A Literature Review on the Integration of AI with AHP/ANP

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Highlights

- This paper provides a comprehensive review of AI integration with AHP and ANP, focusing on applications in critical fields like healthcare, supply chain, and energy policy.
- It examines advancements and methodologies that enhance decision-making by addressing complexity and improving analytical precision.
- Emerging trends, challenges, and future research directions are identified to guide the evolution of Multi-Criteria Decision-Making (MCDM) methods in modern analytics.

ABSTRACT

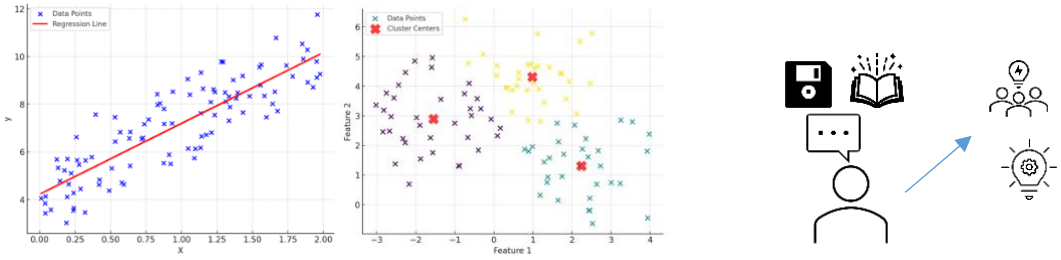
The release of ChatGPT to the public has significantly accelerated interest in artificial intelligence (AI), establishing it as a transformative technology across diverse disciplines. The integration of AI with the Analytic Hierarchy Process (AHP) dates back to the late 20th century, with early explorations involving expert systems and neural networks to enhance decision-making. This paper presents a comprehensive literature review of AI integration with AHP and its network-based extension, the Analytic Network Process (ANP). It focuses on applications in key fields such as healthcare, supply chain, and energy policy. We analyze the methodologies and advancements in combining AI with AHP/ANP, highlighting how these approaches address complex decision-making challenges. Additionally, we discuss emerging trends, identify potential challenges, and propose directions for future research. By providing insights into the current state and evolution of AI-AHP/ANP integration, this study aims to contribute to the ongoing development of Multi-Criteria Decision-Making (MCDM) methods and their applications in modern decision analytics.

Keywords (3-6): literature review, AI, AHP

1. Introduction

Before reviewing the application of AI in analytics and decision-making, it is necessary to distinguish AI from the machine learning discussed in this paper. The AI frequently referenced today refers to generative AI, which consists of large language models trained to produce new content. In contrast, machine learning involves algorithms and processes used for making predictions based on historical data, performing classification, and recognizing patterns to enhance the accuracy of computational results for complex tasks that would otherwise require significant time and effort from humans. While machine

learning focuses on improving predictive accuracy and task efficiency, generative AI emphasizes on originality and creativity.



(a) Machine learning (b) Generative AI

Figure 1 Machine learning vs. Generative AI

2. Real-World Applications of AI

AI is increasingly used in both personal and professional life. Tools like Siri (Apple), Alexa (Amazon), and Google Assistant are widely adopted for tasks such as setting alarms, reminders, playing music, and answering basic questions that were traditionally directed to search engines. In business, AI plays a prominent role in chatbots, which assist with customer support and inquiries, uncover customer preferences, and detect fraud. Retailers leverage AI to recommend products, provide media suggestions, and deliver targeted advertisements based on user preferences. In transportation, AI-powered self-driving software, autonomous vehicles, and drones are hot topics. These technologies are also being utilized to optimize traffic flow. Navigation tools, such as mapping apps, incorporate AI to provide real-time routing and updates.

In decision-making, AI has been integrated with various methods to enhance efficiency and effectiveness. The integration of AI with the Analytic Hierarchy Process (AHP) dates back to the 1990s, when researchers began exploring its combination with expert systems and neural networks. In 1995, Alireza Fallahpour proposed a hybrid model that combined AHP with multi-expression programming (MEP) to address supplier selection challenges. This approach aimed to mitigate the computational complexity of traditional methods by incorporating AI techniques into AHP[1].

Over the years, the integration of AI and AHP has expanded into diverse domains, including healthcare, energy policy planning, and supply chain management. Recent advancements have incorporated machine learning algorithms, fuzzy logic, and neural networks with AHP to tackle complex decision-making scenarios more effectively[2]. When combined with AI, AHP and its network-based extension, the Analytic Network Process (ANP), enable more intricate decision-making processes and simulate outcomes to support better planning.

3. Applications of AI in Integrating AI with AHP and ANP

This paper aims to explore the current status of AI integration with AHP/ANP, focusing on its applications in three main areas: healthcare, supply chain management, and urban planning. We also seek to address several key questions: How is AI being integrated with AHP/ANP methodologies? What advancements have been achieved through this

integration? How has it enhanced the decision-making process and supported complex cases? Finally, what are the future research directions for integrating AI with AHP/ANP methods?

3.1 Healthcare

The integration of AHP and AI is promising for improving decision-making processes, allowing healthcare systems to balance competing demands effectively. Recent research demonstrates that combining AHP with AI helps in structuring complex decision scenarios and using vast data inputs from AI to improve resource allocation decisions, especially under uncertainty, as seen during the COVID-19 pandemic[3-12].

3.2 Supply chain

The integration of Artificial Intelligence (AI) with Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) in supply chain management enhances decision-making by combining AI's predictive analytics and computational efficiency with AHP/ANP's structured frameworks for multi-criteria evaluation. Applications range from supplier selection and risk management to inventory optimization and logistics planning, where AI facilitates real-time data processing and adaptive modeling. This integration improves accuracy, consistency, and comprehensiveness by addressing interconnected criteria and dependencies, though challenges such as data quality, model complexity, and interpretability remain. Emerging trends emphasize the use of big data, real-time decision-support systems, and sustainability-focused models, highlighting the potential of AI-enhanced AHP/ANP to transform supply chain decision-making into a more resilient and adaptive process.

3.3 Energy policy planning

In the field of Energy Policy Planning, the integration of Artificial Intelligence (AI) and Analytic Hierarchy Process (AHP) has gained traction for its ability to enhance decision-making processes in recent years. Combining AI and AHP has offered a hybrid approach for more effective decision-making in energy policy planning. These systems use AI's predictive and optimization capabilities, while AHP offers a framework for structuring complex decisions with multiple criteria. Some of the areas where this combination is beneficial include: energy resource management where AI models can generate multiple scenarios, while AHP helps decision-makers rank the most appropriate ones; and sustainability analysis where AI tools provide quantitative data for energy use and impacts, while AHP helps prioritize policy choices based on stakeholder input[13-18].

4. Methodology

The integration of Artificial Intelligence (AI) with the Analytic Hierarchy Process (AHP) leverages AI as a key methodology to enhance decision-making processes. AI is used to analyze textual data from surveys, reports, and feedback to inform AHP criteria. In addition AI techniques enable the extraction and quantification of qualitative data, such as stakeholder opinions, expert judgments, and textual inputs, converting them into structured pairwise comparisons or criteria weights. This integration automates the interpretation of unstructured data, reduces manual effort, and mitigates biases in decision modeling. By analyzing textual data from surveys, reports, or user feedback, AI supports AHP in capturing diverse perspectives, ensuring comprehensive and informed decision-making. It is particularly valuable for complex scenarios requiring the interpretation of natural language inputs.

Recent advancements in Natural Language Processing (NLP) have significantly enhanced its integration with the Analytic Hierarchy Process (AHP), leading to more efficient and accurate decision-making processes.

5. Challenges and Future of AI and AHP/ANP Integration

Integrating AI with the Analytic Hierarchy Process (AHP) faces challenges related to data quality, contextual understanding, and ambiguity in natural language inputs, which can affect the accuracy and reliability of decision models. NLP models often struggle with domain-specific language and the nuances of subjective judgments, while processing large volumes of data can be computationally intensive. Additionally, biases in pre-trained NLP models and the black-box nature of complex architectures hinder transparency and fairness. The technical complexity of integrating NLP with AHP and the potential reluctance of stakeholders to trust automated interpretations further complicate adoption. Overcoming these challenges requires advancements in NLP techniques, transparent methodologies, and robust validation mechanisms to ensure reliability and stakeholder confidence.

Recent advancements in AI, such as transformer-based models and large language models, have enhanced the ability to process and interpret qualitative data, thereby improving the accuracy of AHP/ANP analyses. However, challenges persist, including ensuring data quality, managing model complexity, and maintaining transparency in AI algorithms. Addressing these issues is crucial for successfully adopting AI-enhanced AHP/ANP methodologies.

6. Key References

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