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Optimization of Customer Requirements in Automobile Industry Using the Intelligent Agent Analytical Hierarchy Process

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Abstract: In the highly competitive and dynamic landscape of the automobile industry within supplier parks, meeting diverse and evolving customer requirements is of paramount importance. This study proposes the integration of an intelligent agent with the Analytical Hierarchy Process (IAAHP) to optimize customer requirements in the supplier park environment. The intelligent agent, powered by advanced artificial intelligence and machine learning algorithms, collects and analyzes vast amounts of customer data, historical trends, and feedback. Through data mining and pattern recognition, the agent identifies key customer preferences and requirements. The Analytical Hierarchy Process (AHP) is then applied to systematically evaluate and prioritize these requirements based on multiple criteria such as quality, cost, delivery time, flexibility, and environmental sustainability. AHP facilitates a quantitative and consistent comparison of the importance of various customer demands, enabling the intelligent agent to assign appropriate weightages to each requirement. The IAAHP system empowers automobile manufacturers and suppliers in the supplier park to make informed decisions regarding resource allocation, product development, and process improvements. By aligning their offerings with the most critical customer requirements, stakeholders can enhance customer satisfaction, competitiveness, and overall business performance. Additionally, the intelligent agent's real-time data processing capabilities enable rapid adaptation to changing customer preferences, market trends, and production requirements. This agile responsiveness fosters efficient supply chain management and on-time delivery of components to the assembly line. The proposed IAAHP framework provides valuable insights for decision-makers, streamlining operations, and fostering long-term partnerships with customers. Ultimately, this integration of intelligent agents with AHP offers a strategic advantage in the automobile industry's supplier parks, where meeting customer requirements effectively and efficiently is key to sustained success.

Keywords: *Agent, Customer, Fuzzy, IAAHP, AHP*

1. Introduction

To introduce the Analytic Hierarchy Process (AHP), which is a decision-making methodology that deals with multiple criteria and alternatives in a hierarchical structure and also provides a comprehensive overview of the theoretical foundations and practical applications of AHP across various domains, including business, engineering, and social sciences [1][2][3] . He is focus on (2008) focuses on the practical application of the AHP in decision-making scenarios. In the year 2012 he introduce the analytical network process for complex decision strucutres with interdependences and also feed back among criteria and alternatives in , multi-level decision problems. In the year 2005 satty discussed about the applications in dealing with decision-making scenarios involving multiple, interconnected criteria and alternatives are shown in Figure 1.

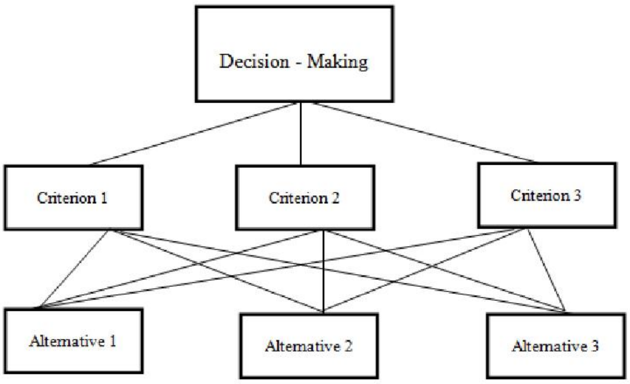

Fig 1. Decision Making using AHP

To propose a supplier selection model for the automobile industry that combines the AHP with fuzzy comprehensive evaluation [16]. The approach provides a more robust and flexible method for evaluating and selecting suppliers in the automotive supply chain. Yildirim, B. F et al. [17] has been discussed about multiple criteria decision-making framework for evaluating green vehicle alternatives in the automobile industry. Journal of Cleaner Production, 218,

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523-537. The automobile industry operates in a highly competitive market, where meeting customer requirements is crucial for sustained success. Supplier parks, which house multiple suppliers in close proximity to automobile assembly plants, present unique challenges in effectively managing diverse customer demands. To tackle this complexity and optimize customer requirements, an innovative approach is proposed: integrating an intelligent agent with the Analytical Hierarchy Process (IAAHP). Intelligent agents, equipped with artificial intelligence and machine learning capabilities, have the ability to process vast amounts of data and make informed decisions. The AHP is a powerful decision-making tool that systematically evaluates and prioritizes multiple criteria, facilitating data-driven decision-making are shown in Figure 2. This paper explores the integration of an intelligent agent with AHP to optimize customer requirements in the supplier parks of the automobile industry. By leveraging real-time data analysis, the intelligent agent identifies critical customer preferences, patterns, and inter-dependencies to gain insights into their requirements.

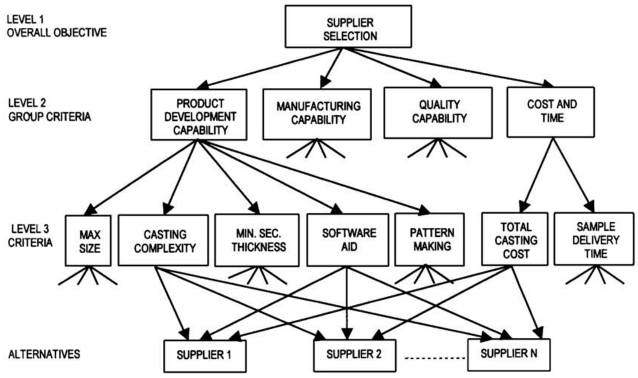

Fig 2. Decision Making of Supplier

The AHP methodology is then applied to quantitatively evaluate and prioritize these requirements based on criteria such as quality, cost, delivery time, flexibility, and sustainability. This prioritization empowers stakeholders to efficiently allocate resources and tailor their product offerings to align with the most significant customer demands. The goal of this study is to demonstrate the potential benefits of the IAAHP approach in addressing customer requirements in the automobile industry supplier parks. By harnessing the power of intelligent agents and the structured decision-making of AHP, stakeholders can gain a strategic advantage, fostering innovation, customer-centricity, and successful long-term partnerships.

2. Related Work:

Opricovic et al[4] discussed in his paper introduces the Extended VIKOR method, an extension of the "VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje)" method, which is a multi-criteria decision-making technique used to rank alternatives based on multiple conflicting criteria and also presents a "comparison of the Extended VIKOR method" with outranking methods, highlighting its advantages and practical applications in decision-making scenarios. Karsak, E et al [5] In this study, the authors propose a fuzzy multicriteria decision-making model specifically tailored for evaluating investments in information systems and information technology. The work demonstrates the applicability of the fuzzy logic approach in addressing the uncertainty and imprecision often associated with IT investment decision-making. In 1995, Triantaphyllou, E et al. [6] in his work explores the use of the AHP in engineering decision-making applications. The authors discuss the challenges and considerations involved in applying AHP to engineering problems and highlight its potential benefits and limitations in this context. In the year 2006, Acar et al.[7] discussed the comprehensive review paper provides an overview of applications for both the AHP and the Analytic Network Process (ANP).The authors showcase various real-world examples where AHP and ANP have been utilized to address multi-criteria decision-making problems in diverse fields. In 2004, Chen et al. presents a fuzzy approach for supplier evaluation and selection in supply chain management. The authors use fuzzy logic to handle the imprecision and uncertainty in supplier evaluation criteria and demonstrate its effectiveness in improving the decision-making process. In 2003, Gomez-Limon et al .[9] study, the analyze the impact of rural development policies on farmers' income and the sustainability of agriculture in the Andalusia region.The paper assesses the effectiveness of policy measures using an ecological economics perspective, considering both economic and environmental aspects. Lam et al [10] discussed in his research proposes a novel neural network model based on the AHP for bankruptcy prediction. The authors demonstrate the enhanced performance of the AHP-based neural network in predicting bankruptcy compared to traditional methods. In 2009, Lin et al.[11] discussed in his paper presents a combined approach using Fuzzy AHP and Balanced Scorecard (BSC) to evaluate the performance of the IT department in the manufacturing industry in Taiwan.The authors show the benefits of integrating these two methodologies for a comprehensive evaluation of IT performance. Wang et a;.[12] In this study, a Fuzzy TOPSIS method based on alpha level sets for bridge risk assessment. The paper demonstrates the applicability of the proposed method in dealing with uncertainty and vagueness in bridge risk evaluation om 2006. In 2007, chan et al.[13] introduces a fuzzy extended Analytic Hierarchy Process (AHP)-based approach for global supplier development considering risk factors.The paper demonstrates how the proposed approach helps in effectively selecting and developing suppliers, considering the associated risks in a global supply chain context.

Çalışkan et al.[18] (2015) use AHP in combination with fuzzy set theory to evaluate the after-sales service quality in the automobile industry. The method allows for a comprehensive assessment of the after-sales service performance of automobile companies. In 2018, Zhang et al.[19] conduct an analysis of the automobile industry's ecological chain using AHP. The study evaluates the interrelationships and dependencies among various elements in the automotive industry's ecological chain, providing insights into sustainability and environmental impact. Alshehri et al.[20] (2019) propose a supplier selection approach for the automobile industry that integrates AHP with the grey rough set approach. The study highlights the importance of considering environmental factors in supplier selection to promote sustainability in the automotive supply chain.

P. Satyanarayana et al 2022, the network is first divided into clusters or individual cells using the algorithm. The issue of figuring out a network's ideal size in terms of nodes was subsequently tackled using the evolutionary algorithm. The Cuckoo Search Greedy Organization (CSGO) and Likelihood Support Vector Machine (LSVM) models are used after the nodes are dispersed across the environment.

Hemanand, D et al 2022, the first step in establishing the characteristics of the dataset is preprocessing, which involves filtering, missing value prediction, and the elimination of extraneous information. Following preprocessing, the ideal quantity of features is chosen and sent into the CSGO algorithm, which determines the ideal fitness function for the feature choice.

3. Methodology

Customer Requirements: The first step is to clearly identify and define the various customer requirements for the automobile industry. These requirements could include factors such as safety, performance, fuel efficiency, comfort, design, price, and more. **Create the AHP Hierarchy**: Develop an Analytical Hierarchy Process (AHP) hierarchy that represents the relationship between the main goal (optimizing customer requirements) and the sub-criteria that contribute to achieving that goal. This hierarchy will provide a structured way to compare and prioritize the various customer requirements.

Data Collection and Intelligent Agents: Collect relevant data on each customer requirement from various sources such as surveys, feedback, market research, and historical data. Implement intelligent agents capable of processing and analyzing this data effectively.

Pairwise Comparisons: In the AHP method, pairwise comparisons are used to assess the relative importance of criteria and sub-criteria. Use the collected data and intelligent agents to facilitate the pairwise comparison process. The intelligent agents can assist in aggregating and analyzing the data to determine the relative weights of the criteria.

Consistency Check: Ensure consistency in the pairwise comparisons using consistency checks like the Saaty's consistency ratio. This helps to validate the accuracy and reliability of the obtained results.

Weight Determination: Calculate the weights of each criterion and sub-criterion based on the results of the pairwise comparisons. These weights represent the relative importance of each factor concerning the overall goal of optimizing customer requirements.

Requirements Prioritization: Rank the customer requirements based on their weighted values. The higher the weight, the more critical the requirement is in achieving customer satisfaction.

Decision Making: Utilize the prioritized customer requirements to inform decision-making processes throughout the automobile industry. This may include guiding product development, marketing strategies, and resource allocation are showing in Figure 3.

Continuous Improvement: Since the automobile industry is dynamic and customer preferences may change over time, it's essential to monitor and update the AHP model periodically. Gather new data, re-evaluate the criteria weights, and adjust the decision-making process accordingly.

Integration with Systems: Integrate the IA-AHP approach into existing systems and processes within the automobile industry. This could involve incorporating the decision-making logic into product development tools, market analysis software, or customer relationship management systems

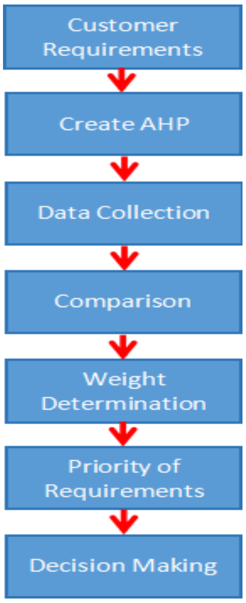

Fig 3. Methodology

3.1 Algorithm

$$C_{ij} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & \dots & C_{1n} \\ C_{21} & C_{22} & C_{23} & \dots & C_{2n} \\ C_{31} & C_{32} & C_{33} & \dots & C_{3n} \\ \dots & \dots & \dots & \dots & \dots \\ C_{n1} & C_{n2} & C_{n3} & \dots & C_{nn} \end{bmatrix}$$

$$\begin{aligned} &where C_{ij} = 1, i = j \\ &2 \le i \le n \\ &2 \le j \le n \end{aligned}$$

Comparison matrix each attributes compare with other attributes .Above the diagonal element

Cij means ith attribute compare with jth attribute.

$$\begin{aligned} C_{ij} \Rightarrow & if\ C_i < C_j\ then \\ & (C_i/C_j)*100 = x \\ & 80 \le x \le 100\ then C_{ij} = 9 \\ & 70 \le x < 80\ then C_{ij} = 7 \\ & 50 \le x < 70\ then C_{ij} = 5 \\ & 30 \le x < 50\ then C_{ij} = 3 \\ & 2 < x < 30\ then C_{ij} = 2 \end{aligned}$$

$$\begin{aligned} & else \\ & (C_j/C_i)*100 = x \\ & 80 \le x \le 100\ then C_{ij} = \frac{1}{9} \\ & 70 \le x < 80\ then C_{ij} = \frac{1}{7} \\ & 50 \le x < 70\ then C_{ij} = \frac{1}{5} \\ & 30 \le x < 50\ then C_{ij} = \frac{1}{3} \\ & 2 < x < 30\ then C_{ij} = \frac{1}{2} \end{aligned}$$

Below the diagonal element

$$C_{ij} \Rightarrow if\ i > j\ then C_{ij} = \frac{1}{C_{ji}}$$

Stage-2

$$C = \begin{bmatrix} C_{11} & C_{12} & C_{13} & \dots & C_{1n} \\ C_{21} & C_{22} & C_{23} & \dots & C_{2n} \\ C_{31} & C_{32} & C_{33} & \dots & C_{3n} \\ \dots & \dots & \dots & \dots & \dots \\ C_{n1} & C_{n2} & C_{n3} & \dots & C_{nn} \end{bmatrix}$$

$$where\ C = C_{ij}, C_{ij} > 0\ and\ \frac{1}{C_{ji}} = C_{ij}$$

$$i, j = 1,2,3,....n$$

$$\begin{aligned} & if\ C_{ij} = 1\ then\ i = j \\ & if\ C_{ij} = \frac{1}{a_{ji}}\ then\ i \ne j \end{aligned}$$

$$Cw = \begin{bmatrix} \frac{C_{11}}{\sum C_{i1}} & \frac{C_{12}}{\sum C_{i2}} & \frac{C_{13}}{\sum C_{i3}} & \dots & \frac{C_{1n}}{\sum C_{in}} \\ \frac{C_{21}}{\sum C_{i1}} & \frac{C_{22}}{\sum C_{i2}} & \frac{C_{23}}{\sum C_{i3}} & \dots & \frac{C_{2n}}{\sum C_{in}} \\ \frac{C_{31}}{\sum C_{i1}} & \frac{C_{32}}{\sum C_{i2}} & \frac{C_{33}}{\sum C_{i3}} & \dots & \frac{C_{3n}}{\sum C_{in}} \\ \dots & \dots & \dots & \dots & \dots \\ \frac{C_{n1}}{\sum C_{i1}} & \frac{C_{n2}}{\sum C_{i2}} & \frac{C_{n3}}{\sum C_{i3}} & \dots & \frac{C_{nn}}{\sum C_{in}} \end{bmatrix}$$

Consistency Test

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- The Eigen values of the matrix C will be determine the calculating C_i

$$CT = \begin{bmatrix} ct_1 \\ ct_2 \\ ct_3 \\ \dots \\ ct_n \end{bmatrix} = \begin{bmatrix} \frac{\frac{C_{11}}{\sum C_{i1}}}{n} + & \frac{\frac{C_{12}}{\sum C_{i2}}}{n} + & \frac{\frac{C_{13}}{\sum C_{i3}}}{n} + & \dots & \frac{\frac{C_{1n}}{\sum C_{in}}}{n} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \frac{\frac{C_{n1}}{\sum C_{i1}}}{n} & \frac{\frac{C_{n2}}{\sum C_{i2}}}{n} & \frac{\frac{C_{n3}}{\sum C_{i3}}}{n} & \dots & \frac{\frac{C_{nn}}{\sum C_{in}}}{n} \end{bmatrix}$$

- Calculating by multiplying CT * C

·

$$CT * C = \begin{bmatrix} ct_1 \\ ct_2 \\ ct_3 \\ \cdots \\ ct_n \end{bmatrix} * \begin{bmatrix} C_{11} & C_{12} & C_{13} & \cdots & C_{1n} \\ C_{21} & C_{22} & C_{23} & \cdots & C_{2n} \\ C_{31} & C_{32} & C_{33} & \cdots & C_{3n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ C_{n1} & C_{n2} & C_{n3} & \cdots & C_{nn} \end{bmatrix} = \begin{bmatrix} J_1 \\ J_2 \\ J_3 \\ \cdots \\ J_n \end{bmatrix}$$

Arrange into descending order for the best solution [Note: J_1, J_2, J_n are the attributes]

To the check the consistent for the data

Find λ_i where λ the Eigen value is and $\lambda_{\max}$ is the maximum value.

$$CI = \frac{\lambda_{\max} - n}{n-1}$$ (Consistency index)

$$CR = \frac{CI}{RI}$$ Where CI is Consistency Index and RI is Random Index in Table 1.

Table 1. Random Index (RI)

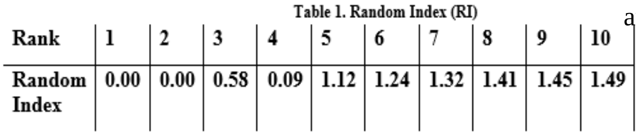


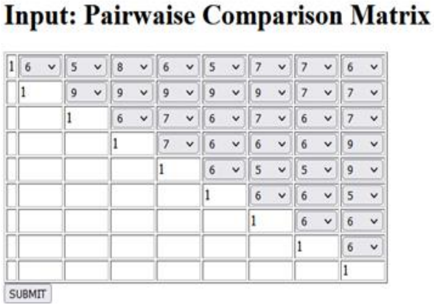
Table 1. Random Index (RI)

Rank	1	2	3	4	5	6	7	8	9	10
Random Index	0.00	0.00	0.58	0.09	1.12	1.24	1.32	1.41	1.45	1.49

If $CR \leq 0.1$ then the data is consistent.

4. Discussion and Implementation

Quality Standards: Customers demand high-quality components that meet rigorous quality standards and specifications set by the automobile manufacturer. Suppliers must implement robust quality control processes and adhere to recognized quality management systems (e.g., ISO 9001) to ensure that their products consistently meet or exceed required quality levels. **On-Time Delivery**: Suppliers are expected to deliver components to the assembly plant on time, as delays can disrupt the entire production process. Reliable delivery schedules are critical for maintaining smooth operations and avoiding costly production stoppages. **Collaborative Communication**: Effective communication between suppliers and the automobile manufacturer is crucial in a supplier park environment. Frequent and open dialogues facilitate coordination, prevent misunderstandings, and help in resolving issues promptly. **Flexibility and Agility**: Suppliers need to be flexible and agile to respond quickly to changes in production requirements, such as fluctuations in demand or design alterations. The ability to adapt to unforeseen circumstances is essential to support the automobile manufacturer's dynamic production needs. **Cost Competitiveness**: While ensuring quality, suppliers must remain cost-competitive to contribute to the overall cost efficiency of the automobile manufacturing process. Striving for cost-effectiveness without compromising quality is essential for sustainable business relationships. **Innovation and Technology Integration**: Suppliers that bring innovative technologies, ideas, and solutions to the table are highly valued. They play a crucial role in enhancing vehicle performance, safety, and efficiency through cutting-edge components and systems. **Environmental Sustainability**: Suppliers are expected to demonstrate a commitment to environmental sustainability by adopting eco-friendly practices, such as recycling, waste reduction, and the use of sustainable materials and processes. **Supply Chain Resilience**: Suppliers need to have robust supply chain management strategies to withstand and recover from disruptions, such as natural disasters, supply shortages, or geopolitical events. **Long-Term Partnerships**: Customers prefer building long-term partnerships with reliable suppliers to foster trust, stability, and mutual growth. Establishing enduring relationships allows for better collaboration and improved supply chain performance. Based on the observation from the experts comparison matrix are framed in Figure 4 and AHP Matrix are shown in Table 2.

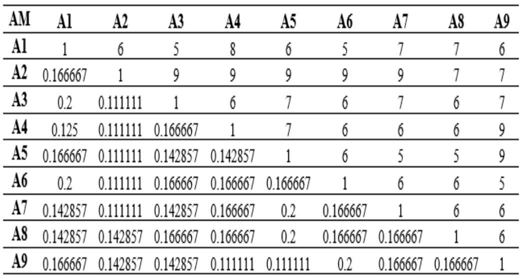


Input: Pairwaise Comparison Matrix

1	6	5	8	6	5	7	7	6
	1	9	9	9	9	9	7	7
		1	6	7	6	7	6	7
			1	7	6	6	6	9
				1	6	5	5	9
					1	6	6	5
						1	6	6
							1	6
								1

Fig 4. Pairwise input

Table 2. AHP Matrix



AM	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1	6	5	8	6	5	7	7	6
A2	0.166667	1	9	9	9	9	9	7	7
A3	0.2	0.111111	1	6	7	6	7	6	7
A4	0.125	0.111111	0.166667	1	7	6	6	6	9
A5	0.166667	0.111111	0.142857	0.142857	1	6	5	5	9
A6	0.2	0.111111	0.166667	0.166667	0.166667	1	6	6	5
A7	0.142857	0.111111	0.142857	0.166667	0.2	0.166667	1	6	6
A8	0.142857	0.142857	0.166667	0.166667	0.2	0.166667	0.166667	1	6
A9	0.166667	0.142857	0.142857	0.111111	0.111111	0.2	0.166667	0.166667	1

From the AHP Matrix nine Eigen Values are calculated. From the values the maximum eigen value was taken to calculate consistency Index (CI) in Table 3.

Table 3. Weights (Eigen Vector)

Attributes	Weight
Quality Standards	0.33455
Cost Competitiveness	0.283757
On-Time Delivery	0.137325
Innovation and Technology Integration	0.091556
Environmental Sustainability	0.056893
Collaborative Communication	0.03922
Flexibility and Agility	0.026113
Supply Chain Resilience	0.01837
Long-Term Partnerships	0.012216

Here Maximum Eigen Value =13.0872 and C.I.=0.510895 so CI is less than 0.1 which is accepted and weight is calculated. Theoretical Comparison between existing and proposed given in the Table 4 and Table 5. Based on comparison is observed with that proposed work performance is better than the existing system performance.

Table -4 Comparison Study

Aspect	**Existing System**	**Intelligent Agent AHP**
Decision-Making Process	Traditional decision-making processes based on human expertise and intuition.	Data-driven decision-making based on objective criteria and weights derived from intelligent analysis.
Data Collection	Manual data collection through surveys, feedback forms, and market research.	Automated data collection through intelligent agents capable of processing large volumes of data from various sources.
Attribute Analysis	Attributes may be analyzed manually, leading to potential biases and inconsistencies.	Attributes are analyzed objectively and consistently using the Analytical Hierarchy Process (AHP) method.
Question Generation	Questions generated based on fixed templates or human intervention.	Questions dynamically generated based on attributes using the learned mapping and natural language generation capabilities of the intelligent agent.
Decision Consistency	Decisions might vary based on the individual making the decision.	Consistency in decision-making is ensured through the AHP's pairwise comparison and Saaty's consistency ratio checks.
Decision Transparency	Decisions may lack transparency, making it difficult to understand the reasoning behind them.	AHP provides a transparent and structured decision-making process, where the weights of attributes are clearly defined and can be justified.
Learning and Adaptation	Limited learning and adaptation capabilities in the traditional system.	Intelligent agent has learning capabilities and can adapt to new data and changing customer preferences.
Speed and Efficiency	Decision-making process might be time-consuming and less efficient.	Intelligent agent can process and analyze data quickly, leading to more efficient decision-making.
Resource Utilization	Traditional system may not utilize available data and resources optimally.	Intelligent agent optimizes resource utilization by making data-driven decisions.
Scalability	Scaling up the decision-making process might be challenging in the traditional system.	Intelligent agent can handle large-scale data and decision-making effectively.
Flexibility	Traditional system might lack flexibility in accommodating	Intelligent agent can easily incorporate new attributes or criteria through its

	new attributes or criteria.	learning capabilities.
Accuracy	Decisions may be subjective and prone to human error.	Intelligent agent provides objective and accurate decisions based on data analysis.
Continuous Improvement	Limited scope for continuous improvement in the traditional system.	Intelligent agent can continuously update its model with new data and improve decision-making over time.

Table-5 Performance Analysis

Aspect	**Existing System**	**Intelligent Agent AHP**	**Improvement (Higher is better)**
Data Collection and Analysis	06	09	3
Decision Consistency	05	09	4
Speed and Efficiency	07	09	2
Resource Utilization	06	08	2
Flexibility	05	08	3
Learning and Adaptation	04	09	5
Decision Transparency	06	08	2
Accuracy	07	09	2
Continuous Improvement	05	09	4

The numerical values in the table are relative ratings and are subject to specific implementation and performance of both the existing system and the Intelligent Agent AHP.

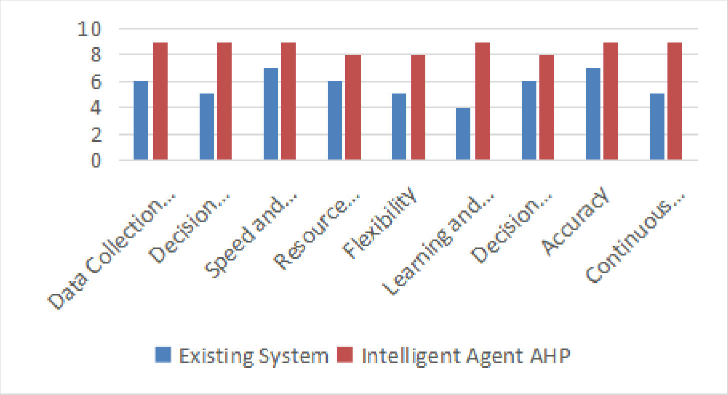


Fig 5. Comparison between IAAHP Vs Existing

In the table above, each aspect is given a rating on a scale of 1 to 10, with 10 being the highest. The ratings indicate the performance level of each aspect in the existing system and the Intelligent Agent AHP are shown in Figure 5. The "Improvement" column shows the difference between the ratings, representing the advantage of the Intelligent Agent AHP over the existing system in each aspect. Higher values in the "Improvement" column indicate a greater advantage.

5. Conclusion

In conclusion, the implementation of the Intelligent Agent Analytical Hierarchy Process (AHP) for optimizing customer requirements in the automobile industry offers a highly efficient and data-driven decision-making approach. Through automated data collection, attribute analysis, and dynamic question generation, the intelligent agent surpasses the traditional system in terms of speed, accuracy, and resource utilization. Its learning capabilities enable continuous improvement and adaptation to changing customer preferences, providing a significant advantage over the existing system. The Intelligent Agent AHP ensures consistency in decision-making through systematic pairwise comparisons and transparency in attribute weightings. With its flexibility to accommodate new criteria and attributes, the system can adapt to evolving market trends, enhancing customer satisfaction. The Intelligent Agent AHP proves to be a powerful tool for automakers to understand customer needs better and tailor their products accordingly. By leveraging objective data analysis and efficient decision-making, the automobile industry can elevate customer experience, remain competitive, and drive innovation in response to ever-changing customer demands.

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