Dynamic Decision-Making in Autonomous Vehicles Using AHP and BOCR Models

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ABSTRACT

Self-driving cars are revolutionizing the automotive landscape by leveraging advanced technologies to enable fully autonomous operations. Despite their potential, significant challenges remain in ensuring real-time decision-making that mimics or exceeds human judgment. This paper introduces a robust decision-making framework that integrates the Analytic Hierarchy Process (AHP) for driver preference customization and a Benefits-Opportunities-Costs-Risks (BOCR) model for dynamic adaptation to real-world conditions. By addressing critical factors such as traffic, safety, and passenger comfort, the proposed solution enhances both the practical and ethical dimensions of autonomous driving. This study highlights the potential for self-driving technology to improve public trust and sustainability, contributing to smarter and safer mobility solutions.

Keywords

Self-driving cars, AHP, BOCR, real-time decision-making, autonomous vehicles, ethics.

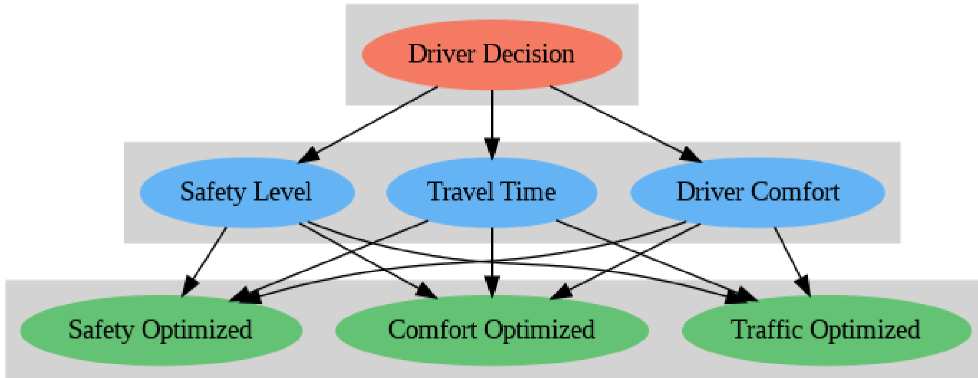
Introduction

The rapid advancement of autonomous vehicle technology has unlocked the potential for fully self-driving cars. These vehicles promise transformative changes in transportation, from increased safety to reduced environmental impact. However, the lack of a human driver introduces unprecedented challenges in decision-making, particularly under unpredictable conditions. How should an autonomous vehicle react to sudden lane changes, unexpected pedestrian crossings, or traffic and passenger comfort demands? This paper examines these questions and proposes a comprehensive decision-making framework to address such challenges. The system prioritizes adaptability and safety by integrating driver preferences and real-time data, ensuring optimal performance in diverse conditions.

Proposed Solution

To address the challenges of real-time decision-making, we propose a dual-model solution. The first component, an Analytic Hierarchy Process (AHP) model, allows drivers to establish their preferences before commencing a journey. These preferences define the default mode of operation, whether prioritizing safety, traffic efficiency, or passenger comfort.

1AHP User selects the driving mode



There are 3 alternative modes to be chosen:

1. **Safety optimized mode**: Be alert and make quick and fast moves to avoid any safety risk, like sudden turns, hole avoidance, and pedestrian avoidance.
2. **Traffic-optimized mode: Look for the best routes to minimize the time it takes** to get from point A to point B.
3. **Comfort-optimized mode: Find the most comfortable route with minimum turns** and smooth road conditions.

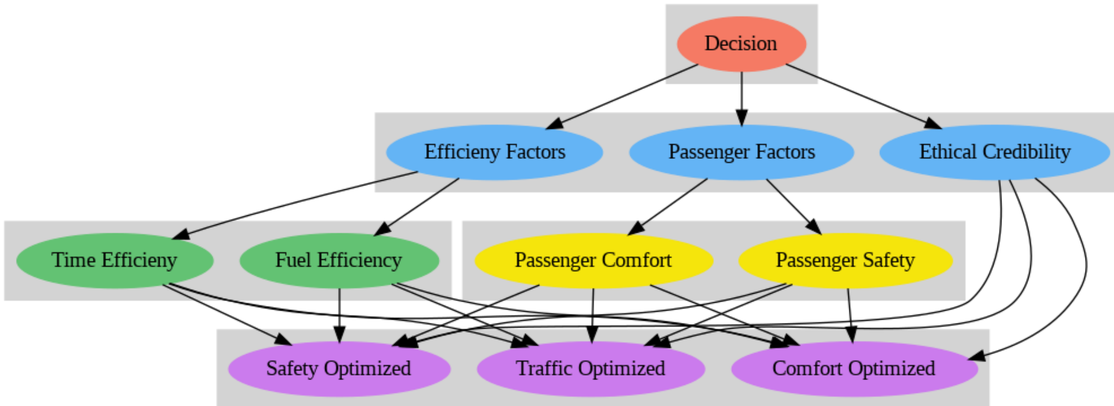
This model can be expanded to include a multitude of criteria to fully describe the drivers preference depending on the situation, but the aforementioned model is the minimum required setup to ensure that the model can be customized on the driver's personal preferences.

Benefits, Opportunities, Costs, and Risks Analysis

The second component, a Benefits-Opportunities-Costs-Risks (BOCR) model, dynamically evaluates situational conditions and adapts the vehicle's mode accordingly. Together, these models ensure that the vehicle operates in alignment with both driver expectations and real-world demands.

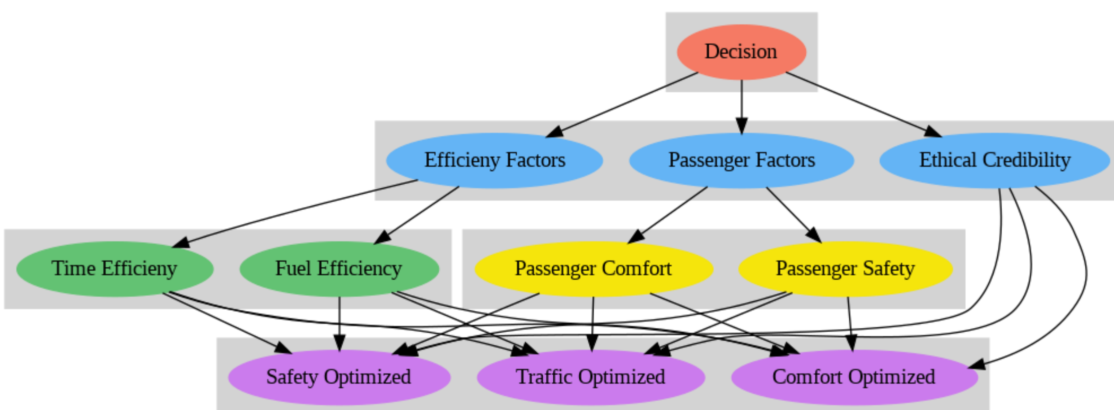
Strategic Objectives and Decision Framework

The strategic objectives of the proposed system are defined by the conditions the vehicle encounters in real-time. Key factors include traffic density, proximity to pedestrians and other vehicles, prevailing weather conditions, and road quality. Additionally, the system considers passenger comfort and the presence of emergency vehicles. Each factor informs the BOCR model, enabling the vehicle to dynamically switch between operational modes to ensure optimal performance.

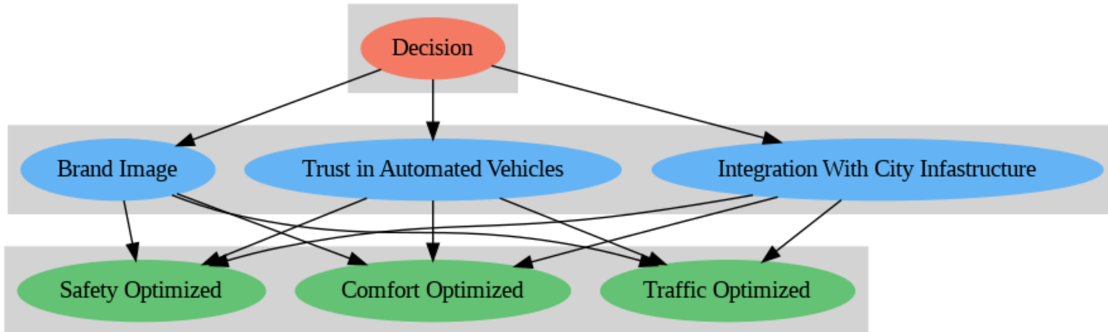


Three distinct alternatives guide the system's decision-making process. The Safety-Optimized Mode prioritizes rapid responses to potential risks, including sudden turns and obstacle avoidance. The Traffic-Optimized Mode emphasizes efficiency, selecting the fastest routes and minimizing travel time. Lastly, the Comfort-Optimized Mode focuses on passenger experience, favoring routes with minimal turns and smooth road surfaces. The system achieves a balanced and responsive operational framework by considering these alternatives in conjunction with the driver's AHP-defined preferences.

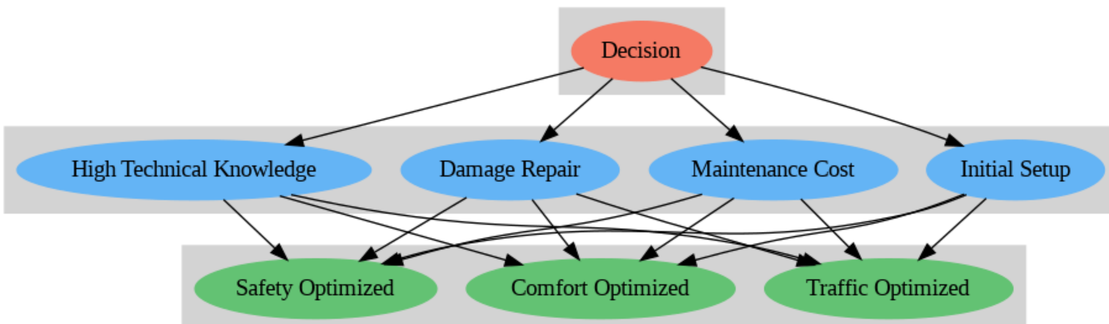
The proposed system offers numerous benefits, including enhanced ethical credibility by prioritizing safety and sustainability. Time efficiency is achieved through optimal routing, while fuel efficiency is improved by minimizing unnecessary maneuvers. Passenger safety and comfort are central to the system's design, ensuring a positive user experience.



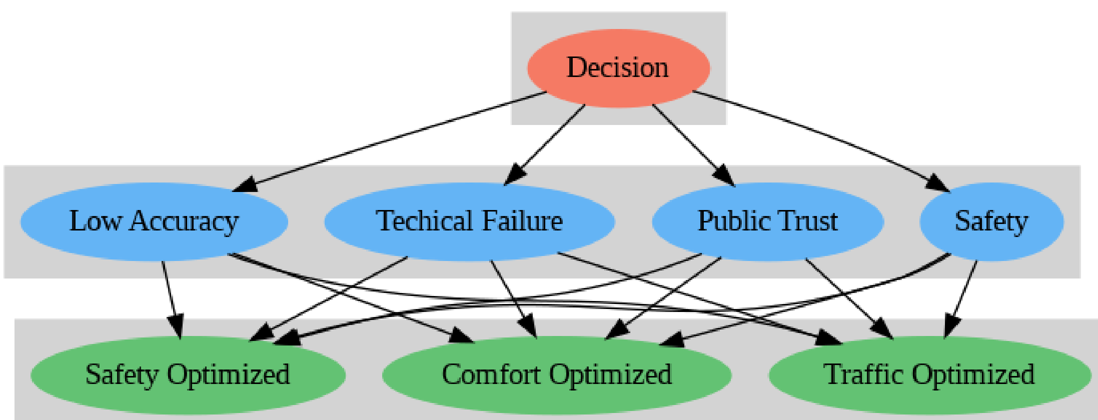
The system also presents significant opportunities. By enhancing public trust in autonomous vehicles, it fosters greater adoption of self-driving technology. Integration with smart city infrastructure, such as traffic sensors and real-time data networks, further amplifies its potential impact. These opportunities contribute to a positive brand image, positioning the system as a leader in the autonomous vehicle market.



However, the system is not without costs. Initial setup and maintenance expenses are considerable, while damage repair and the need for highly skilled personnel add to the financial burden.



Risks include technical failures, low accuracy in data interpretation, and potential safety concerns that could undermine public trust. Addressing these challenges is critical for the system's long-term success.



Conclusions

The integration of AHP and BOCR models provides a robust solution for real-time decision-making in self-driving cars. By prioritizing safety and adaptability, the system addresses key challenges in autonomous vehicle operations. This study highlights the importance of balancing technical innovation with ethical considerations, ensuring that the system aligns with societal expectations. Future work will focus on enhancing the accuracy and reliability of data inputs and exploring opportunities for broader integration with smart city technologies.

Limitations

Despite its strengths, the proposed system faces certain limitations. Ensuring the accuracy of real-time data remains a challenge, particularly in complex urban environments. Miscalculations in forced safety mode could lead to unintended consequences, underscoring the need for rigorous validation. Additionally, limitations in sensor coverage and data resolution could hinder performance in diverse conditions. Addressing these issues will be critical for the continued development and deployment of the system.

Key References

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