	2	2	2	3	2	2	2

4.1.4 Qualitative information about pickup trucks

Quality criteria should be assessed by decision-makers using the scale specified in Table 4.2, Weightage Preference. Scores are assigned to each criterion based on their respective perspectives, as illustrated in Tables 4.6 through 4.10, reflecting supplier evaluations according to various decision-makers C_9, C_{11}, C_{16}, C_{17}, and C_{18}. Additionally, as noted in Table 4.5, specific quality-based criteria are classified as 'no' and 'yes' with weights of 0 and 1, respectively.

Table 4.5 Information on each alternative for qualitative criteria of the yes/no type.

Criteria	Alternative						
	A_1	A_2	A_3	A_4	A_5	A_6	A_7
C_{10}	0	0	1	1	1	1	0
C_{13}	0	0	1	1	1	1	0
C_{14}	0	1	1	0	0	0	0
C_{15}	0	0	1	0	1	1	0

Table 4.6 Supplier evaluations based on several decision-makers' 9th criteria.

Evaluate The criteria 9 by	A_1	A_2	A_3	A_4	A_5	A_6	A_7
D_1	SAI	SI	SI	MSI	SI	MSI	MSI
D_2	MSI	MI	LMI	MI	MI	LMI	MI
D_3	MSI	MSI	MI	MI	LMI	MSI	MI
D_4	MSI	MSI	MI	MI	MI	MSI	MI
D_5	MI	MSI	MI	MSI	MI	MI	MSI
D_6	SI	SI	SI	MSI	MSI	SI	SI

Table 4.7 Supplier evaluations based on several decision-makers' 11th criteria.

Evaluate The criteria 11 by	A_1	A_2	A_3	A_4	A_5	A_6	A_7
D_1	LMI	MI	SI	MI	MSI	MSI	MSI
D_2	MI	MI	SAI	MSI	MSI	MSI	MSI
D_3	MSI	MI	SAI	MI	SI	MSI	MSI
D_4	MI	MI	AI	MSI	MSI	MSI	MSI
D_5	MI	MI	SI	LMI	MSI	MSI	MSI
D_6	LMI	MI	SI	LMI	LMI	MSI	MSI

Table 4.8 Supplier evaluations based on several decision-makers' 16th criteria.

Evaluate The criteria 16 by	A_1	A_2	A_3	A_4	A_5	A_6	A_7
D_1	SI	AI	SI	MSI	SAI	MSI	MSI
D_2	SI	AI	SAI	SAI	SI	MSI	MSI
D_3	MSI	SAI	AI	MSI	SAI	SI	SI
D_4	SAI	MSI	SI	AI	MSI	SI	MSI
D_5	MSI	SAI	AI	SI	MSI	MSI	SAI
D_6	MSI	MSI	SI	SI	SAI	AI	SAI

Table 4.9 Supplier evaluations based on several decision-makers' 17th criteria.

Evaluate The criteria 17 by	A_1	A_2	A_3	A_4	A_5	A_6	A_7
D_1	AI	SI	MSI	SI	AI	SAI	MSI
D_2	SI	SI	AI	SAI	MSI	AI	SAI
D_3	AI	MSI	AI	SAI	SAI	SI	MSI
D_4	SI	MSI	SI	AI	AI	SAI	SAI
D_5	AI	AI	SI	SAI	MSI	SAI	MSI
D_6	SAI	AI	AI	SAI	MSI	SI	SI

Table 4.10 Supplier evaluations based on several decision-makers' 18th criteria.

Evaluate The criteria 18 by	A_1	A_2	A_3	A_4	A_5	A_6	A_7
D_1	MSI	SI	MSI	MSI	AI	MI	MI
D_2	SI	MSI	AI	MSI	MI	MSI	AI
D_3	MSI	MI	AI	SI	MI	SI	MSI
D_4	AI	AI	MSI	MSI	SI	MI	MI
D_5	MI	MSI	MSI	AI	AI	SI	MI
D_6	MSI	MSI	SI	AI	MSI	MI	SI

4.2 The consistency check n=18

In both F-AHP and F-AHP&TOPSIS, ensuring the reliability of pairwise comparison judgments is crucial, and the consistency check plays a pivotal role in achieving this goal. Initially, Table 4.11 presents the Average Pairwise Comparison Matrix (PCM), which consolidates multiple judgments into a cohesive representation. Subsequent normalization of this matrix, as illustrated in Table 4.12, standardizes values to facilitate meaningful comparisons across criteria or alternatives. Following normalization, calculating the Priority Vector provides valuable insights into their relative importance. Table 4.13 then demonstrates the calculation of the Consistency Measure, which is crucial for assessing the coherence of judgments through the Consistency Ratio.

Table 4.11 The average pairwise comparison matrix (PCM)**.**

criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	1.00	0.95	0.72	0.78	0.76	0.67	0.74	0.74	0.94
C_2	1.08	1.00	0.79	0.83	0.81	0.72	0.80	0.80	1.00
C_3	1.65	1.57	1.00	1.13	1.14	1.01	1.13	1.13	1.39
C_4	1.50	1.40	0.94	1.00	1.00	0.89	1.01	1.01	1.27
C_5	1.46	1.37	0.95	1.01	1.00	0.89	1.00	1.00	1.27
C_6	1.68	1.58	1.10	1.17	1.16	1.00	1.16	1.16	1.43
C_7	1.43	1.35	0.95	1.02	1.01	0.90	1.00	1.00	1.27
C_8	1.43	1.35	0.95	1.02	1.01	0.90	1.00	1.00	1.27
C_9	1.20	1.12	0.77	0.86	0.85	0.74	0.85	0.85	1.00
C_{10}	0.52	0.48	0.33	0.40	0.39	0.34	0.38	0.38	0.42
C_{11}	0.81	0.74	0.54	0.59	0.58	0.51	0.58	0.58	0.69
C_{12}	1.37	1.28	0.87	0.94	0.94	0.83	0.94	0.94	1.15
C_{13}	1.41	1.31	0.89	0.98	0.97	0.85	0.98	0.98	1.18
C_{14}	1.46	1.37	0.95	1.03	1.03	0.91	1.02	1.02	1.25
C_{15}	0.75	0.72	0.48	0.50	0.50	0.44	0.50	0.50	0.66
C_{16}	1.14	1.10	0.65	0.76	0.78	0.69	0.77	0.77	0.94
C_{17}	1.50	1.40	0.97	1.05	1.05	0.91	1.05	1.05	1.27
C_{18}	1.58	1.47	1.06	1.14	1.13	0.99	1.12	1.12	1.37
Sum	22.96	21.53	14.92	16.21	16.11	14.20	16.03	16.03	19.76

Table 4.11 The average pairwise comparison matrix (PCM) (Cont.)

criteria	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
C_1	2.88	1.43	0.82	0.81	0.75	1.84	1.32	0.74	0.68
C_2	3.11	1.51	0.88	0.86	0.80	2.06	1.46	0.79	0.72
C_3	4.18	2.24	1.20	1.18	1.11	2.80	1.64	1.10	1.04
C_4	4.00	2.02	1.08	1.07	1.01	2.35	1.63	0.99	0.93
C_5	4.00	1.99	1.09	1.07	1.01	2.36	1.69	0.99	0.92
C_6	4.53	2.26	1.25	1.22	1.16	2.73	1.95	1.12	1.05
C_7	3.89	1.97	1.10	1.08	1.01	2.39	1.67	1.00	0.92
C_8	3.89	1.97	1.10	1.08	1.01	2.39	1.67	1.00	0.92
C_9	2.98	1.57	0.89	0.86	0.82	2.29	1.32	0.80	0.75
C_{10}	1.00	0.61	0.40	0.38	0.36	1.23	0.52	0.35	0.32
C_{11}	1.89	1.00	0.62	0.60	0.57	1.58	0.94	0.55	0.50
C_{12}	3.62	1.84	1.00	0.98	0.92	2.35	1.51	0.90	0.85
C_{13}	3.65	1.88	1.03	1.00	0.95	2.52	1.54	0.93	0.87
C_{14}	3.90	1.99	1.09	1.06	1.00	2.63	1.65	0.99	0.92
C_{15}	2.09	1.03	0.56	0.55	0.52	1.00	0.85	0.50	0.48
C_{16}	2.75	1.54	0.81	0.79	0.75	1.92	1.00	0.75	0.71
C_{17}	3.96	2.01	1.11	1.08	1.03	2.65	1.71	1.00	0.94
C_{18}	4.16	2.10	1.20	1.17	1.11	2.92	1.88	1.08	1.00
Sum	60.47	30.97	17.22	16.83	15.90	40.01	25.95	15.56	14.53

Table 4.12 Normalize pairwise comparison matrix.

	Norm C_1	Norm C_2	Norm C_3	Norm C_4	Norm C_5	Norm C_6	Norm C_7	Norm C_8	Norm C_9
Norm C_1	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Norm C_2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Norm C_3	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Norm C_4	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Norm C_5	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Norm C_6	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Norm C_7	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Norm C_8	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Norm C_9	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Norm C_{10}	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Norm C_{11}	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03
Norm C_{12}	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Norm C_{13}	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Norm C_{14}	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Norm C_{15}	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Norm C_{16}	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.05
Norm C_{17}	0.07	0.07	0.07	0.06	0.06	0.06	0.07	0.07	0.06
Norm C_{18}	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07

Table 4.12 Normalize pairwise comparison matrix (Cont.)

	Norm C_{10}	Norm C_{11}	Norm C_{12}	Norm C_{13}	Norm C_{14}	Norm C_{15}	Norm C_{16}	Norm C_{17}	Norm C_{18}
Norm C_1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Norm C_2	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05
Norm C_3	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.07	0.07
Norm C_4	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Norm C_5	0.07	0.06	0.06	0.06	0.06	0.06	0.07	0.06	0.06
Norm C_6	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Norm C_7	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Norm C_8	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Norm C_9	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05
Norm C_{10}	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02
Norm C_{11}	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03
Norm C_{12}	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Norm C_{13}	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Norm C_{14}	0.06	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.06
Norm C_{15}	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03
Norm C_{16}	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.05
Norm C_{17}	0.07	0.06	0.06	0.06	0.06	0.07	0.07	0.06	0.06
Norm C_{18}	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07

Table 4.13 Calculate the consistency measure.

Criteria	Priority	PCM*Priority	λ_i
C_1	0.05	0.91	19.39
C_2	0.05	0.98	19.41
C_3	0.07	1.36	19.37
C_4	0.06	1.23	19.39
C_5	0.06	1.23	19.39
C_6	0.07	1.41	19.39
C_7	0.06	1.22	19.38
C_8	0.06	1.22	19.38
C_9	0.05	1.01	19.39
C_{10}	0.02	0.44	19.34
C_{11}	0.04	0.69	19.37
C_{12}	0.06	1.14	19.39
C_{13}	0.06	1.17	19.39
C_{14}	0.06	1.24	19.40
C_{15}	0.03	0.62	19.37
C_{16}	0.05	0.91	19.35
C_{17}	0.06	1.26	19.40
C_{18}	0.07	1.36	19.39
		Average (λ_{max})	19.38

Calculate the Consistency Index (CI) using the formula equation (3.1), where $\lambda_{max} = 19.38$ and n=18, resulting in CI= $\frac{(19.38-18)}{(18-1)}$ = 0.08. Next, calculate the consistency ratio (CR) using the formula equation (3.2), with RI = 1.56 for n = 18, giving CR= $\frac{0.08}{1.56}$ = 0.052. Since CR < 0.1, the matrix is consistent.

4.3 A case study of pickup truck fleet purchase using the Fuzzy AHP

Firstly, using the procedure indicated in Section 3.5, we compute Step by step as follows: Step 1 to select the best alternative from a set of 7 alternatives $\{A_1, A_2, A_3, \ldots, A_7\}$, 6 experts $\{D_1, D_2, D_3, \ldots, D_6\}$ are invited to determine the alternatives corresponding to 18 criteria $\{C_1, C_2, C_3, \ldots, C_{18}\}$, and Table 4.3 gives the rankings of the criteria used by various decision-makers. Furthermore, Table 4.14 offers a quantification of the scores of the first decision maker, thereby transforming them into weighted values, thereby enabling a quantitative assessment of preferences as per Table 4.2. Step 2 Conduct pairwise comparisons to assess alternatives against each criterion. Assign weights to both criteria and alternatives using appropriate linguistic terms, as outlined in Table 4.15 for pairwise comparisons. Table 4.16 presents the averaged preferences of each decision maker, reflecting the outcome of Step 3. Step 4 involves normalizing both the weights assigned to criteria and the rating scores allocated to alternatives. The outcome of this process is detailed in Table 4.17. Step 5 Normalize De-fuzzified Numbers as Presented in Table 4.18. Step 6 Compute a Weighted Standardized Decision Matrix Using Normalized Values and Calculate the Total Weighted Standardized Value for Each Alternative, as Illustrated in Table 4.19. Step 7 Calculate the Total Weighted Standardized Value for Each Alternative and Rank Alternatives Based on the Results. Table 4.20 Reflects the Outcome from F-AHP.

Table 4.14 The first decision maker evaluates the criteria by rating each criterion.

D_1	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
Evaluate	LMI	LMI	SI	MI	MI	LMI	MSI	MSI	LI
Scale	4	4	7	5	5	4	6	6	3

Table 4.14 The first decision maker evaluates the criteria by rating each criterion (Cont.)

D_1	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
Evaluate	EI	ELI	LMI	LMI	MI	ELI	MI	LMI	MI
Scale	1	2	4	4	5	2	5	4	5

Table 4.15 Pairwise comparison.

D_1	C_1	C_2	C_3	…	C_{18}
C_1	(3/3,4/4,5/5)	(3/3,4/4,5/5)	(3/6,4/7,5/8)	…	(3/4,4/5,5/6)
C_2	(3/3,4/4,5/5)	…	…	…	(3/4,4/5,5/6)
C_3	(6/3,7/4,8/5)	…	…	…	(6/4,7/5,8/6)
...	…	…	…	…	…
C_{18}	(4/3,5/4,6/5)	(4/3,5/4,6/5)	(4/6,5/7,6/8)	…	(4/4,5/5,6/6)

Table 4.16 The preferences of each decision maker were averaged.

Criteria	l	m	u	Criteria	l	m	u
C_1	0.045	0.047	0.048	C_{10}	0.019	0.023	0.028
C_2	0.049	0.05	0.051	C_{11}	0.031	0.035	0.039
C_3	0.073	0.07	0.067	C_{12}	0.059	0.059	0.058
C_4	0.065	0.063	0.062	C_{13}	0.061	0.06	0.06
C_5	0.065	0.063	0.062	C_{14}	0.065	0.064	0.063
C_6	0.076	0.073	0.068	C_{15}	0.029	0.032	0.036
C_7	0.065	0.063	0.062	C_{16}	0.045	0.047	0.049
C_8	0.065	0.063	0.062	C_{17}	0.067	0.065	0.064
C_9	0.051	0.052	0.053	C_{18}	0.072	0.07	0.068

Table 4.17 Normalize the weights of criteria.

Criteria	l	m	u	Normalized
C_1	0.045	0.047	0.048	0.047
C_2	0.049	0.050	0.051	0.050
C_3	0.073	0.070	0.067	0.070
C_4	0.065	0.063	0.062	0.064
C_5	0.065	0.063	0.062	0.063
C_6	0.076	0.073	0.068	0.072
C_7	0.065	0.063	0.062	0.063
C_8	0.065	0.063	0.062	0.063
C_9	0.051	0.052	0.053	0.052
C_{10}	0.019	0.023	0.028	0.023
C_{11}	0.031	0.035	0.039	0.035
C_{12}	0.059	0.059	0.058	0.059
C_{13}	0.061	0.060	0.060	0.060
C_{14}	0.065	0.064	0.063	0.064
C_{15}	0.029	0.032	0.036	0.032
C_{16}	0.045	0.047	0.049	0.047
C_{17}	0.067	0.065	0.064	0.065
C_{18}	0.072	0.070	0.068	0.070
	Sum			1

Table 4.18 Normalize de-fuzzified numbers.

C_1	norm	C_2	norm	C_3	norm	C_4	norm	C_5	norm	C_6	norm
A_1	0.159	A_1	0.161	A_1	0.146	A_1	0.132	A_1	0.146	A_1	0.153
A_2	0.126	A_2	0.133	A_2	0.121	A_2	0.145	A_2	0.106	A_2	0.124
A_3	0.132	A_3	0.151	A_3	0.169	A_3	0.145	A_3	0.190	A_3	0.166
A_4	0.159	A_4	0.133	A_4	0.127	A_4	0.171	A_4	0.116	A_4	0.127
A_5	0.166	A_5	0.145	A_5	0.160	A_5	0.132	A_5	0.153	A_5	0.120
A_6	0.132	A_6	0.143	A_6	0.161	A_6	0.132	A_6	0.135	A_6	0.135
A_7	0.126	A_7	0.133	A_7	0.116	A_7	0.145	A_7	0.153	A_7	0.176
sum	1	sum	1	sum	1	sum	1	sum	1	sum	1

Table 4.18 Normalize de-fuzzified numbers (Cont.)

C_7	norm	C_8	norm	C_9	norm	C_{10}	norm	C_{11}	norm	C_{12}	norm
A_1	0.151	A_1	0.124	A_1	0.158	A_1	0.00	A_1	0.119	A_1	0.133
A_2	0.164	A_2	0.135	A_2	0.154	A_2	0.00	A_2	0.124	A_2	0.133
A_3	0.133	A_3	0.180	A_3	0.135	A_3	0.25	A_3	0.190	A_3	0.133
A_4	0.167	A_4	0.152	A_4	0.138	A_4	0.25	A_4	0.123	A_4	0.200
A_5	0.121	A_5	0.140	A_5	0.132	A_5	0.25	A_5	0.144	A_5	0.133
A_6	0.113	A_6	0.129	A_6	0.141	A_6	0.25	A_6	0.150	A_6	0.133
A_7	0.151	A_7	0.140	A_7	0.141	A_7	0.00	A_7	0.150	A_7	0.133
sum	1	sum	1	sum	1	sum	1	sum	1	sum	1

Table 4.18 Normalize de-fuzzified numbers (Cont.)

C_{13}	norm	C_{14}	norm	C_{15}	norm	C_{16}	norm	C_{17}	norm	C_{18}	norm
A_1	0.00	A_1	0.00	A_1	0.00	A_1	0.134	A_1	0.152	A_1	0.141
A_2	0.00	A_2	0.50	A_2	0.00	A_2	0.152	A_2	0.137	A_2	0.141
A_3	0.25	A_3	0.50	A_3	0.33	A_3	0.155	A_3	0.146	A_3	0.155
A_4	0.25	A_4	0.00	A_4	0.00	A_4	0.143	A_4	0.151	A_4	0.155
A_5	0.25	A_5	0.00	A_5	0.33	A_5	0.144	A_5	0.137	A_5	0.148
A_6	0.25	A_6	0.00	A_6	0.33	A_6	0.136	A_6	0.148	A_6	0.127
A_7	0.00	A_7	0.00	A_7	0.00	A_7	0.137	A_7	0.129	A_7	0.133
sum	1	sum	1	sum	1	sum	1	sum	1	sum	1

Table 4.19 Normalized values.

	Criteria	weight	A_1	A_2	A_3	A_4	A_5	A_6	A_7
Normalized values	C_1	0.05	0.16	0.13	0.13	0.16	0.17	0.13	0.13
	C_2	0.05	0.16	0.13	0.15	0.13	0.14	0.14	0.13
	C_3	0.07	0.15	0.12	0.17	0.13	0.16	0.16	0.12
	C_4	0.06	0.13	0.14	0.14	0.17	0.13	0.13	0.14
	C_5	0.06	0.15	0.11	0.19	0.12	0.15	0.13	0.15
	C_6	0.07	0.15	0.12	0.17	0.13	0.12	0.13	0.18
	C_7	0.06	0.15	0.16	0.13	0.17	0.12	0.11	0.15
	C_8	0.06	0.12	0.13	0.18	0.15	0.14	0.13	0.14
	C_9	0.05	0.16	0.15	0.14	0.14	0.13	0.14	0.14
	C_{10}	0.02	0.00	0.00	0.25	0.25	0.25	0.25	0.00
	C_{11}	0.03	0.12	0.12	0.19	0.12	0.14	0.15	0.15
	C_{12}	0.06	0.13	0.13	0.13	0.20	0.13	0.13	0.13
	C_{13}	0.06	0.00	0.00	0.25	0.25	0.25	0.25	0.00
	C_{14}	0.06	0.00	0.50	0.50	0.00	0.00	0.00	0.00
	C_{15}	0.03	0.00	0.00	0.33	0.00	0.33	0.33	0.00
	C_{16}	0.05	0.13	0.15	0.16	0.14	0.14	0.14	0.14
	C_{17}	0.07	0.15	0.14	0.15	0.15	0.14	0.15	0.13
	C_{18}	0.07	0.14	0.14	0.15	0.15	0.15	0.13	0.13

Table 4.20 Result from F-AHP.

Alternatives	Brand	Model	F-AHP	
			Score	Rank
A_1	MITSUBISHI	Triton Mega Cab Plus 2WD 2.4 GLX 6MT	0.118	6
A_2	ISUZU	Spark 1.9 Ddi B	0.143	4
A_3	FORD	Ranger XLT Open Cab XLT 2.0L Turbo HR 6MT	0.191	1
A_4	TOYOTA	Hilux Revo Standard Cab 4x2 2.4 Entry	0.142	5
A_5	NISSAN	KC Calibre E 6MT	0.147	2
A_6	MG	EXTENDER 2.0 GRAND D 6MT	0.144	3
A_7	MAZDA	BT-50 STANDARD CAB 1.9E	0.115	7

Each criterion's evaluation involves multiplying the supplier's assigned weight. Higher-priority options are selected based on the overall matrix. The best supplier is determined by totaling the weights. AHP scores for each supplier are provided in Table 4.20. The final score sums all criteria weights. The FORD model Ranger XLT Open Cab XLT 2.0L Turbo HR 6MT achieves the highest score, ranking first. Following this, NISSAN secures the second position, followed by MG, ISUZU, TOYOTA, MITSUBISHI, and lastly, MAZDA. Among these, FORD wins due to its scores in Cost, Maintenance & Repair, Distribution of Payload, Infotainment System Features, Connectivity Options, Traction Control System, Collision Avoidance Systems, Backup Cameras and Parking Sensors, and Brand Reputation as shown in Table 4.19.

4.4 A case study of pickup truck fleet purchase using the Fuzzy TOPSIS

Start by enumerating all potential alternatives $\{A_1, A_2, A_3, \dots, A_7\}$, and identifying diverse evaluation criteria $\{C_1, C_2, C_3, \dots, C_{18}\}$. Also, assign a team of decision makers $\{D_1, D_2, D_3, \dots, D_6\}$,.

Table 4.21 originates from the averaged fuzzy scores provided by all six decision-makers for the relevant alternatives across each criterion, considering the importance or weight assigned to each criterion. The optimal value for each criterion depends on its type, as indicated in Table 4.22.

Subsequent steps involve calculating the aggregated fuzzy weights for criteria and deriving the aggregated fuzzy ratings for alternatives, detailed in Table 4.23. Additionally, the process encompasses normalizing the fuzzy decision matrix and creating a weighted normalized matrix, presented in Table 4.24.

Moreover, it entails computing the fuzzy PIS A and fuzzy NIS A, as outlined in Table 4.25, and determining the distance of each alternative from fuzzy NIS and fuzzy PIS using Euclidean distance, shown in Table 4.26. Furthermore, the procedure involves computing the closeness coefficient to rank alternatives.

The results are displayed in Table 4.27 for the computation of the closeness coefficient and in Table 4.28 for the ranking results obtained from the F-TOPSIS method.

Table 4.21 Decision-maker averages for fuzzy criterion weights.

Initial	Criterion	Alternatives	l	m	u
C_1	Engine Size (L)	A_1	2.4	2.4	2.4
		A_2	1.9	1.9	1.9
		A_3	2	2	2
		A_4	2.4	2.4	2.4
		A_5	2.5	2.5	2.5
		A_6	2	2	2
		A_7	1.9	1.9	1.9
C_2	Maximum Power (PS/ 3500 rpm)	A_1	181	181	181
		A_2	150	150	150
		A_3	170	170	170
		A_4	150	150	150
		A_5	163	163	163
		A_6	161	161	161
		A_7	150	150	150
C_3	Cost(฿)	A_1	697,000	697,000	697,000
		A_2	577,000	577,000	577,000
		A_3	809,000	809,000	809,000
		A_4	604,000	604,000	604,000
		A_5	765,000	765,000	765,000
		A_6	769,000	769,000	769,000
		A_7	553,000	553,000	553,000
C_4	Resale Value (5 year)	A_1	0.5	0.5	0.5
		A_2	0.55	0.55	0.55
		A_3	0.55	0.55	0.55
		A_4	0.65	0.65	0.65
		A_5	0.5	0.5	0.5
		A_6	0.5	0.5	0.5
		A_7	0.55	0.55	0.55

Table 4.21 Decision-maker averages for fuzzy criterion weights (Cont.)

Initial	Criterion	Alternatives	l	m	u
C_5	Maintenance&repair 5 Year Maintenance Cost (฿)	A_1	70,407	70,407	70,407
		A_2	51,269	51,269	51,269
		A_3	91,517	91,517	91,517
		A_4	55,998	55,998	55,998
		A_5	73,867	73,867	73,867
		A_6	64,939	64,939	64,939
		A_7	73,867	73,867	73,867
C_6	Fuel Consumption Rate (L/km)	A_1	0.085	0.085	0.085
		A_2	0.069	0.069	0.069
		A_3	0.093	0.093	0.093
		A_4	0.071	0.071	0.071
		A_5	0.067	0.067	0.067
		A_6	0.075	0.075	0.075
		A_7	0.098	0.098	0.098
C_7	Maximum Payload Rating (m^3)	A_1	1.582	1.582	1.582
		A_2	1.723	1.723	1.723
		A_3	1.399	1.399	1.399
		A_4	1.75	1.75	1.75
		A_5	1.268	1.268	1.268
		A_6	1.188	1.188	1.188
		A_7	1.588	1.588	1.588
C_8	Distribution of Payload (pounds)	A_1	1100	1100	1100
		A_2	1200	1200	1200
		A_3	1600	1600	1600
		A_4	1350	1350	1350
		A_5	1250	1250	1250
		A_6	1150	1150	1150
		A_7	1250	1250	1250

Table 4.21 Decision-maker averages for fuzzy criterion weights (Cont.)

Initial	Criterion	Alternatives	l	m	u
C_9	Warranty Coverage (1-9)	A_1	4.571	6.333	7.333
		A_2	5.167	6.167	7.167
		A_3	4.5	5.5	6.5
		A_4	4.5	5.5	6.5
		A_5	4.333	5.333	6.333
		A_6	4.667	5.667	6.667
		A_7	4.667	5.667	6.667
C_{10}	Infotainment System Features (1:Touchable,0:Not Touchable)	A_1	0	0	0
		A_2	0	0	0
		A_3	1	1	1
		A_4	1	1	1
		A_5	1	1	1
		A_6	1	1	1
		A_7	0	0	0
C_{11}	Connectivity Options (1-9)	A_1	3.83	4.83	5.83
		A_2	4	5	6
		A_3	6.67	7.67	8.5
		A_4	4	5	6
		A_5	4.83	5.83	6.83
		A_6	5	6	7
		A_7	5	6	7
C_{12}	Number of Airbags (airbags)	A_1	2	2	2
		A_2	2	2	2
		A_3	2	2	2
		A_4	3	3	3
		A_5	2	2	2
		A_6	2	2	2
		A_7	2	2	2

Table 4.21 Decision-maker averages for fuzzy criterion weights (Cont.)

Initial	Criterion	Alternatives	l	m	u
C_{13}	Traction Control System (TCS) (1:Yes, 0:No)	A_1	0	0	0
		A_2	0	0	0
		A_3	1	1	1
		A_4	1	1	1
		A_5	1	1	1
		A_6	1	1	1
		A_7	0	0	0
C_{14}	Collision Avoidance Systems (1:Yes, 0:No)	A_1	0	0	0
		A_2	1	1	1
		A_3	1	1	1
		A_4	0	0	0
		A_5	0	0	0
		A_6	0	0	0
		A_7	0	0	0
C_{15}	Backup Cameras and Parking Sensors (1:Yes, 0:No)	A_1	0	0	0
		A_2	0	0	0
		A_3	1	1	1
		A_4	0	0	0
		A_5	1	1	1
		A_6	1	1	1
		A_7	0	0	0
C_{16}	Brand Reputation (1-9)	A_1	5.67	6.67	7.67
		A_2	6.67	7.67	8.33
		A_3	6.83	7.83	8.5
		A_4	6.17	7.17	8
		A_5	6.17	7.17	8.17
		A_6	5.83	6.83	7.67
		A_7	5.83	6.83	7.83

Table 4.21 Decision-maker averages for fuzzy criterion weights (Cont.)

Initial	Criterion	Alternatives	l	m	u
C_{17}	Dealer Network Accessibility (1-9)	A_1	7.17	8.17	8.67
		A_2	6.33	7.33	8
		A_3	6.83	7.83	8.33
		A_4	7	8	8.83
		A_5	6.33	7.33	8
		A_6	6.83	7.83	8.67
		A_7	5.83	6.83	7.83
C_{18}	Service quality (1-9)	A_1	5.5	6.5	7.33
		A_2	5.5	6.5	7.33
		A_3	6.17	7.17	7.83
		A_4	6.17	7.17	7.83
		A_5	5.83	6.83	7.5
		A_6	4.83	5.83	6.83
		A_7	5.17	6.17	7

Table 4.22. Cost and benefit evaluation matrix.

Criteria	l- or u+	Category	Criteria	l- or u+	Category
C_1	2.5	Benefit	C_{10}	2	Benefit
C_2	181	Benefit	C_{11}	8.5	Benefit
C_3	553000	Cost	C_{12}	3	Benefit
C_4	0.65	Benefit	C_{13}	2	Benefit
C_5	51269	Cost	C_{14}	2	Benefit
C_6	0.067	Cost	C_{15}	2	Benefit
C_7	1.75	Benefit	C_{16}	8.5	Benefit
C_8	1600	Benefit	C_{17}	8.833	Benefit
C_9	7.333	Benefit	C_{18}	7.833	Benefit

Table 4.23 Aggregated fuzz weight.

Criterion	Aggregated fuzzy weight		
	l	m	u
C_1	3.833	4.833	5.833
C_2	4.167	5.167	6.167
C_3	6.167	7.167	8.000
C_4	5.500	6.500	7.500
C_5	5.500	6.500	7.500
C_6	6.500	7.500	8.167
C_7	5.500	6.500	7.500
C_8	5.500	6.500	7.500
C_9	4.333	5.333	6.333
C_{10}	1.667	2.333	3.333
C_{11}	2.667	3.667	4.667
C_{12}	5.000	6.000	7.000
C_{13}	5.167	6.167	7.167
C_{14}	5.500	6.500	7.500
C_{15}	2.500	3.333	4.333
C_{16}	3.833	4.833	5.833
C_{17}	5.667	6.667	7.667
C_{18}	6.167	7.167	8.167

Table 4.24 Normalize the fuzzy decision matrix.

Initial	Criterion	Alternatives	Fuzz Normalize rating			Fuzz Normalize weight rating		
			l	m	u	l	m	u
C_1	Engine Size (L)	A_1	0.16	0.16	0.16	0.61	0.77	0.93
		A_2	0.13	0.13	0.13	0.48	0.61	0.73
		A_3	0.13	0.13	0.13	0.51	0.64	0.77
		A_4	0.16	0.16	0.16	0.61	0.77	0.93
		A_5	0.17	0.17	0.17	0.63	0.80	0.97
		A_6	0.13	0.13	0.13	0.51	0.64	0.77
		A_7	0.13	0.13	0.13	0.48	0.61	0.73
C_2	Maximum Power (PS/ 3500 rpm)	A_1	0.16	0.16	0.16	0.67	0.83	0.99
		A_2	0.13	0.13	0.13	0.56	0.69	0.82
		A_3	0.15	0.15	0.15	0.63	0.78	0.93
		A_4	0.13	0.13	0.13	0.56	0.69	0.82
		A_5	0.14	0.14	0.14	0.60	0.75	0.89
		A_6	0.14	0.14	0.14	0.60	0.74	0.88
		A_7	0.13	0.13	0.13	0.56	0.69	0.82
C_3	Cost(฿)	A_1	0.15	0.15	0.15	0.90	1.05	1.17
		A_2	0.12	0.12	0.12	0.75	0.87	0.97
		A_3	0.17	0.17	0.17	1.05	1.21	1.36
		A_4	0.13	0.13	0.13	0.78	0.91	1.01
		A_5	0.16	0.16	0.16	0.99	1.15	1.28
		A_6	0.16	0.16	0.16	0.99	1.15	1.29
		A_7	0.12	0.12	0.12	0.71	0.83	0.93

Table 4.24 Normalize the fuzzy decision matrix (Cont.)

Initial	Criterion	Alternatives	Fuzz Normalize rating			Fuzz Normalize weight rating		
			l	m	u	l	m	u
C_4	Resale Value (5 year)	A_1	0.13	0.13	0.13	0.72	0.86	0.99
		A_2	0.14	0.14	0.14	0.80	0.94	1.09
		A_3	0.14	0.14	0.14	0.80	0.94	1.09
		A_4	0.17	0.17	0.17	0.94	1.11	1.28
		A_5	0.13	0.13	0.13	0.72	0.86	0.99
		A_6	0.13	0.13	0.13	0.72	0.86	0.99
		A_7	0.14	0.14	0.14	0.80	0.94	1.09
C_5	Maintenance &repair 5 Year Maintenance Cost (฿)	A_1	0.15	0.15	0.15	0.80	0.95	1.10
		A_2	0.11	0.11	0.11	0.59	0.69	0.80
		A_3	0.19	0.19	0.19	1.04	1.23	1.42
		A_4	0.12	0.12	0.12	0.64	0.76	0.87
		A_5	0.15	0.15	0.15	0.84	1.00	1.15
		A_6	0.13	0.13	0.13	0.74	0.88	1.01
		A_7	0.15	0.15	0.15	0.84	1.00	1.15
C_6	Fuel Consumption Rate (L/km)	A_1	0.15	0.15	0.15	0.99	1.15	1.25
		A_2	0.12	0.12	0.12	0.80	0.93	1.01
		A_3	0.17	0.17	0.17	1.08	1.25	1.36
		A_4	0.13	0.13	0.13	0.82	0.95	1.03
		A_5	0.12	0.12	0.12	0.78	0.90	0.98
		A_6	0.13	0.13	0.13	0.88	1.01	1.10
		A_7	0.18	0.18	0.18	1.15	1.32	1.44

Table 4.24 Normalize the fuzzy decision matrix (Cont.)

Initial	Criterion	Alternatives	Fuzz Normalize rating			Fuzz Normalize weight rating		
			l	m	u	l	m	u
C_7	Maximum Payload Rating (m^3)	A_1	0.15	0.15	0.15	0.83	0.98	1.13
		A_2	0.16	0.16	0.16	0.90	1.07	1.23
		A_3	0.13	0.13	0.13	0.73	0.87	1.00
		A_4	0.17	0.17	0.17	0.92	1.08	1.25
		A_5	0.12	0.12	0.12	0.66	0.79	0.91
		A_6	0.11	0.11	0.11	0.62	0.74	0.85
		A_7	0.15	0.15	0.15	0.83	0.98	1.13
C_8	Distribution of Payload (pounds)	A_1	0.12	0.12	0.12	0.68	0.80	0.93
		A_2	0.13	0.13	0.13	0.74	0.88	1.01
		A_3	0.18	0.18	0.18	0.99	1.17	1.35
		A_4	0.15	0.15	0.15	0.83	0.99	1.14
		A_5	0.14	0.14	0.14	0.77	0.91	1.05
		A_6	0.13	0.13	0.13	0.71	0.84	0.97
		A_7	0.14	0.14	0.14	0.77	0.91	1.05
C_9	Warranty Coverage	A_1	0.14	0.16	0.16	0.61	0.84	0.98
		A_2	0.16	0.15	0.15	0.69	0.82	0.96
		A_3	0.14	0.14	0.14	0.60	0.73	0.87
		A_4	0.14	0.14	0.14	0.60	0.73	0.87
		A_5	0.13	0.13	0.13	0.58	0.71	0.85
		A_6	0.14	0.14	0.14	0.62	0.75	0.90
		A_7	0.14	0.14	0.14	0.62	0.75	0.90

Table 4.24 Normalize the fuzzy decision matrix (Cont.)

Initial	Criterion	Alternatives	Fuzz Normalize rating			Fuzz Normalize weight rating		
			l	m	u	l	m	u
C_{10}	Infotainment System Features (1:Touchable,0:Not Touchable)	A_1	0.00	0.00	0.00	0.00	0.00	0.00
		A_2	0.00	0.00	0.00	0.00	0.00	0.00
		A_3	0.25	0.25	0.25	0.42	0.58	0.83
		A_4	0.25	0.25	0.25	0.42	0.58	0.83
		A_5	0.25	0.25	0.25	0.42	0.58	0.83
		A_6	0.25	0.25	0.25	0.42	0.58	0.83
		A_7	0.00	0.00	0.00	0.00	0.00	0.00
C_{11}	Connectivity Options	A_1	0.12	0.12	0.12	0.31	0.44	0.58
		A_2	0.12	0.12	0.13	0.32	0.45	0.59
		A_3	0.20	0.19	0.18	0.53	0.70	0.84
		A_4	0.12	0.12	0.13	0.32	0.45	0.59
		A_5	0.15	0.14	0.14	0.39	0.53	0.68
		A_6	0.15	0.15	0.15	0.40	0.55	0.69
		A_7	0.15	0.15	0.15	0.40	0.55	0.69
C_{12}	Number of Airbags	A_1	0.13	0.13	0.13	0.67	0.80	0.93
		A_2	0.13	0.13	0.13	0.67	0.80	0.93
		A_3	0.13	0.13	0.13	0.67	0.80	0.93
		A_4	0.20	0.20	0.20	1.00	1.20	1.40
		A_5	0.13	0.13	0.13	0.67	0.80	0.93
		A_6	0.13	0.13	0.13	0.67	0.80	0.93
		A_7	0.13	0.13	0.13	0.67	0.80	0.93
C_{13}	Traction Control System (TCS) (1:Yes, 0:No)	A_1	0.00	0.00	0.00	0.00	0.00	0.00
		A_2	0.00	0.00	0.00	0.00	0.00	0.00
		A_3	0.25	0.25	0.25	1.29	1.54	1.79
		A_4	0.25	0.25	0.25	1.29	1.54	1.79
		A_5	0.25	0.25	0.25	1.29	1.54	1.79
		A_6	0.25	0.25	0.25	1.29	1.54	1.79
		A_7	0.00	0.00	0.00	0.00	0.00	0.00

Table 4.24 Normalize the fuzzy decision matrix (Cont.)

Initial	Criterion	Alternatives	Fuzz Normalize rating			Fuzz Normalize weight rating		
			l	m	u	l	m	u
C_{14}	Collision Avoidance Systems (1:Yes, 0:No)	A_1	0.00	0.00	0.00	0.00	0.00	0.00
		A_2	0.50	0.50	0.50	2.75	3.25	3.75
		A_3	0.50	0.50	0.50	2.75	3.25	3.75
		A_4	0.00	0.00	0.00	0.00	0.00	0.00
		A_5	0.00	0.00	0.00	0.00	0.00	0.00
		A_6	0.00	0.00	0.00	0.00	0.00	0.00
		A_7	0.00	0.00	0.00	0.00	0.00	0.00
C_{15}	Backup Cameras and Parking Sensors (1:Yes, 0:No)	A_1	0.00	0.00	0.00	0.00	0.00	0.00
		A_2	0.00	0.00	0.00	0.00	0.00	0.00
		A_3	0.33	0.33	0.33	0.83	1.11	1.44
		A_4	0.00	0.00	0.00	0.00	0.00	0.00
		A_5	0.33	0.33	0.33	0.83	1.11	1.44
		A_6	0.33	0.33	0.33	0.83	1.11	1.44
		A_7	0.00	0.00	0.00	0.00	0.00	0.00
C_{16}	Brand Reputation	A_1	0.13	0.13	0.14	0.50	0.64	0.80
		A_2	0.15	0.15	0.15	0.59	0.74	0.87
		A_3	0.16	0.16	0.15	0.61	0.75	0.88
		A_4	0.14	0.14	0.14	0.55	0.69	0.83
		A_5	0.14	0.14	0.15	0.55	0.69	0.85
		A_6	0.14	0.14	0.14	0.52	0.66	0.80
		A_7	0.14	0.14	0.14	0.52	0.66	0.81

Table 4.24 Normalize the fuzzy decision matrix (Cont.)

Initial	Criterion	Alternatives	Fuzz Normalize rating			Fuzz Normalize weight rating		
			l	m	u	l	m	u
C_{17}	Dealer Network Accessibility	A_1	0.15	0.15	0.15	0.88	1.02	1.14
		A_2	0.14	0.14	0.14	0.77	0.92	1.05
		A_3	0.15	0.15	0.14	0.84	0.98	1.10
		A_4	0.15	0.15	0.15	0.86	1.00	1.16
		A_5	0.14	0.14	0.14	0.77	0.92	1.05
		A_6	0.15	0.15	0.15	0.84	0.98	1.14
		A_7	0.13	0.13	0.13	0.71	0.85	1.03
C_{18}	Service quality	A_1	0.14	0.14	0.14	0.87	1.01	1.16
		A_2	0.14	0.14	0.14	0.87	1.01	1.16
		A_3	0.16	0.16	0.15	0.97	1.11	1.24
		A_4	0.16	0.16	0.15	0.97	1.11	1.24
		A_5	0.15	0.15	0.15	0.92	1.06	1.19
		A_6	0.12	0.13	0.13	0.76	0.91	1.08
		A_7	0.13	0.13	0.14	0.81	0.96	1.11

Table 4.25 Fuzzy PIS A and Fuzzy NIS A.

Criteria	A+	A-	Criteria	A+	A-
C_1	0.966	0.482	C_{10}	0.833	0.000
C_2	0.992	0.556	C_{11}	0.841	0.307
C_3	1.356	0.714	C_{12}	1.400	0.667
C_4	1.283	0.724	C_{13}	1.792	0.000
C_5	1.424	0.585	C_{14}	3.750	0.000
C_6	1.439	0.777	C_{15}	1.444	0.000
C_7	1.250	0.622	C_{16}	0.883	0.503
C_8	1.348	0.680	C_{17}	1.161	0.713
C_9	0.985	0.579	C_{18}	1.238	0.761

Table 4.26 Euclidean Distance from Fuzzy NIS and Fuzzy PIS

Criteria	Alternatives	SS to A+	SS to A-	Criteria	Alternatives	SS to A+	SS to A-
C_1	A_1	0.17	0.30	C_4	A_1	0.58	0.09
	A_2	0.42	0.08		A_2	0.39	0.18
	A_3	0.35	0.11		A_3	0.39	0.18
	A_4	0.17	0.30		A_4	0.15	0.51
	A_5	0.14	0.36		A_5	0.58	0.09
	A_6	0.35	0.11		A_6	0.58	0.09
	A_7	0.42	0.08		A_7	0.39	0.18
C_2	A_1	0.13	0.28	C_5	A_1	0.72	0.44
	A_2	0.31	0.09		A_2	1.63	0.06
	A_3	0.18	0.20		A_3	0.18	1.34
	A_4	0.31	0.09		A_4	1.37	0.11
	A_5	0.22	0.15		A_5	0.60	0.55
	A_6	0.23	0.14		A_6	0.94	0.29
	A_7	0.31	0.09		A_7	0.60	0.55
C_3	A_1	0.34	0.35	C_6	A_1	0.32	0.41
	A_2	0.76	0.09		A_2	0.85	0.08
	A_3	0.12	0.77		A_3	0.17	0.65
	A_4	0.65	0.13		A_4	0.78	0.10
	A_5	0.18	0.59		A_5	0.95	0.05
	A_6	0.18	0.60		A_6	0.61	0.17
	A_7	0.87	0.06		A_7	0.10	0.87

Table 4.26 Euclidean Distance from Fuzzy NIS and Fuzzy PIS (Cont.)

Criteria	Alternatives	SS to A+	SS to A-	Criteria	Alternatives	SS to A+	SS to A-
C_7	A_1	0.27	0.43	C_{11}	A_1	0.52	0.09
	A_2	0.15	0.65		A_2	0.48	0.10
	A_3	0.48	0.21		A_3	0.12	0.49
	A_4	0.14	0.69		A_4	0.48	0.10
	A_5	0.68	0.11		A_5	0.33	0.19
	A_6	0.82	0.06		A_6	0.30	0.21
	A_7	0.26	0.44		A_7	0.30	0.21
C_8	A_1	0.92	0.08	C_{12}	A_1	1.12	0.09
	A_2	0.70	0.15		A_2	1.12	0.09
	A_3	0.16	0.78		A_3	1.12	0.09
	A_4	0.44	0.33		A_4	0.20	0.93
	A_5	0.61	0.20		A_5	1.12	0.09
	A_6	0.81	0.11		A_6	1.12	0.09
	A_7	0.61	0.20		A_7	1.12	0.09
C_9	A_1	0.16	0.23	C_{13}	A_1	9.63	0.00
	A_2	0.11	0.22		A_2	9.63	0.00
	A_3	0.22	0.11		A_3	0.31	7.26
	A_4	0.22	0.11		A_4	0.31	7.26
	A_5	0.26	0.09		A_5	0.31	7.26
	A_6	0.19	0.13		A_6	0.31	7.26
	A_7	0.19	0.13		A_7	9.63	0.00
C_{10}	A_1	2.08	0.00	C_{14}	A_1	42.19	0.00
	A_2	2.08	0.00		A_2	1.25	32.19
	A_3	0.24	1.21		A_3	1.25	32.19
	A_4	0.24	1.21		A_4	42.19	0.00
	A_5	0.24	1.21		A_5	42.19	0.00
	A_6	0.24	1.21		A_6	42.19	0.00
	A_7	2.08	0.00		A_7	42.19	0.00

Table 4.26 Euclidean Distance from Fuzzy NIS and Fuzzy PIS (Cont.)

Criteria	Alternatives	SS to A+	SS to A-	Criteria	Alternatives	SS to A+	SS to A-
C_{15}	A_1	6.26	0.00	C_{17}	A_1	0.10	0.30
	A_2	6.26	0.00		A_2	0.22	0.16
	A_3	0.48	4.02		A_3	0.14	0.23
	A_4	6.26	0.00		A_4	0.12	0.30
	A_5	0.48	4.02		A_5	0.22	0.16
	A_6	0.48	4.02		A_6	0.14	0.27
	A_7	6.26	0.00		A_7	0.31	0.12
C_{16}	A_1	0.21	0.11	C_{18}	A_1	0.20	0.23
	A_2	0.11	0.19		A_2	0.20	0.23
	A_3	0.09	0.22		A_3	0.09	0.40
	A_4	0.15	0.14		A_4	0.09	0.40
	A_5	0.15	0.16		A_5	0.14	0.29
	A_6	0.19	0.11		A_6	0.36	0.12
	A_7	0.19	0.12		A_7	0.28	0.16

Table 4.27 Closeness coefficient by F-TOPSIS Method.

Alternatives	d+	d-	CC
A_1	8.118	1.848	0.185
A_2	5.166	5.878	0.532
A_3	2.469	7.102	0.742
A_4	7.367	3.565	0.326
A_5	7.027	3.945	0.360
A_6	7.075	3.871	0.354
A_7	8.130	1.819	0.183

Table 4.28 Result from F-TOPSIS.

Alternatives	Brand	Model	F-TOPSIS	
			Score	Rank
A_1	MITSUBISHI	Triton Mega Cab Plus 2WD 2.4 GLX 6MT	0.185	6
A_2	ISUZU	Spark 1.9 Ddi B	0.532	2
A_3	FORD	Ranger XLT Open Cab XLT 2.0L Turbo HR 6MT	0.742	1
A_4	TOYOTA	Hilux Revo Standard Cab 4x2 2.4 Entry	0.326	5
A_5	NISSAN	KC Calibre E 6MT	0.360	3
A_6	MG	EXTENDER 2.0 GRAND D 6MT	0.354	4
A_7	MAZDA	BT-50 STANDARD CAB 1.9E	0.183	7

In the F-TOPSIS method, the best supplier is determined based on the closeness coefficient, with a higher coefficient indicating a better alternative. Upon applying the F-TOPSIS model, the results show that alternative 3, identified as the FORD Ranger XLT Open Cab XLT 2.0L Turbo HR 6MT, has achieved Rank 1 with a closeness coefficient of 0.742. Following closely behind are ISUZU, NISSAN, MG, TOYOTA, MITSUBISHI, and lastly, MAZDA. FORD emerges victorious due to its superiority in Cost, Maintenance & Repair, Distribution of Payload, Infotainment System Features, Connectivity Options, Traction Control System, Collision Avoidance Systems, Backup Cameras and Parking Sensors, Brand Reputation, and Service Quality.

4.5 A case study of pickup truck fleet purchase using the Fuzzy AHP&TOPSIS

In the initial phase, all potential alternatives $\{A_1, A_2, A_3, \ldots, A_i\}$ for i=1, 2, 3, …, m are comprehensively listed alongside diverse evaluation criteria $\{C_1, C_2, C_3, \ldots, C_j\}$ for j=1, 2, 3, …, n. Concurrently, a group of decision-makers $\{D_1, D_2, D_3, \ldots, D_k\}$ is selected. Subsequently, a meticulous pairwise comparison is executed in Step 2 to evaluate alternatives based on each criterion. This process involves assigning weights to both criteria and alternatives using suitable linguistic terms, as evidenced by the findings from Table 4.14, derived from decision-maker evaluations, and Table 4.15, outlining pairwise comparisons. Following this assessment, the determination of Average Importance Weights and Normalized Weights for Criteria is presented through Table 4.29. Decision-makers proceed to evaluate criteria and alternatives with respect to each criterion using pair-wise comparisons and the Saaty scale results shown in Table 4.30. and Table 4.32 Next, Step 5 involves constructing the weighted normalized rating matrix, illustrated in Table 4.32. Subsequent tables detail the outcomes of subsequent steps: Table 4.33 presents results from Step 6, determining positive ideal solutions A+ and negative ideal solutions A-, while Table 4.34 showcases outcomes from Step 7, computing the distance from alternatives to the PIS and NIS. Finally, the late step computes the closeness coefficient, with results displayed in Table 4.35, and provides rankings in Table 4.36.

Table 4.29 Average importance weights and normalized weights for criteria.

Criteria	Normalize the weights	Criteria	Normalize the weights
C_1	0.047	C_{10}	0.023
C_2	0.05	C_{11}	0.036
C_3	0.07	C_{12}	0.058
C_4	0.063	C_{13}	0.06
C_5	0.063	C_{14}	0.063
C_6	0.073	C_{15}	0.032
C_7	0.063	C_{16}	0.047
C_8	0.063	C_{17}	0.065
C_9	0.052	C_{18}	0.07

Table 4.30 Pairwise comparison and saaty scale evaluation results of quantitative criteria.

Criteria	Alternative	Average	Normalize	Criteria	Alternative	Average	Normalize
C_1	A_1	2.4	0.418	C_5	A_1	70,407	0.381
	A_2	1.9	0.331		A_2	51,269	0.277
	A_3	2	0.348		A_3	91,517	0.495
	A_4	2.4	0.418		A_4	55,998	0.303
	A_5	2.5	0.435		A_5	73,867	0.399
	A_6	2	0.348		A_6	64,939	0.351
	A_7	1.9	0.331		A_7	73,867	0.399
C_2	A_1	181	0.425	C_6	A_1	0.085	0.4
	A_2	150	0.352		A_2	0.069	0.324
	A_3	170	0.399		A_3	0.093	0.435
	A_4	150	0.352		A_4	0.071	0.331
	A_5	163	0.382		A_5	0.067	0.313
	A_6	161	0.378		A_6	0.075	0.353
	A_7	150	0.352		A_7	0.098	0.461
C_3	A_1	697,000	0.383	C_7	A_1	1.582	0.395
	A_2	577,000	0.317		A_2	1.723	0.43
	A_3	809,000	0.444		A_3	1.399	0.349
	A_4	604,000	0.331		A_4	1.75	0.437
	A_5	765,000	0.42		A_5	1.268	0.317
	A_6	769,000	0.422		A_6	1.188	0.297
	A_7	553,000	0.303		A_7	1.588	0.397
C_4	A_1	0.5	0.347	C_8	A_1	1100	0.325
	A_2	0.55	0.381		A_2	1200	0.354
	A_3	0.55	0.381		A_3	1600	0.472
	A_4	0.65	0.451		A_4	1350	0.398
	A_5	0.5	0.347		A_5	1250	0.369
	A_6	0.5	0.347		A_6	1150	0.339
	A_7	0.55	0.381		A_7	1250	0.369

Table 4.30 Pairwise comparison and saaty scale evaluation results of quantitative criteria (Cont.)

Criteria	Alternative	Average	Normalize	Criteria	Alternative	Average	Normalize
C_{10}	A_1	0	0	C_{13}	A_1	0	0
	A_2	0	0		A_2	0	0
	A_3	1	0.25		A_3	1	0.25
	A_4	1	0.25		A_4	1	0.25
	A_5	1	0.25		A_5	1	0.25
	A_6	1	0.25		A_6	1	0.25
	A_7	0	0		A_7	0	0
C_{12}	A_1	2	0.348	C_{14}	A_1	0	0
	A_2	2	0.348		A_2	1	0.5
	A_3	2	0.348		A_3	1	0.5
	A_4	3	0.522		A_4	0	0
	A_5	2	0.348		A_5	0	0
	A_6	2	0.348		A_6	0	0
	A_7	2	0.348		A_7	0	0
C_{15}	A_1	0	0				
	A_2	0	0				
	A_3	1	0.33				
	A_4	0	0				
	A_5	1	0.33				
	A_6	1	0.33				
	A_7	0	0				

Table 4.31 Pairwise comparison and saaty scale evaluation results of qualitative criteria.

Criteria	Alternative	Normalize	Criteria	Alternative	Normalize
C_9	A1	0.158	C_{16}	A1	0.133
	A2	0.154		A2	0.153
	A3	0.136		A3	0.156
	A4	0.138		A4	0.143
	A5	0.132		A5	0.143
	A6	0.141		A6	0.136
	A7	0.141		A7	0.136
C_{11}	A1	0.119	C_{17}	A1	0.153
	A2	0.124		A2	0.138
	A3	0.19		A3	0.147
	A4	0.123		A4	0.15
	A5	0.144		A5	0.138
	A6	0.149		A6	0.147
	A7	0.149		A7	0.128
C_{18}	A1	0.141			
	A2	0.141			
	A3	0.155			
	A4	0.155			
	A5	0.148			
	A6	0.126			
	A7	0.133			

Table 4.32 Weighted normalized rating matrix.

Criteria	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**A_6**	**A_7**	Cost/Benefit
C_1	0.007	0.006	0.006	0.007	0.008	0.006	0.006	Benefit
C_2	0.008	0.007	0.008	0.007	0.007	0.007	0.007	Benefit
C_3	0.010	0.008	0.012	0.009	0.011	0.011	0.008	Cost
C_4	0.008	0.009	0.009	0.011	0.008	0.008	0.009	Benefit
C_5	0.009	0.007	0.012	0.007	0.010	0.009	0.010	Cost
C_6	0.011	0.009	0.012	0.009	0.009	0.010	0.013	Cost
C_7	0.010	0.010	0.008	0.011	0.008	0.007	0.010	Benefit
C_8	0.008	0.009	0.011	0.010	0.009	0.008	0.009	Benefit
C_9	0.008	0.008	0.007	0.007	0.007	0.007	0.007	Benefit
C_{10}	0.000	0.000	0.006	0.006	0.006	0.006	0.000	Benefit
C_{11}	0.004	0.004	0.007	0.004	0.005	0.005	0.005	Benefit
C_{12}	0.008	0.008	0.008	0.012	0.008	0.008	0.008	Benefit
C_{13}	0.000	0.000	0.015	0.015	0.015	0.015	0.000	Benefit
C_{14}	0.000	0.032	0.032	0.000	0.000	0.000	0.000	Benefit
C_{15}	0.000	0.000	0.011	0.000	0.011	0.011	0.000	Benefit
C_{16}	0.006	0.007	0.007	0.007	0.007	0.006	0.006	Benefit
C_{17}	0.010	0.009	0.010	0.010	0.009	0.010	0.008	Benefit
C_{18}	0.010	0.010	0.011	0.011	0.010	0.009	0.009	Benefit

Table 4.33 Positive ideal solution (A+) and negative ideal solution (A-).

Criteria	A+	A-
C_1	0.008	0.006
C_2	0.008	0.007
C_3	0.008	0.012
C_4	0.011	0.008
C_5	0.007	0.012
C_6	0.009	0.013
C_7	0.011	0.007
C_8	0.011	0.008
C_9	0.008	0.007
C_{10}	0.006	0.000
C_{11}	0.007	0.004
C_{12}	0.012	0.008
C_{13}	0.015	0.000
C_{14}	0.032	0.000
C_{15}	0.011	0.000
C_{16}	0.007	0.006
C_{17}	0.010	0.008
C_{18}	0.011	0.009

Table 4.34 Distance from alternatives to PIS and NIS.

Alternatives	d+	d-
A_1	0.038	0.005
A_2	0.020	0.033
A_3	0.009	0.038
A_4	0.034	0.019
A_5	0.033	0.020
A_6	0.033	0.020
A_7	0.038	0.005

Table 4.35 Closeness coefficient by F-AHP&TOPSIS.

Alternatives	d+	d-	CC
A_1	0.038	0.005	0.124
A_2	0.020	0.033	0.618
A_3	0.009	0.038	0.808
A_4	0.034	0.019	0.356
A_5	0.033	0.020	0.381
A_6	0.033	0.020	0.378
A_7	0.038	0.005	0.124

Table 4.36 Result from F-AHP&TOPSIS.

Alternatives	Brand	Model	F-AHP&TOPSIS	
			Score	Rank
A_1	MITSUBISHI	Triton Mega Cab Plus 2WD 2.4 GLX 6MT	0.124	6
A_2	ISUZU	Spark 1.9 Ddi B	0.618	2
A_3	FORD	Ranger XLT Open Cab XLT 2.0L Turbo HR 6MT	0.808	1
A_4	TOYOTA	Hilux Revo Standard Cab 4x2 2.4 Entry	0.356	5
A_5	NISSAN	KC Calibre E 6MT	0.381	3
A_6	MG	EXTENDER 2.0 GRAND D 6MT	0.378	4
A_7	MAZDA	BT-50 STANDARD CAB 1.9E	0.124	7

The evaluation utilizing both the F-AHP and TOPSIS methods revealed that the FORD Ranger XLT Open Cab XLT 2.0L Turbo HR 6MT achieved Rank 1 with a closeness coefficient of 0.742. Following closely behind are ISUZU, NISSAN, MG, TOYOTA, MITSUBISHI, and lastly, MAZDA. These rankings underscore the meticulous assessment of suppliers across various criteria, ultimately pinpointing FORD as the most favorable option among the evaluated suppliers due to its superiority in Cost, Maintenance & Repair, Distribution of Payload, Infotainment System Features, Connectivity Options, Traction Control System, Collision Avoidance Systems, Backup Cameras and Parking Sensors, Brand Reputation, and Service Quality.

4.6 A case study of pickup truck fleet purchase using the Best-Worst Method

The decision criteria, defined by the Decision Maker, are denoted as $\{C_1, C_2, C_3, \ldots, C_j\}$ for j=1, 2, 3, …, n. Likewise, the Decision Makers are represented by the set $\{D_1, D_2, D_3, \ldots, D_k\}$. Each criterion undergoes evaluation through the assignment of scores, a process facilitated by multiple decision-makers, whose individual assessments are subsequently averaged. The results of these evaluations are showcased in Table 4.37, where the criterion with the highest score is considered the most favorable, and conversely, the one with the lowest score is regarded as the least favorable, based on collective decision-maker assessments. In this instance, criterion 6, pertaining to Fuel Consumption Rate (L/km), emerges as the top-ranking choice, underscoring its superiority. Conversely, criterion 10, concerning Infotainment System Features (1: Touchable, 0: Not Touchable), is identified as the least desirable option due to its lower score.

The decision maker calculates the priority of the best criterion over others (BO) by assessing and comparing their scores, as depicted in Table 4.38. Meanwhile, Table 4.39 presents the results from the step where the decision maker evaluates the priority of other criteria over the worst criterion (OW) by comparing their scores. Following this assessment, the optimal weights of the criteria were determined using Microsoft Excel Solver 2021, yielding the results outlined in Table 4.40.

After the Pairwise Comparison and Saaty Scale Evaluation, the results are presented in Table 4.41. Subsequently, the process continues with obtaining normalized values, depicted in Table 4.42. Table 4.43 displays the results obtained from the Generalized Pairwise Comparison Method for Each Alternative. Then, the priority calculation results, derived from multiplying the weights from Table 4.40 with the results from Table 4.43, are presented in Table 4.44.

Finally, the sum of scores is showcased in Table 4.45, and the resulting rankings are depicted in Table 4.46.

Table 4.37 Criterion evaluation average scores by decision makers.

The average score of each criterion								
C_1	C_2	C_3	C_4	C_5	**C_6**	C_7	C_8	C_9
4.83	5.17	7.17	6.50	6.50	**7.50**	6.50	6.50	5.33

Table 4.37 Criterion evaluation average scores by decision makers (Cont.)

The average score of each criterion								
C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
2.33	3.67	6.00	6.17	6.50	3.33	4.83	6.67	7.17

Table 4.38 Priority comparison of best criterion over other criteria (A_{Bj}).

Best to Others	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_6	1.68	1.58	1.10	1.17	1.16	1.00	1.16	1.16	1.43

Table 4.38 Priority comparison of best criterion over other criteria (A_{Bj}) (Cont.)

Best to Others	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
C_6	4.53	2.26	1.25	1.22	1.16	2.73	1.95	1.12	1.05

Table 4.39 Other criteria priority comparison over worst criterion (A_{jw}).

Others to the Worst	C_{10}	Others to the Worst	C_{10}
C_1	2.88	C_{10}	1.00
C_2	3.11	C_{11}	1.89
C_3	4.18	C_{12}	3.62
C_4	4.00	C_{13}	3.65
C_5	4.00	C_{14}	3.90
C_6	4.53	C_{15}	2.09
C_7	3.89	C_{16}	2.75
C_8	3.89	C_{17}	3.96
C_9	2.98	C_{18}	4.16

Table 4.40 Optimal weights of the criteria.

Weights (W_j*)	Criterion								
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
	0.047	0.050	0.070	0.067	0.067	0.075	0.065	0.065	0.051

Table 4.40 Optimal weights of the criteria (Cont.)

Weights (W_j*)	Criterion								
	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
	0.016	0.034	0.061	0.061	0.065	0.029	0.041	0.066	0.069

Table 4.40 Optimal weights of the criteria (Cont.)

KSI* (ξ)	0.004

Table 4.41 Pairwise comparison and saaty scale evaluation results.

Criterion	Alternatives	D_1	D_2	D_3	D_4	D_5	D_6
C_1	A_1	2.40	2.40	2.40	2.40	2.40	2.40
	A_2	1.90	1.90	1.90	1.90	1.90	1.90
	A_3	2.00	2.00	2.00	2.00	2.00	2.00
	A_4	2.40	2.40	2.40	2.40	2.40	2.40
	A_5	2.50	2.50	2.50	2.50	2.50	2.50
	A_6	2.00	2.00	2.00	2.00	2.00	2.00
	A_7	1.90	1.90	1.90	1.90	1.90	1.90
C_2	A_1	181.00	181.00	181.00	181.00	181.00	181.00
	A_2	150.00	150.00	150.00	150.00	150.00	150.00
	A_3	170.00	170.00	170.00	170.00	170.00	170.00
	A_4	150.00	150.00	150.00	150.00	150.00	150.00
	A_5	163.00	163.00	163.00	163.00	163.00	163.00
	A_6	161.00	161.00	161.00	161.00	161.00	161.00
	A_7	150.00	150.00	150.00	150.00	150.00	150.00

Table 4.41 Pairwise comparison and saaty scale evaluation results (Cont.)

Criterion	Alternatives	D_1	D_2	D_3	D_4	D_5	D_6
C_3	A_1	697000	697000	697000	697000	697000	697000
	A_2	577000	577000	577000	577000	577000	577000
	A_3	809000	809000	809000	809000	809000	809000
	A_4	604000	604000	604000	604000	604000	604000
	A_5	765000	765000	765000	765000	765000	765000
	A_6	769000	769000	769000	769000	769000	769000
	A_7	553000	553000	553000	553000	553000	553000
C_4	A_1	0.50	0.50	0.50	0.50	0.50	0.50
	A_2	0.55	0.55	0.55	0.55	0.55	0.55
	A_3	0.55	0.55	0.55	0.55	0.55	0.55
	A_4	0.65	0.65	0.65	0.65	0.65	0.65
	A_5	0.50	0.50	0.50	0.50	0.50	0.50
	A_6	0.50	0.50	0.50	0.50	0.50	0.50
	A_7	0.55	0.55	0.55	0.55	0.55	0.55
C_5	A_1	70407	70407	70407	70407	70407	70407
	A_2	51269	51269	51269	51269	51269	51269
	A_3	91517	91517	91517	91517	91517	91517
	A_4	55998	55998	55998	55998	55998	55998
	A_5	73867	73867	73867	73867	73867	73867
	A_6	64939	64939	64939	64939	64939	64939
	A_7	73867	73867	73867	73867	73867	73867
C_6	A_1	0.09	0.09	0.09	0.09	0.09	0.09
	A_2	0.07	0.07	0.07	0.07	0.07	0.07
	A_3	0.09	0.09	0.09	0.09	0.09	0.09
	A_4	0.07	0.07	0.07	0.07	0.07	0.07
	A_5	0.07	0.07	0.07	0.07	0.07	0.07
	A_6	0.08	0.08	0.08	0.08	0.08	0.08
	A_7	0.10	0.10	0.10	0.10	0.10	0.10

Table 4.41 Pairwise comparison and saaty scale evaluation results (Cont.)

Criterion	Alternatives	D_1	D_2	D_3	D_4	D_5	D_6
C_7	A_1	1.58	1.58	1.58	1.58	1.58	1.58
	A_2	1.72	1.72	1.72	1.72	1.72	1.72
	A_3	1.40	1.40	1.40	1.40	1.40	1.40
	A_4	1.75	1.75	1.75	1.75	1.75	1.75
	A_5	1.27	1.27	1.27	1.27	1.27	1.27
	A_6	1.19	1.19	1.19	1.19	1.19	1.19
	A_7	1.59	1.59	1.59	1.59	1.59	1.59
C_8	A_1	1100	1100	1100	1100	1100	1100
	A_2	1200	1200	1200	1200	1200	1200
	A_3	1600	1600	1600	1600	1600	1600
	A_4	1350	1350	1350	1350	1350	1350
	A_5	1250	1250	1250	1250	1250	1250
	A_6	1150	1150	1150	1150	1150	1150
	A_7	1250	1250	1250	1250	1250	1250
C_9	A_1	8.00	6.00	6.00	6.00	5.00	7.00
	A_2	7.00	5.00	6.00	6.00	6.00	7.00
	A_3	7.00	4.00	5.00	5.00	5.00	7.00
	A_4	6.00	5.00	5.00	5.00	6.00	6.00
	A_5	7.00	5.00	4.00	5.00	5.00	6.00
	A_6	6.00	4.00	6.00	6.00	5.00	7.00
	A_7	6.00	5.00	5.00	5.00	6.00	7.00
C_{10}	A_1	0.00	0.00	0.00	0.00	0.00	0.00
	A_2	0.00	0.00	0.00	0.00	0.00	0.00
	A_3	1.00	1.00	1.00	1.00	1.00	1.00
	A_4	1.00	1.00	1.00	1.00	1.00	1.00
	A_5	1.00	1.00	1.00	1.00	1.00	1.00
	A_6	1.00	1.00	1.00	1.00	1.00	1.00
	A_7	0.00	0.00	0.00	0.00	0.00	0.00

Table 4.41 Pairwise comparison and saaty scale evaluation results (Cont.)

Criterion	Alternatives	D_1	D_2	D_3	D_4	D_5	D_6
C_{11}	A_1	4.00	5.00	6.00	5.00	5.00	4.00
	A_2	5.00	5.00	5.00	5.00	5.00	5.00
	A_3	7.00	8.00	8.00	9.00	7.00	7.00
	A_4	5.00	6.00	5.00	6.00	4.00	4.00
	A_5	6.00	6.00	7.00	6.00	6.00	4.00
	A_6	6.00	6.00	6.00	6.00	6.00	6.00
	A_7	6.00	6.00	6.00	6.00	6.00	6.00
C_{12}	A_1	2.00	2.00	2.00	2.00	2.00	2.00
	A_2	2.00	2.00	2.00	2.00	2.00	2.00
	A_3	2.00	2.00	2.00	2.00	2.00	2.00
	A_4	3.00	3.00	3.00	3.00	3.00	3.00
	A_5	2.00	2.00	2.00	2.00	2.00	2.00
	A_6	2.00	2.00	2.00	2.00	2.00	2.00
	A_7	2.00	2.00	2.00	2.00	2.00	2.00
C_{13}	A_1	0.00	0.00	0.00	0.00	0.00	0.00
	A_2	0.00	0.00	0.00	0.00	0.00	0.00
	A_3	1.00	1.00	1.00	1.00	1.00	1.00
	A_4	1.00	1.00	1.00	1.00	1.00	1.00
	A_5	1.00	1.00	1.00	1.00	1.00	1.00
	A_6	1.00	1.00	1.00	1.00	1.00	1.00
	A_7	0.00	0.00	0.00	0.00	0.00	0.00
C_{14}	A_1	0.00	0.00	0.00	0.00	0.00	0.00
	A_2	1.00	1.00	1.00	1.00	1.00	1.00
	A_3	1.00	1.00	1.00	1.00	1.00	1.00
	A_4	0.00	0.00	0.00	0.00	0.00	0.00
	A_5	0.00	0.00	0.00	0.00	0.00	0.00
	A_6	0.00	0.00	0.00	0.00	0.00	0.00
	A_7	0.00	0.00	0.00	0.00	0.00	0.00

Table 4.41 Pairwise comparison and saaty scale evaluation results (Cont.)

Criterion	Alternatives	D_1	D_2	D_3	D_4	D_5	D_6
C_{15}	A_1	0.00	0.00	0.00	0.00	0.00	0.00
	A_2	0.00	0.00	0.00	0.00	0.00	0.00
	A_3	1.00	1.00	1.00	1.00	1.00	1.00
	A_4	0.00	0.00	0.00	0.00	0.00	0.00
	A_5	1.00	1.00	1.00	1.00	1.00	1.00
	A_6	1.00	1.00	1.00	1.00	1.00	1.00
	A_7	0.00	0.00	0.00	0.00	0.00	0.00
C_{16}	A_1	7.00	7.00	6.00	8.00	6.00	6.00
	A_2	9.00	9.00	8.00	6.00	8.00	6.00
	A_3	7.00	8.00	9.00	7.00	9.00	7.00
	A_4	6.00	8.00	6.00	9.00	7.00	7.00
	A_5	8.00	7.00	8.00	6.00	6.00	8.00
	A_6	6.00	6.00	7.00	7.00	6.00	9.00
	A_7	6.00	6.00	7.00	6.00	8.00	8.00
C_{17}	A_1	9.00	7.00	9.00	7.00	9.00	8.00
	A_2	7.00	7.00	6.00	6.00	9.00	9.00
	A_3	6.00	9.00	9.00	7.00	7.00	9.00
	A_4	7.00	8.00	8.00	9.00	8.00	8.00
	A_5	9.00	6.00	8.00	9.00	6.00	6.00
	A_6	8.00	9.00	7.00	8.00	8.00	7.00
	A_7	6.00	8.00	6.00	8.00	6.00	7.00
C_{18}	A_1	6.00	7.00	6.00	9.00	5.00	6.00
	A_2	7.00	6.00	5.00	9.00	6.00	6.00
	A_3	6.00	9.00	9.00	6.00	6.00	7.00
	A_4	6.00	6.00	7.00	6.00	9.00	9.00
	A_5	9.00	5.00	5.00	7.00	9.00	6.00
	A_6	5.00	6.00	7.00	5.00	7.00	5.00
	A_7	5.00	9.00	6.00	5.00	5.00	7.00

Table 4.42 Normalized values.

Criterion	Alternatives	Average	Normalized
C_1	A_1	2.4	0.83
	A_2	1.9	0
	A_3	2	0.17
	A_4	2.4	0.83
	A_5	2.5	1
	A_6	2	0.17
	A_7	1.9	0
C_2	A_1	181	1
	A_2	150	0
	A_3	170	0.65
	A_4	150	0
	A_5	163	0.42
	A_6	161	0.35
	A_7	150	0
C_3	A_1	697000	0.44
	A_2	577000	0.91
	A_3	809000	0
	A_4	604000	0.8
	A_5	765000	0.17
	A_6	769000	0.16
	A_7	553000	1
C_4	A_1	0.5	0
	A_2	0.55	0.33
	A_3	0.55	0.33
	A_4	0.65	1
	A_5	0.5	0
	A_6	0.5	0
	A_7	0.55	0.33

Table 4.42 Normalized values (Cont.)

Criterion	Alternatives	Average	Normalized
C_5	A_1	70407	0.52
	A_2	51269	1
	A_3	91517	0
	A_4	55998	0.88
	A_5	73867	0.44
	A_6	64939	0.66
	A_7	73867	0.44
C_6	A_1	0.09	0.42
	A_2	0.07	0.94
	A_3	0.09	0.16
	A_4	0.07	0.87
	A_5	0.07	1
	A_6	0.08	0.74
	A_7	0.1	0
C_7	A_1	1.58	0.7
	A_2	1.72	0.95
	A_3	1.4	0.38
	A_4	1.75	1
	A_5	1.27	0.14
	A_6	1.19	0
	A_7	1.59	0.71
C_8	A_1	1100	0
	A_2	1200	0.2
	A_3	1600	1
	A_4	1350	0.5
	A_5	1250	0.3
	A_6	1150	0.1
	A_7	1250	0.3

Table 4.42 Normalized values (Cont.)

Criterion	Alternatives	Average	Normalized
C_9	A_1	6.33	1
	A_2	6.17	0.83
	A_3	5.5	0.17
	A_4	5.5	0.17
	A_5	5.33	0
	A_6	5.67	0.33
	A_7	5.67	0.33
C_{10}	A_1	0.00	0.00
	A_2	0.00	0.00
	A_3	1.00	0.25
	A_4	1.00	0.25
	A_5	1.00	0.25
	A_6	1.00	0.25
	A_7	0.00	0.00
C_{11}	A_1	4.83	0
	A_2	5	0.06
	A_3	7.67	1
	A_4	5	0.06
	A_5	5.83	0.35
	A_6	6	0.41
	A_7	6	0.41
C_{12}	A_1	2	0
	A_2	2	0
	A_3	2	0
	A_4	3	1
	A_5	2	0
	A_6	2	0
	A_7	2	0

Table 4.42 Normalized values (Cont.)

Criterion	Alternatives	Average	Normalized
C_{13}	A_1	0.00	0.00
	A_2	0.00	0.00
	A_3	1.00	0.25
	A_4	1.00	0.25
	A_5	1.00	0.25
	A_6	1.00	0.25
	A_7	0.00	0.00
C_{14}	A_1	0.00	0.00
	A_2	1.00	0.50
	A_3	1.00	0.50
	A_4	0.00	0.00
	A_5	0.00	0.00
	A_6	0.00	0.00
	A_7	0.00	0.00
C_{15}	A_1	0.00	0.00
	A_2	0.00	0.00
	A_3	1.00	0.33
	A_4	0.00	0.00
	A_5	1.00	0.33
	A_6	1.00	0.33
	A_7	0.00	0.00
C_{16}	A_1	6.67	0
	A_2	7.67	0.86
	A_3	7.83	1
	A_4	7.17	0.43
	A_5	7.17	0.43
	A_6	6.83	0.14
	A_7	6.83	0.14

Table 4.42 Normalized values (Cont.)

Criterion	Alternatives	Average	Normalized
C_{17}	A_1	8.17	1
	A_2	7.33	0.38
	A_3	7.83	0.75
	A_4	8	0.88
	A_5	7.33	0.38
	A_6	7.83	0.75
	A_7	6.83	0
C_{18}	A_1	6.5	0.5
	A_2	6.5	0.5
	A_3	7.17	1
	A_4	7.17	1
	A_5	6.83	0.75
	A_6	5.83	0
	A_7	6.17	0.25

Table 4.43 Generalized pairwise comparison method results for each alternative.

Alternatives/Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	0.159	0.161	0.146	0.132	0.146	0.152	0.151	0.124	0.158
A_2	0.126	0.133	0.121	0.145	0.106	0.124	0.164	0.135	0.154
A_3	0.132	0.151	0.169	0.145	0.190	0.167	0.133	0.180	0.137
A_4	0.159	0.133	0.127	0.171	0.116	0.127	0.167	0.152	0.137
A_5	0.166	0.145	0.160	0.132	0.153	0.120	0.121	0.140	0.133
A_6	0.132	0.143	0.161	0.132	0.135	0.134	0.113	0.129	0.141
A_7	0.126	0.133	0.116	0.145	0.153	0.176	0.151	0.140	0.141

Table 4.43 Generalized pairwise comparison method results for each alternative (Cont.)

Alternatives/Criteria	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
A_1	0.000	0.120	0.133	0.000	0.000	0.000	0.133	0.153	0.141
A_2	0.000	0.124	0.133	0.000	0.500	0.000	0.153	0.138	0.141
A_3	0.250	0.190	0.133	0.250	0.500	0.333	0.156	0.147	0.155
A_4	0.250	0.124	0.200	0.250	0.000	0.000	0.143	0.150	0.155
A_5	0.250	0.145	0.133	0.250	0.000	0.333	0.143	0.138	0.148
A_6	0.250	0.149	0.133	0.250	0.000	0.333	0.136	0.147	0.126
A_7	0.000	0.149	0.133	0.000	0.000	0.000	0.136	0.128	0.134

Table 4.44 Priority calculation results.

Alternatives/Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	0.008	0.008	0.010	0.009	0.010	0.011	0.010	0.008	0.008
A_2	0.006	0.007	0.008	0.010	0.007	0.009	0.011	0.009	0.008
A_3	0.006	0.008	0.012	0.010	0.013	0.013	0.009	0.012	0.007
A_4	0.008	0.007	0.009	0.011	0.008	0.010	0.011	0.010	0.007
A_5	0.008	0.007	0.011	0.009	0.010	0.009	0.008	0.009	0.007
A_6	0.006	0.007	0.011	0.009	0.009	0.010	0.007	0.008	0.007
A_7	0.006	0.007	0.008	0.010	0.010	0.013	0.010	0.009	0.007

Table 4.44 Priority calculation results (Cont.)

Alternatives/Criteria	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
A_1	0.000	0.004	0.008	0.000	0.000	0.000	0.005	0.010	0.010
A_2	0.000	0.004	0.008	0.000	0.033	0.000	0.006	0.009	0.010
A_3	0.004	0.006	0.008	0.015	0.033	0.010	0.006	0.010	0.011
A_4	0.004	0.004	0.012	0.015	0.000	0.000	0.006	0.010	0.011
A_5	0.004	0.005	0.008	0.015	0.000	0.010	0.006	0.009	0.010
A_6	0.004	0.005	0.008	0.015	0.000	0.010	0.006	0.010	0.009
A_7	0.000	0.005	0.008	0.000	0.000	0.000	0.006	0.008	0.009

Table 4.45 Sum of scores.

Alternatives/Criteria	Total Score
A_1	0.119
A_2	0.145
A_3	0.191
A_4	0.142
A_5	0.145
A_6	0.142
A_7	0.117

Table 4.46 Result from BWM.

Alternatives	Brand	Model	BWM	
			Score	Rank
A_1	MITSUBISHI	Triton Mega Cab Plus 2WD 2.4 GLX 6MT	0.119	6
A_2	ISUZU	Spark 1.9 Ddi B	0.145	3
A_3	FORD	Ranger XLT Open Cab XLT 2.0L Turbo HR 6MT	0.191	1
A_4	TOYOTA	Hilux Revo Standard Cab 4x2 2.4 Entry	0.142	5
A_5	NISSAN	KC Calibre E 6MT	0.145	2
A_6	MG	EXTENDER 2.0 GRAND D 6MT	0.142	4
A_7	MAZDA	BT-50 STANDARD CAB 1.9E	0.117	7

In accordance with the BWM approach, the selection of the superior supplier hinges on the total score, with a higher cumulative score indicating a more favorable alternative. Upon the application of the BWM model, it becomes evident that FORD has secured Rank 1, boasting a score of 0.191. NISSAN closely follows, attaining Rank 2 with a score of 0.145, followed by ISUZU, MG, TOYOTA, MITSUBISHI, and lastly, MAZDA. The FORD Ranger XLT Open Cab XLT 2.0L Turbo HR 6MT emerges as the most favorable option among the evaluated suppliers due to its superiority in Maximum Power, Cost, Resale Value, Maintenance & Repair, Fuel Consumption Rate, Distribution of Payload, Infotainment System Features, Connectivity Options, Traction Control System, Collision Avoidance Systems, Backup Cameras and Parking Sensors, Brand Reputation, Dealer Network Accessibility, and Service Quality.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

This paper introduces a diverse range of approaches to address supplier selection challenges, providing organizations with the necessary tools and insights to navigate the complexities of pick-up truck selection. It focuses on methodologies such as the Fuzzy Analytic Hierarchy Process (Fuzzy AHP), the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (Fuzzy TOPSIS), the combined application of Fuzzy AHP and TOPSIS, and The Best-Worst Method. The summarized results of each method are presented in Table 5.1. Upon averaging the rankings, as shown in Table 5.2, FORD Ranger XLT Open Cab XLT 2.0L Turbo HR 6MT emerges as the top-ranked choice, closely followed by ISUZU, NISSAN, MG, TOYOTA, MITSUBISHI, and finally, MAZDA

Notably, all four methods yield the same outcome, with FORD Ranger XLT Open Cab XLT 2.0L Turbo HR 6MT securing the first position and MAZDA BT-50 STANDARD CAB 1.9E consistently ranking last. Although the rankings for positions 2-4 vary slightly, a closer examination reveals that these four methods consistently align in their outcomes. Furthermore, the ranking results of F-TOPSIS and F-AHP & TOPSIS are identical.

Table 5.1 Results comparison.

Alternatives	Brand	F-AHP		F-TOPSIS		F-AHP&TOPSIS		BWM	
		Score	Rank	Score	Rank	Score	Rank	Score	Rank
A_1	MITSUBISHI	0.118	6	0.185	6	0.124	6	0.119	6
A_2	ISUZU	0.143	4	0.532	2	0.618	2	0.145	3
A_3	FORD	0.191	1	0.742	1	0.808	1	0.191	1
A_4	TOYOTA	0.142	5	0.326	5	0.356	5	0.142	5
A_5	NISSAN	0.147	2	0.360	3	0.381	3	0.145	2
A_6	MG	0.144	3	0.354	4	0.378	4	0.142	4
A_7	MAZDA	0.115	7	0.183	7	0.124	7	0.117	7

Table 5.2 Overall rank.

Alternatives	Brand	Average Score	Overall Rank
A_1	MITSUBISHI	0.137	6
A_2	ISUZU	0.359	2
A_3	FORD	0.483	1
A_4	TOYOTA	0.241	5
A_5	NISSAN	0.258	3
A_6	MG	0.254	4
A_7	MAZDA	0.135	7

5.2 Recommendation

The comparison of results from all four methods utilizes the same dataset, consisting of 18 criteria for consideration, involving six decision-makers, and seven pick-up truck options available in Thailand. As a direction for future research, we suggest experimenting with multiple datasets for further consideration and exploring other interesting methodologies, such as the integration of two methods in a hybrid manner, and updating studies with new methodologies in the future.

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APPENDIX

APPENDIX A

SOLVING A LINEAR PROGRAMMING MODEL TO DETERMINE OPTIMAL WEIGHTS FOR CRITERIA IN BWM USING MICROSOFT EXCEL SOLVER 2021

Criteria Number = 18	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
Names of Criteria	Engine Size (L)	Maximum Power (PS/ 3500 rpm)	Cost(฿)	Resale Value 5 year(%)	Maintenance &repair 5 Year Maintenance Cost(฿)	Fuel Consumption Rate (L/km)	Maximum Payload Rating (m^3)	Distribution of Payload (pounds)	Warranty Coverage (1-9)

Criteria Number = 18	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
Names of Criteria	Infotainment System Features (2:Touchable,1:Not Touchable)	Connectivity Options (1-9)	Number of Airbags (airbags)	Traction Control System (TCS)(2:Yes, 1:No)	Collision Avoidance Systems (2:Yes, 1:No)	Backup Cameras and Parking Sensors (2:Yes, 1:No)	Brand Reputation	Dealer Network Accessibility	Service quality

Select the Best	Fuel Consumption Rate
Select the Worst	Infotainment System Features

Best to Others	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_6	1.68	1.58	1.10	1.17	1.16	1.00	1.16	1.16	1.43

Best to Others	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
C_6	4.53	2.26	1.25	1.22	1.16	2.73	1.95	1.12	1.05

Figure A.1 The priority comparison of best criterion over other criteria.

Others to the Worst	C_{10}
C_1	2.88
C_2	3.11
C_3	4.18
C_4	4.00
C_5	4.00
C_6	4.53
C_7	3.89
C_8	3.89
C_9	2.98
C_{10}	1.00
C_{11}	1.89
C_{12}	3.62
C_{13}	3.65
C_{14}	3.90
C_{15}	2.09
C_{16}	2.75
C_{17}	3.96
C_{18}	4.16

Figure A.2 The other criteria priority comparison over worst criterion.

Weights	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
	0.047	0.050	0.070	0.067	0.067	0.075	0.065	0.065	0.051	0.016	0.034	0.061	0.061	0.065	0.029	0.041	0.066	0.069

(ξ) KSI* 0.004 ***** Note that we are actually optimizing the Ksi cell, meaning that our LP model minimizes inconsistencies!

Condition1	-0.01	<=	0	Condition2	0.00	>=	0	Condition3	0.00	<=	0	Condition4	0.01	>=	0	Condition5	1.000	=	1
	-0.01	<=	0		0.00	>=	0		0.00	<=	0		0.01	>=	0				
	-0.01	<=	0		0.00	>=	0		0.00	<=	0		0.01	>=	0				
	-0.01	<=	0		0.00	>=	0		0.00	<=	0		0.01	>=	0				
	-0.01	<=	0		0.00	>=	0		0.00	<=	0		0.01	>=	0				
	0.00	<=	0		0.00	>=	0		0.00	<=	0		0.01	>=	0				
	0.00	<=	0		0.00	>=	0		0.00	<=	0		0.01	>=	0				
	0.00	<=	0		0.00	>=	0		0.00	<=	0		0.01	>=	0				
	0.00	<=	0		0.01	>=	0		0.00	<=	0		0.01	>=	0				
	0.00	<=	0		0.01	>=	0		0.00	<=	0		0.00	>=	0				
	0.00	<=	0		0.00	>=	0		0.00	<=	0		0.01	>=	0				
	0.00	<=	0		0.00	>=	0		0.00	<=	0		0.01	>=	0				
	0.00	<=	0		0.00	>=	0		0.00	<=	0		0.01	>=	0				
	0.00	<=	0		0.00	>=	0		0.00	<=	0		0.01	>=	0				
	-0.01	<=	0		0.00	>=	0		-0.01	<=	0		0.00	>=	0				
	-0.01	<=	0		0.00	>=	0		-0.01	<=	0		0.00	>=	0				
	0.00	<=	0		0.01	>=	0		0.00	<=	0		0.01	>=	0				
	0.00	<=	0		0.01	>=	0		0.00	<=	0		0.01	>=	0				

$$\text{Min } \xi$$
$$w_B - a_{Bj}w_j - \xi \le 0, \forall j$$
$$w_B - a_{Bj}w_j + \xi \ge 0, \forall j$$
$$w_j - a_j w_W - \xi \le 0, \forall j$$
$$w_j - a_j w_W + \xi \ge 0, \forall j$$
$$\sum_{j=1}^{n} w_j = 1, w_j \ge 0$$

Figure A.3 Calculating the weights of the criteria.

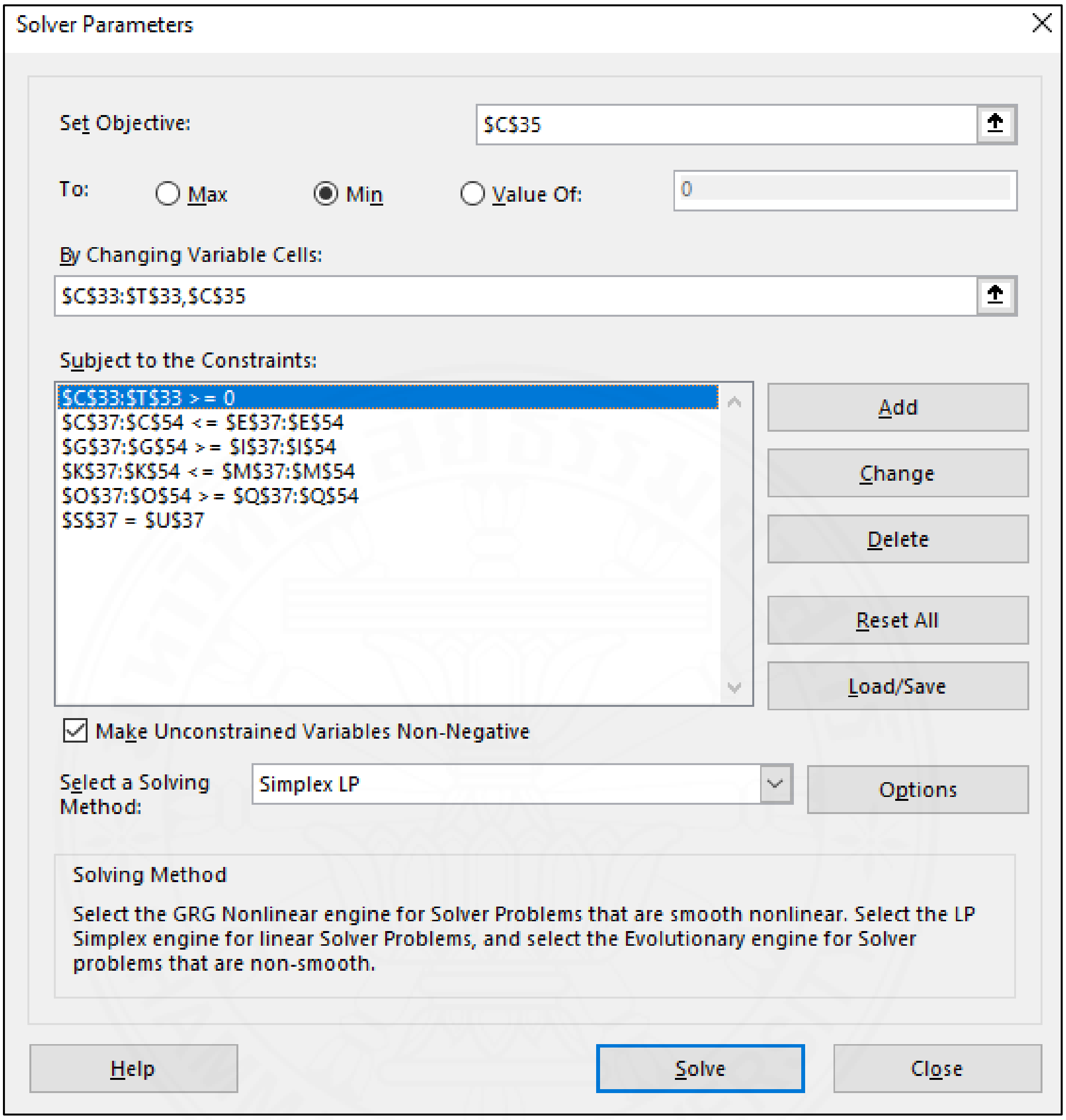

Figure A.4 Solver parameters.

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