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AI-ENABLED CAMPUS BIKE POOLING FRAMEWORK FOR SUSTAINABLE TRANSPORTATION

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Abstract

In recent years, the number of personal vehicles used by college students has increased significantly, especially two-wheelers such as bikes and scooters. While these vehicles provide convenience and flexibility, they also contribute to heavy traffic congestion near campuses, increased fuel expenses for students, and higher levels of carbon emissions. In many cases, students travel from similar residential areas at nearly the same time each day, yet they use separate vehicles instead of sharing rides. This results in unnecessary fuel consumption, parking space issues, and environmental impact. Although commercial ride-sharing platforms exist, they are mainly designed for large-scale urban transportation and do not specifically address the structured and predictable commuting patterns found in academic institutions.

This research review paper explores the potential of developing an Artificial Intelligence (AI)-enabled bike pooling system designed specifically for college campuses. The study examines existing research on intelligent transportation systems and highlights how machine learning techniques such as clustering algorithms, route optimization methods, and demand prediction models can improve ride matching efficiency. By analyzing user location data and travel schedules, an AI system can intelligently group students traveling along similar routes and at similar times. The paper also discusses practical considerations such as safety, trust, privacy protection, and real-time coordination between users.

A conceptual framework is proposed that integrates institutional identity verification, geolocation services, smart ride matching, and an analytics dashboard to estimate fuel savings and carbon emission reduction. The findings suggest that a structured, AI-driven bike pooling system can reduce traffic congestion around campuses, lower transportation costs for students, and promote environmentally responsible commuting habits. This study emphasizes that technology-driven mobility solutions can play an important role in building sustainable and smart campus ecosystems.

Keywords: *Artificial Intelligence (AI), Bike, Pooling, Sustainable Transportation.*

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1. Introduction

Every day, without realizing it, hundreds of students make the same journey in separate vehicles, along the same roads, at almost the same time. What seems like a normal daily routine quietly contributes to traffic congestion, rising fuel costs, and increasing environmental impact. A small change in coordination could transform this everyday pattern into a smarter and more sustainable system. This research begins with a simple question: *What if students who travel from nearby areas could connect, share, and commute together using intelligent technology?* By exploring this idea, the study aims to reimagine campus transportation through the power of Artificial Intelligence in a way that is practical, safe, and environmentally responsible.

1.1 Background and Motivation

Every morning, college campuses present a familiar scene—hundreds of students arriving individually on their bikes and scooters, often at the same time and from nearby areas. This leads to traffic congestion near campus gates, crowded parking spaces, and unnecessary fuel consumption. In countries like India, two-wheelers are a common and affordable mode of transport for students, but when most choose to travel alone despite having similar schedules and routes, it creates avoidable traffic and environmental impact. Although ride-sharing applications exist, they are mainly designed for large cities and commercial use, not for structured and secure environments like college campuses. This gap between daily commuting patterns and the lack of coordination creates the motivation for this study.

1.2 *Need for Sustainable Campus Transportation*

When hundreds of vehicles enter a campus daily, the combined fuel usage and carbon emissions become significant. Even a small reduction in the number of vehicles through organized pooling can lower traffic density, reduce pollution, and ease parking pressure. Sustainable campus transportation is not only environmentally beneficial but also economically helpful for students by reducing fuel and maintenance costs. Therefore, improving commuting systems within educational institutions can positively impact both students and campus management.

1.3 Overview of the Proposed Approach

With the advancement of Artificial Intelligence and Machine Learning, it is possible to design systems that intelligently analyze travel patterns and match students efficiently. By using basic information such as location and class schedules, an AI-based system can group students traveling along similar routes and times. This study proposes a simple, secure, and campus-specific bike pooling framework that focuses on efficiency, safety, and sustainability within a trusted academic network.

2. Literature Review

Transportation systems have evolved significantly with the growth of digital platforms and Artificial Intelligence. Researchers have explored how smart mobility solutions can reduce congestion, improve travel efficiency, and optimize resource usage. Ride-sharing applications are one of the most visible outcomes of this transformation, using GPS, mobile connectivity, and intelligent algorithms to connect users in real time. However, most existing systems are designed for large urban areas and are not specifically tailored for structured environments like college campuses.

2.1 Ride-Sharing and Machine Learning in Mobility

Studies show that machine learning plays a crucial role in improving ride-sharing efficiency. Clustering algorithms such as K-Means are commonly used to group users based on location, enabling effective ride matching. Route optimization techniques help identify shorter and fuel-efficient paths, while predictive models are used to estimate peak travel demand. These technologies reduce travel time and fuel consumption. Despite their effectiveness in city-level transportation, their application in smaller, predictable ecosystems like campuses remains limited.

2.2 Environmental and Safety Considerations

Research also highlights the environmental benefits of pooling systems. Fewer vehicles on the road lead to lower fuel usage and reduced carbon emissions, which is especially impactful in short-distance commuting environments such as colleges. At the same time, user trust and safety are critical factors. Studies emphasize the importance of identity verification, feedback systems, and secure platforms to increase user confidence. Since most public ride-sharing platforms operate in open networks, there is strong potential to develop a safer, campus-specific pooling system within a controlled academic environment.

3. Problem Statement

In most college campuses today, a large number of students commute daily using their personal two-wheelers. Although many of them travel from nearby residential areas and attend classes at similar time intervals, they commute individually instead of sharing rides. This leads to unnecessary fuel consumption, traffic congestion near campus gates, parking shortages, and increased carbon emissions. Over time, this pattern creates both economic and environmental challenges.

Existing ride-sharing platforms are primarily designed for large-scale urban transportation and commercial use. They operate in open public environments and do not consider structured commuting patterns found in academic institutions. These platforms do not integrate student schedules, institutional identity verification, or locality-based clustering tailored for campus communities. As a result, they are not fully suitable for organized and secure bike pooling within college ecosystems.

Despite advancements in Artificial Intelligence and intelligent transportation systems, there is currently a lack of a dedicated AI-enabled bike pooling framework specifically designed for closed academic environments. The absence of such a system prevents efficient ride matching, optimized route planning, and structured sustainability tracking within campuses.

Therefore, the core problem addressed in this study is the need to design a smart, safe, and efficient AI-based bike pooling system that leverages predictable student travel patterns, institutional verification, and intelligent matching algorithms to reduce fuel consumption, traffic congestion, and environmental impact in college campuses.

4. Objectives of the Study

The main objective of this study is to explore how Artificial Intelligence can be used to improve transportation within college campuses through a structured bike pooling system. The research aims to propose a conceptual AI-enabled framework that can intelligently match students based on their location and travel time using techniques such as clustering and route optimization. The goal is to reduce traffic congestion, fuel consumption, and carbon emissions while maintaining safety and trust within a campus network. In addition, the study seeks to review existing ride-sharing systems, understand their limitations in campus settings, analyze suitable machine learning approaches, evaluate environmental and economic benefits, identify challenges like privacy and safety concerns, and suggest future improvements to make the system more practical and scalable.

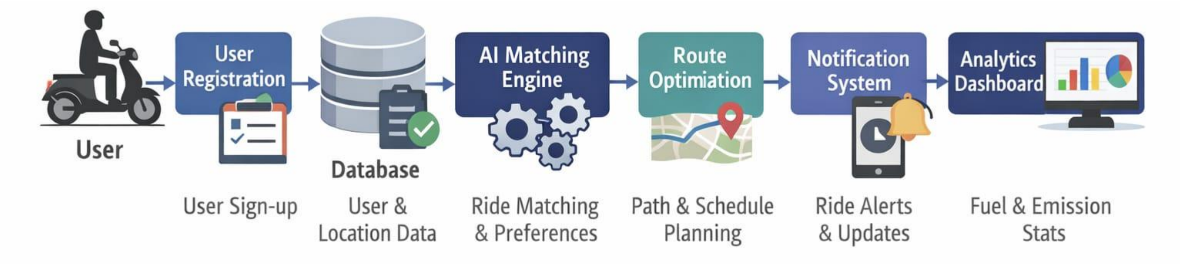
5. Proposed AI-Based Bike Pooling Framework

This section presents a conceptual AI-enabled bike pooling framework designed specifically for college campuses. Unlike commercial ride-sharing platforms, the proposed system focuses on predictable student schedules, verified institutional identities, and localized commuting patterns. The framework aims to ensure intelligent ride matching, safety, and sustainability within a closed academic ecosystem.

5.1 System Overview

The proposed system is developed as a mobile and web-based platform integrated with the college database. Students register using their institutional credentials, ensuring that only verified campus members can access the system. During registration, users provide essential details such as residential location, preferred travel time, and vehicle availability.

Using this structured data, the AI engine analyzes commuting patterns and suggests suitable ride matches. The primary objective is to reduce unnecessary vehicle usage while maintaining convenience, efficiency, and security for students.



5.2 AI-Based Ride Matching and Route Optimization

The core of the framework is the AI-driven matching engine. Machine learning techniques such as clustering algorithms (e.g., K-Means) are used to group students based on geographical proximity. These groups are further filtered according to time compatibility to ensure efficient rider-passenger pairing.

Once matches are finalized, route optimization algorithms calculate the shortest and most fuel-efficient path. If real-time traffic data is available, the system can dynamically adjust routes to avoid congestion. This combined approach minimizes travel distance, reduces waiting time, and improves overall commuting efficiency.

5.3 Safety and Trust Mechanism

Safety is a critical component of the system. Since the platform operates within a verified academic network, institutional authentication ensures that only registered students participate. Additional trust-building features include ride history tracking, a feedback system, and emergency alert functionality.

By maintaining a closed and monitored environment, the system enhances user confidence and encourages wider adoption among students.

5.4 Sustainability and Analytics Dashboard

An integrated analytics dashboard tracks system performance and environmental impact. The platform estimates fuel savings, reduction in carbon emissions, and overall participation rates based on shared rides.

These insights help create awareness about sustainable commuting and allow institutions to measure the environmental benefits of the pooling system over time.

5.5 Mathematical Model for Optimization

To enhance the technical foundation of the proposed AI-enabled bike pooling framework, a mathematical model is formulated. The purpose of this model is to group nearby students, match compatible travel times, and estimate fuel and emission savings.

5.5.1 Distance Calculation for Grouping Students

Each student's home location can be represented using coordinates:

Student i = (x1, y1)

Student j = (x2, y2)

The distance between two students is calculated using:

Distance = $\mathrm{sqrt}((x1 - x2)^2 + (y1 - y2)^2)$

This helps the system identify students who live close to each other. Students with smaller distances between them are grouped together.

5.5.2 Time Compatibility Condition

Let:

Ti = travel time of student i

Tj = travel time of student j

Two students can be matched if:

|Ti - Tj| ≤ 15 minutes

This ensures that students sharing a ride have similar departure times.

5.5.3 Route Optimization

The road network can be represented as:

G = (V, E)

Where:

V = locations

E = roads connecting locations

The system selects the route with minimum total distance:

Minimum Travel Distance = sum of road distances in selected path

This reduces fuel usage and travel time.

5.5.4 Fuel Saving Estimation Model

Let:

N = total number of students

r = percentage of students using pooling

D = average distance travelled (km)

F = fuel consumption per km

Fuel used without pooling:

Fuel-without = N × D × F

Fuel used with pooling:

Fuel-with = (1 - r) × N × D × F

Fuel saved:

Fuel-saved = r × N × D × F

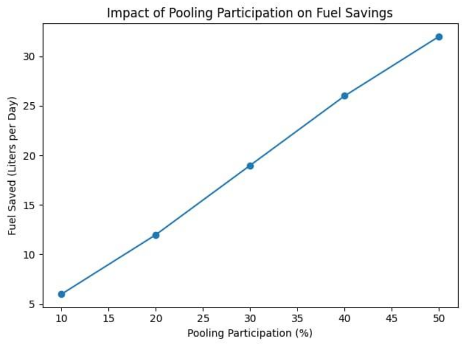


Figure illustrates that fuel savings increase proportionally with higher pooling participation rates. This indicates that even moderate adoption levels can lead to significant reductions in fuel consumption.

5.5.5 Carbon Emission Reduction

If 1 litre of petrol produces approximately 2.31 kg of CO_2:

CO_2 Reduction = Fuel-saved × 2.31

This helps estimate the environmental benefit of the system.

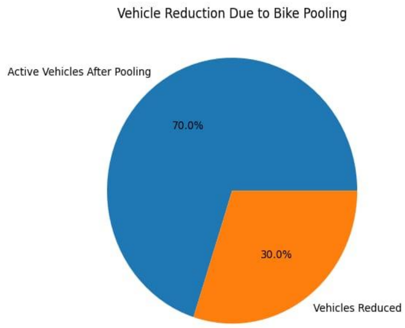


Figure represents the percentage distribution of active vehicles and reduced vehicles after implementing the pooling system. A 30% adoption rate significantly decreases the number of vehicles entering campus.

6. Methodology

This study adopts a conceptual and review-based methodology focused on analyzing existing intelligent transportation research and designing a structured AI-enabled bike pooling framework for college campuses. Instead of implementing a working prototype, the approach emphasizes understanding established machine learning techniques and adapting them logically to a campus environment.

6.1 Data Collection and Analysis Approach

The research relies primarily on secondary data from academic journals, conference papers, and published studies related to ride-sharing systems, intelligent transportation, clustering techniques, and route optimization models. These sources were examined to understand how AI is currently used in mobility solutions.

In addition, common commuting patterns observed in college environments—such as predictable class schedules, residential clusters, and peak travel hours—were conceptually analyzed. These real-world observations helped shape a campus-oriented pooling framework.

6.2 Algorithm Selection and System Design

The selection of algorithms is based on practicality, efficiency, and scalability. Clustering techniques such as K-Means are chosen for grouping students by geographical proximity, as they are simple and computationally efficient. For route optimization, graph-based shortest path algorithms are preferred due to their reliability in minimizing travel distance and fuel usage.

Basic predictive models may also be incorporated to estimate peak travel demand. The overall system design focuses on real-time feasibility and adaptability within a campus-scale network.

6.3 System Workflow and Performance Considerations

The workflow begins with student registration and secure storage of location and schedule data. The AI engine then groups users based on proximity and filters matches according to time compatibility. Once a match is confirmed, the route optimization module calculates the most efficient travel path, and users are notified accordingly. Post-ride feedback is recorded to improve future matching accuracy.

Performance evaluation would consider matching efficiency, reduction in vehicle usage, fuel savings, and system response time. Since campus travel distances are relatively short and schedules are predictable, the system is expected to operate with manageable computational load. Scalability and real-time responsiveness remain key design considerations.

7. Challenges and Limitations

While the proposed AI-enabled bike pooling framework offers significant advantages, certain challenges and limitations must be acknowledged. Identifying these factors is important to ensure realistic expectations and practical implementation.

One of the primary challenges is data privacy. The system requires access to user location and schedule information, which may raise concerns among students. Ensuring secure data storage, encryption, and transparent data usage policies is essential to build trust. Without strong privacy protection measures, user adoption may be affected.

Another important concern is safety and gender sensitivity. Although institutional verification increases security, some students may still hesitate to share rides. Special consideration must be given to safety mechanisms such as verified profiles, ride history tracking, and emergency alert features. Building a strong trust environment is critical for the success of the platform.

The effectiveness of the system also depends heavily on user participation and adoption. If only a limited number of students use the platform, ride matching efficiency may decrease. Encouraging active participation through awareness campaigns or incentives will be necessary for long-term sustainability.

Additionally, legal and policy-related constraints may arise. Issues such as liability in case of accidents, insurance coverage, and institutional responsibility must be clearly defined before large-scale deployment. These factors may require administrative approval and regulatory compliance.

Finally, since this study is conceptual and review-based, it does not include real-world implementation or experimental validation. Practical deployment may reveal technical or behavioral challenges that are not fully captured in theoretical analysis.

8. Future Scope

The proposed AI-enabled bike pooling system has strong potential for further improvement and real-world implementation. In the future, the platform can be enhanced by introducing stronger verification methods and clearer safety features so that students feel more comfortable and secure while sharing rides. Adding simple reward systems, such as points or recognition for frequent users, can encourage more participation and build a culture of sustainable commuting on campus. The system can also be connected with campus traffic and parking management to reduce congestion near entry gates and improve space utilization. If successfully implemented in one institution, the model can gradually be expanded to other colleges and universities, creating a wider network of eco-friendly student transportation systems. With continuous development and institutional support, this framework can evolve into a practical and impactful mobility solution for academic communities.

9. Conclusion

This study highlights the need for smarter and more sustainable transportation solutions within college campuses. Every day, a large number of students travel individually from nearby areas, leading to unnecessary traffic congestion, fuel consumption, and environmental impact. Although technology has transformed urban mobility, campus-specific pooling systems remain largely unexplored.

The proposed AI-enabled bike pooling framework demonstrates how simple machine learning techniques and structured data can be used to improve commuting efficiency in academic institutions. By grouping students based on location and schedule, optimizing routes, and ensuring safety through verified identities, the system offers a practical and secure solution tailored specifically for campus environments.

Beyond reducing fuel costs and traffic congestion, the framework also promotes environmental responsibility among students. It encourages a shift from individual commuting to collaborative and sustainable travel habits. While the study is conceptual in nature, it lays a strong foundation for future implementation and real-world testing.

With proper institutional support and student participation, an AI-based bike pooling system has the potential to transform everyday commuting into a smarter, safer, and more eco-friendly practice. This approach not only improves campus mobility but also contributes to building greener and more responsible academic communities.

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