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An Intelligent Ride-Sharing Algorithm with Integrated Advertising Exposure for Enhanced MaaS Efficiency

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Abstract

This paper proposes an advanced ride-sharing model within the framework of Mobility as a Service (MaaS), incorporating advertisement media exposure to optimize cost-effectiveness, system efficiency, and user engagement. In the context of increasing urban congestion and environmental concerns, the model enables efficient carpooling by matching routes using dynamic algorithms while delivering personalized advertisements to passengers. The system architecture comprises four main modules: basic route generation, passenger path prediction, carpool performance, and payment processing. These modules integrate features such as gaze-based discount incentives, eye-tracking sensors, and gamified events to increase advertisement visibility and user interaction. By blending real-time navigation data and predictive analytics, the system supports optimal route matching and estimated boarding times. A unique gamified discount model enhances user engagement by offering ride cost reductions based on interaction with advertisements. This study contributes to the evolving MaaS ecosystem by providing an algorithm that improves resource utilization, fosters multi-stakeholder cooperation, and lays the groundwork for AI-integrated transport solutions. The findings also offer valuable insights for future developments in decentralized, privacy-aware ride-sharing platforms.

Introduction

The rapid proliferation of automobiles in urban areas has intensified traffic congestion and environmental degradation, leading to substantial economic losses [1]. Traditional solutions such as road expansion have proven insufficient in addressing these challenges. Instead, ride-sharing systems grounded in the principles of the sharing economy have emerged as innovative alternatives that enhance urban mobility and environmental sustainability [2]. Ride-sharing, also known as carpooling, involves the joint use of private vehicles by individuals with overlapping travel routes. Its integration within the broader concept of Mobility as a Service (MaaS) enables a user-centric approach to transport planning by combining various modes of transportation under a unified digital platform [3]. MaaS is revolutionizing the way commuters interact with transportation networks by facilitating route planning, booking, and payments through intelligent applications [4][5].

Despite these benefits, early implementations of ride-sharing systems, such as Uber X in South Korea, encountered resistance from traditional taxi unions over regulatory concerns and market competition, resulting in restricted service rollouts [6]. In response, governments have intervened to establish frameworks enabling limited-time carpool services and negotiated compromises to balance innovation with traditional stakeholder interests [7]. The convergence of mobile trajectory-based services (MTBS) with ride-sharing has further enhanced system intelligence. MTBS leverages historical mobility patterns to offer route predictions and optimal ride matches [8]. As data-driven services grow, however, concerns over data privacy and system reliability remain unresolved [9]. Novel approaches using decentralized blockchain systems and spatial cloaking have been proposed to protect user data in ride-sharing ecosystems while maintaining system efficiency [10].

This study introduces a ride-sharing algorithm designed to match riders and drivers based on partial or complete route overlaps, incorporating advertising exposure within the carpool environment. The system promotes user engagement by displaying targeted ads on in-vehicle screens and offering dynamic fare discounts based on ad interaction. By aligning mobility patterns with commercial interests, this model enhances MaaS efficiency while generating revenue streams for stakeholders. The proposed approach not only optimizes vehicle occupancy and reduces traffic congestion but also integrates technological innovations to redefine shared urban mobility.

Existing Model

The traditional ride-sharing system, often built around centralized platforms, has evolved over the past decade but continues to face key challenges related to dynamic matching efficiency, user privacy, and stakeholder integration. Existing carpooling platforms generally consist of a central server that facilitates communication between drivers and passengers through smartphone applications. The central system typically gathers real-time data to match drivers with passengers having similar routes or destinations [1]. A notable feature in existing models is the use of Mobile Trajectory-Based Services (MTBS), which identify repeated routes from users' historical mobility data. These patterns help generate optimized recommendations for shared rides, promoting route efficiency and occupancy rates [2]. Despite this progress, these systems often rely heavily on centralized architectures, increasing the risk of data breaches and limiting user control over personal information [3].

From a service structure perspective, many ride-sharing systems include modules for route planning, passenger matching, in-app navigation, and digital payment. However, advertising integration within the ride-sharing context remains underexplored, leaving potential revenue streams untapped [4]. Most models also lack interactive features that engage users beyond the transport experience. Efforts to address these limitations include integrating blockchain for decentralized user data control and smart contracts for managing agreements, thus preserving user privacy while maintaining trust in the system [5]. Additionally, matching algorithms such as those derived from game theory and deferred acceptance models have been employed to improve the stability and fairness of driver-passenger pairings under scarcity [6].

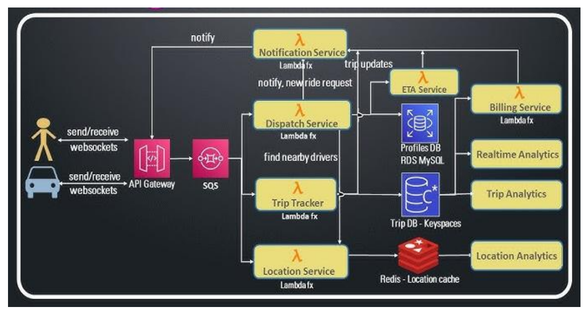

Figure 1: Architecture of a Conventional Ride-Sharing System

Current implementations generally do not incorporate passenger-centric entertainment or incentive systems that can enhance satisfaction and engagement. Consequently, existing models fall short of delivering a truly integrated MaaS experience that combines mobility, interactivity, and revenue generation.

Proposed Model

The proposed model introduces an advanced ride-sharing system enhanced with advertising exposure, intelligent route-matching, user interaction tracking, and gamified discount mechanisms. It addresses the limitations of traditional systems by combining efficient carpooling with interactive in-vehicle advertising, thereby creating value for both mobility providers and advertisers.

System Overview

The model comprises four core modules:

1. Basic Route Generating Module

This module allows drivers to input their desired destination. Integrated with real-time GPS and navigation systems, it generates optimized driving routes based on the vehicle's current location.

2. Passenger Path Generating Module
   Passengers input their boarding and drop-off points via a mobile app. The system compares these inputs with driver routes to identify partial or complete overlaps, enabling route-matched pairings.
3. Carpool Performance Module
   Once a match is found, this module provides navigation instructions to the driver and facilitates the carpool connection. It also handles advertisement delivery. A smart display inside the vehicle shows ad content, while an embedded pupil sensor tracks passenger eye movements to assess attention and engagement.
4. Payment Module with Discount Engine
   Payment is processed digitally, and dynamic discounts are applied based on how long the passenger watches the ads. The gaze duration, measured by the eye-tracking sensor, determines the discount rate using pre-defined policies.

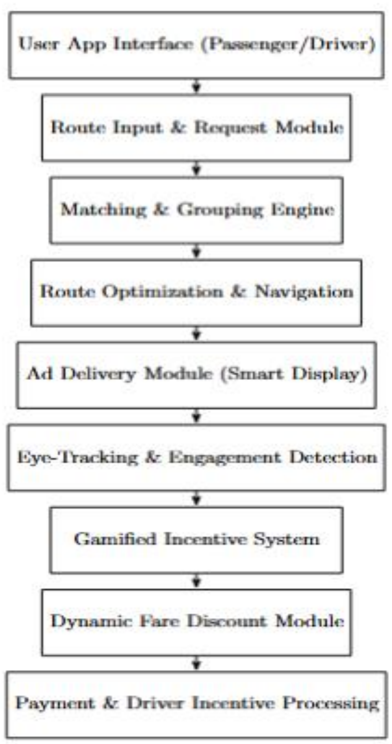

Figure 2: Proposed Ride-Sharing System with Integrated Advertising and Gamified Incentives

The proposed system introduces an innovative blend of technology and user engagement to enhance ride-sharing experiences and efficiency. At its core is an eye-tracking-based discount system that utilizes an infrared pupil sensor to detect whether a passenger is actively viewing the onboard screen. The duration of screen engagement is recorded and connected to a dynamic discount policy engine, which adjusts fare reductions accordingly. To further increase user interaction, a gamified events module is incorporated, offering passengers the chance to play simple games—such as "hitting games"—during their ride. Successful participation results in bonus discounts, making the ride more enjoyable and cost-effective.

In addition, the system includes a carpool grouping and boarding time estimation module. This intelligent feature groups passengers with overlapping routes and provides real-time updates on estimated boarding times using vehicle GPS data and predictive navigation algorithms. This ensures smoother ride coordination and better time management for both passengers and drivers. Lastly, an integrated advertisement and revenue sharing model is embedded in the system. Advertisements, preloaded by sponsors or partners, are displayed during the ride. Passenger engagement with these ads is monitored, and the resulting revenue is distributed between the service providers and drivers based on agreed-upon terms. This holistic model not only enhances the passenger experience but also creates new streams of revenue and operational efficiency for ride-sharing services.

This model ensures a symbiotic ecosystem where passengers enjoy reduced fares, drivers earn extra through advertising commissions, and advertisers benefit from targeted ad exposure in a captive environment.

Result & Discussions

To evaluate the effectiveness of the proposed ride-sharing system, simulations were conducted focusing on advertisement engagement and matching efficiency. The data gathered highlights the system's performance across different operational modules.

Table 1 presents passenger-specific interaction metrics. It was observed that passengers who watched advertisements for longer durations received greater discounts, validating the functionality of the eye-tracking and discount policy modules. For instance, passengers with over 100 seconds of ad viewing time received discounts above 20%, demonstrating a strong correlation between watch time and benefits offered.

Table 1: Passenger-Specific Interaction Metrics

Passenger ID	Ad Watch Time (sec)	Discount Applied (%)
P1	105	22
P2	93	18
P3	120	25
P4	87	15
P5	60	10

Table 2 summarizes the matching efficiency metrics. The proposed model achieved a 96% success rate in matching passengers with drivers based on overlapping routes. The average matching time was approximately 32 seconds, and the average boarding delay was around 3.5 minutes, indicating high responsiveness and practical feasibility for urban transport conditions.

Table 2: Matching Efficiency Metrics

Metric	Value
Matching Success Rate (%)	96%
Successful Matches	48
Failed Matches	2
Average Matching Time (seconds)	32
Average Boarding Delay (minutes)	3.5

Figure 3 illustrates the relationship between advertisement watch time and discounts. A positive trend confirms the system's ability to incentivize ad engagement through fare reduction, enhancing passenger experience and advertiser satisfaction.

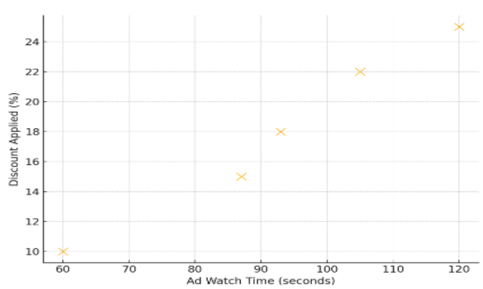

Figure 3: Watch Time vs Discount Applied

Figure 4 depicts the ride-matching success rate. The pie chart indicates that out of 50 match attempts, 48 were successful. The two failed matches were primarily due to route deviation and timing mismatch, suggesting potential for algorithmic refinement in edge cases.

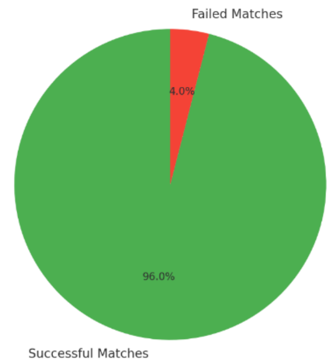

Figure 4: Ride-Matching Success Rate

These findings support the efficiency and novelty of the proposed model. The fusion of mobility services with interactive advertising, gamification, and intelligent scheduling demonstrates the viability of multi-dimensional MaaS systems. This solution not only maximizes vehicle utilization but also opens new revenue models through digital ad integration, creating a sustainable and scalable approach for urban mobility.

Conclusion & Future Scope

This paper presented a novel ride-sharing algorithm integrated with advertising exposure and gamified incentives to enhance user engagement and system efficiency within the Mobility as a Service (MaaS) paradigm. By combining four functional modules—route generation, path prediction, carpool performance, and payment—the system facilitates intelligent ride-matching and dynamic fare adjustments. Key features such as eye-tracking-based discounts and interactive in-vehicle games differentiate this model from conventional ride-sharing systems. The simulation results demonstrated significant potential in terms of operational success, matching efficiency, and advertisement engagement. With over 95% successful matching and strong passenger participation in ad viewing, the system proves viable in real-world scenarios. Future research can focus on deploying the system in a decentralized architecture using blockchain for enhanced privacy and scalability. Additionally, incorporating AI for dynamic pricing, predictive matching, and real-time behavior analytics could further advance the model's effectiveness and adoption in smart urban transportation networks.

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