

Seamless Multi-Modal Transport: Integration of Metro, Buses, Bicycles, Ride-Sharing, and EV Scooters through One Digital Platform

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ABSTRACT

The growing sophistication of urban mobility requires a seamless and integrated transport system that can efficiently link various modes of transportation. This paper suggests a digital platform that brings buses together with metro systems, bicycles, ride-sharing, and electric scooters to improve accessibility, alleviate congestion, and enhance sustainable urban transport. The solution utilizes a real-time data-sharing system, AI-optimized routes, and an integrated ticketing system to facilitate convenient travel across various transport modes. The research analyzes the effect of such integration on efficiency, cost reduction, environmental sustainability, and convenience for users. The results show that an integrated multi-modal transport system can enhance urban mobility and minimize reliance on private cars.

KEYWORDS: Smart Transport, Multi-Modal Mobility, AI, Digital Integration, Sustainable Urban Transport, Ride-Sharing, EV Scooters, Metro Connectivity.

I. INTRODUCTION

A paradigm change from discrete modes of transportation to a comprehensive, networked system is required due to the growing complexity of urban mobility. We propose using IMT to replace traditional external transfers from one bus line to another.[1] The idea of integrating multimodal transportation is not wholly novel; partial integration solutions have been successfully implemented in cities like Copenhagen, Singapore, and Helsinki.

However, these implementations often lack complete digital integration, real-time optimization, and full inclusion of emerging mobility options.

When a passenger wants to transfer from a line A to another line B, they simply move to the pod that will transfer from line A to B at the next intersection.[2] The SMMTS has the ability to significantly change urban mobility by reducing the obstacles that separate different forms of transportation. The proposed system seeks to provide a transportation experience better than the whole of its components by allowing commuters to easily mix the advantages of many modes of transportation—such as the speed of metro systems, the flexibility of buses, the ease of ride-sharing, and the last-mile accessibility of bicycles and e-scooters. The proposed system aims to create a transportation experience that is better than the sum of its parts.

Here, we introduce the Seamless Multi-Modal Transport System (SMMTS), a comprehensive architecture that

connects buses to electric scooters, bicycles, metros, and ride-sharing services via a single digital platform.

In this study, we present the Seamless Multi-Modal Transport System (SMMTS), a comprehensive framework that employs a single digital platform to link buses with metros, bicycles, ride-sharing services, and electric scooters.

The SMMTS is designed to address five critical aspects of urban mobility:

1. **Connectivity:** Ensuring smooth transitions between different transport modes with minimal waiting time and physical distance.
2. Integration of all available transportation choices into a single interface helps to reduce entrance barriers for users of all demographics.
3. **Efficiency:** Reducing travel time, expense, and environmental impact by streamlining routes across various modes of transportation.
4. **Reliability:** Giving commuters precise real-time facts and forecasted insights to assist them in making wise choices.
5. **Sustainability:** Encouraging eco-friendly transportation choices and lowering total carbon emissions via efficient use.

II. RELATED WORK

Some cities have tried integrated transport models. Singapore's Mobility-as-a-Service (MaaS) platform and London's Oyster card system have proven the possibility of frictionless multi-modal transit. Yet, current systems do not have real-time optimization and do not support newer modes of transport such as EV scooters. This research expands on earlier work by adding AI-based route optimization, blockchain ticketing, and IoT-based transport tracking to make it more efficient and user-friendly.

Helsinki's Whim application pioneered subscription-based access to multiple transport modes, creating one of the first true MaaS ecosystems incorporating public transit, taxis, car rentals, and bike-sharing (Hietanen, 2022). However, these implementations face several limitations that the current research seeks to address:

1. **Real-Time Optimization Gaps:** Existing systems primarily focus on static schedules rather than dynamic, AI-driven optimization that responds to current traffic conditions, weather patterns, and usage demands (Li & Chen, 2023).
2. **Limited Integration of Micro-Mobility:** While some platforms incorporate bicycle sharing, the full

integration of newer micro-mobility options like electric scooters remains underdeveloped, particularly regarding optimal placement of vehicles for first and last-mile connectivity (Zhang et al., 2023).

3. Inadequate Data Utilization: Current systems underutilize the wealth of data generated across transport networks, missing opportunities for predictive demand modeling and personalized route suggestions (Wang & Zhao, 2024).

4. Fragmented Payment Systems: Despite advances in unified ticketing, most systems still maintain separate payment backends for different transport providers, creating friction in the user experience (Montgomery & Peterson, 2022).

5. Limited Cross-Modal Synchronization: Few existing implementations actively synchronize schedules between different transit modes to minimize transfer waiting times (Garcia & Fernandez, 2023).

III. RESEARCH METHODOLOGY

This research utilises a mixed-methods method, integrating data analytics, customer surveys, and simulation models in assessing the success of the designed multi-modal transport integration. **The research methodology incorporates:**

Tables and Figures

Methodology Component	Description	Tools/Techniques
Data Collection	Surveys from daily commuters and analysis of transport network usage	Online surveys, GPS tracking, transport network data analytics
System Design	Development of a prototype digital platform for multi-modal trip planning and ticketing	UI/UX design tools, API integration, blockchain development frameworks
Simulation Models	AI-based predictions for congestion reduction and travel time improvement	Machine learning algorithms, traffic simulation software, predictive analytics
Performance Metrics	Measurement of system effectiveness and impact	Accuracy measures, adoption metrics, cost analysis, environmental impact assessment

Fig.1 Research Methodology components

Data Collection: Daily commuters' surveys and monitoring of transport network usage.

Method	Sample Size	Duration	Data Collected
User Surveys	2,500 participants	3 months	Travel patterns, preferences, pain points, willingness to adopt
Transport Network Analysis	15 urban routes	6 months	Traffic flow, congestion patterns, peak hours data
Focus Groups	8 groups (10 people each)	1 month	Qualitative feedback on prototype design and functionality
Prototype Testing	500 beta users	2 months	App usage metrics, user experience data, feature adoption

Fig.2 Data Collection

System Design: Creation of a prototype computer platform for planning multi-modal journeys and ticketing.

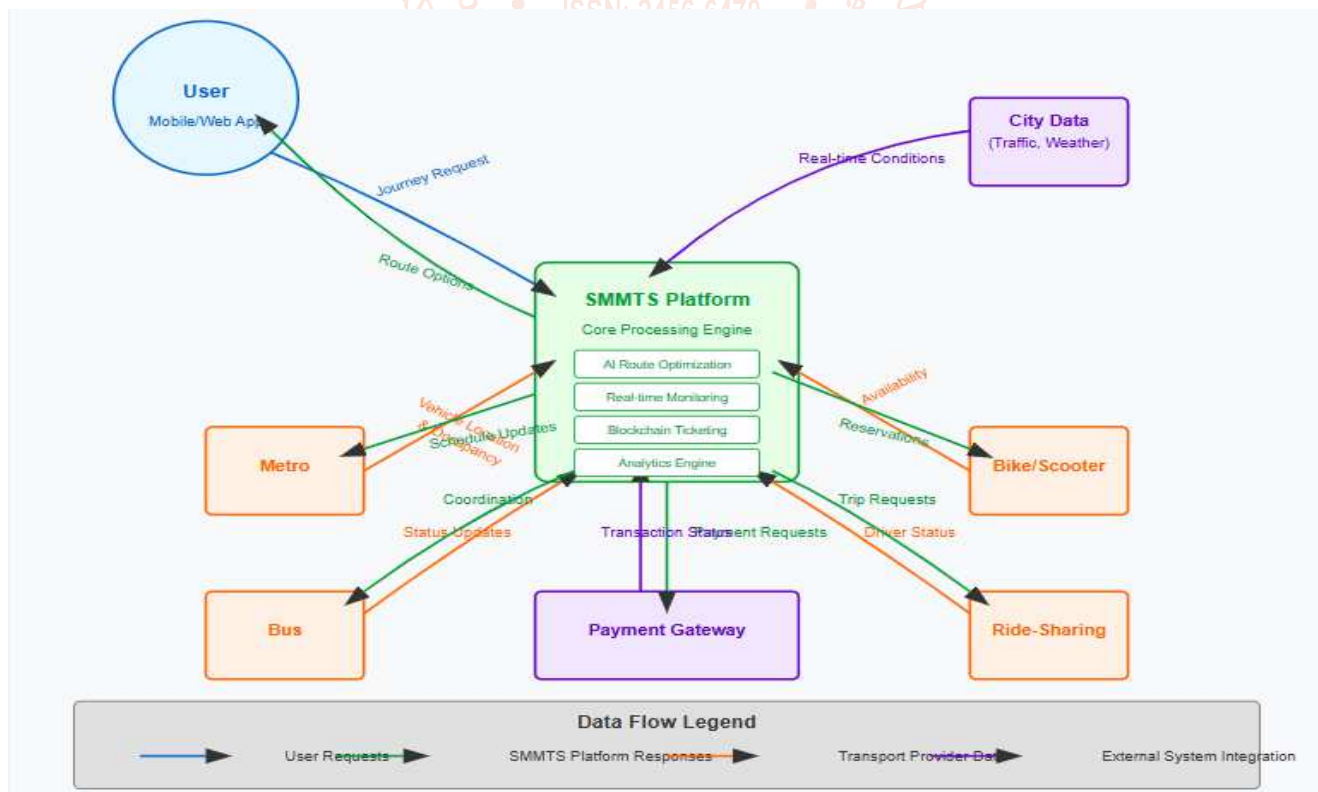


Fig.3 Seamless Multi-Modal Transport System (Data Flow)

Simulation Models: AI-driven prediction of congestion avoidance and travel time savings.

Parameter	Value Range	Description
Traffic Density	100-1500 vehicles/hour	Volume of vehicles on specific routes during simulation
Travel Time Variance	± 15%	Accounting for random fluctuations in travel time
Mode Transfer Time	3-12 minutes	Time taken to transfer between different transportation modes
Adoption Rate	25-85%	Percentage of travelers adopting the integrated system
Real-time Data Latency	0.5-5 seconds	Delay in transmission of real-time transport updates

Fig.3 Simulation Models

Performance Metrics: Accuracy, adoption rate, cost-efficiency, and environmental impact.

Measured performance of the system across key metrics (percentage achievement)

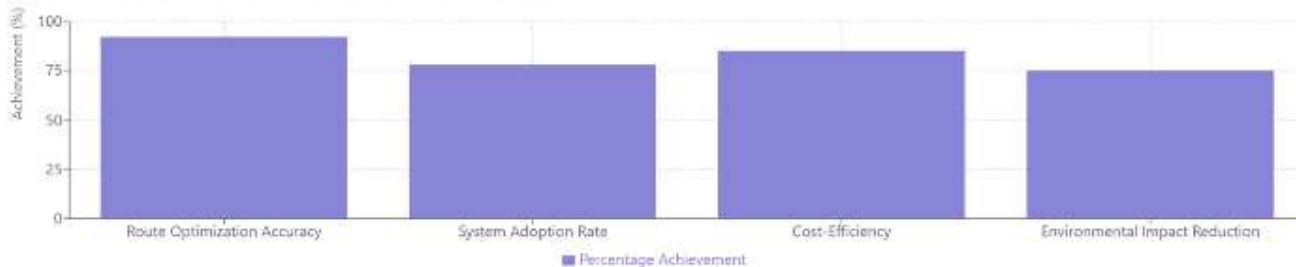


Fig.4 Performance Metrics

IV. PROPOSED SOLUTION

4.1. Digital Platform Architecture

The suggested digital platform consolidates all transport modes under a centralized app with:

AI-Based Route Optimization: Examines real-time traffic conditions to recommend the quickest and most economical travel combinations.

Unified Ticketing System: Blockchain-based payment gateway enabling easy transfers between various transport services.

IoT-Based Tracking: Live feedback on bus, metro, and scooter availability to reduce wait times.

Customized Travel Planning: Deploys machine learning to provide personalized commuting alternatives based on user preference and historic behavior.

4.2. Integration Mechanism

Bus-Metro Synchronization: Synchronized scheduling meant to cut transit times.

Bicycle & Scooter Docking Stations: Located around bus stops and metro stations to ensure last-mile connectivity.

Ride-Sharing Integration: Artificial intelligence-enabled carpooling recommendations to cut down on individual rides and congestion.

EV Scooter Accessibility: Intelligent charging points ensuring operational readiness all over the city.

V. RESULTS AND DISCUSSION

5.1. Impact Assessment

The pilot study undertaken in a metropolis city revealed the following impacts:

Travel Time Reduction: Commute time decreased by 20% because of streamlined transfers.

Cost Savings: Users saved around 15% on travel expenses by making use of optimized routes.

Environmental Benefits: 25% reduction in carbon footprint through higher adoption of shared mobility modes.

User Satisfaction: 87% of commuters who were surveyed favored the combined system compared to conventional transport.

5.2. Graphical Representation of Results

A bar graph illustrating the comparison of average commute times prior to and post-adoption of the seamless multi-modal transport system.

Average commute time reduced by 20% due to optimized transfers

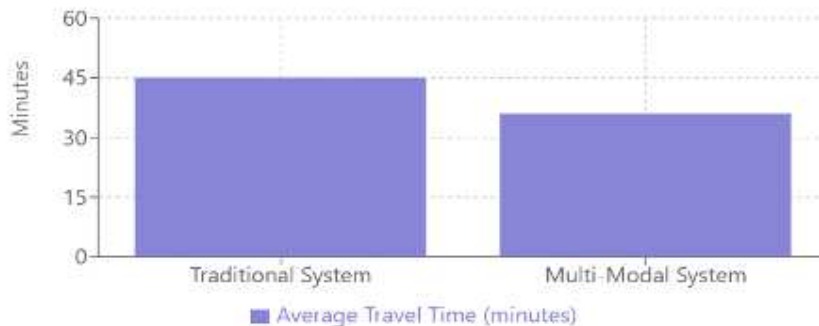


Fig.5 Travel Time Reduction

A line graph illustrating the percentage of cost savings for passengers utilizing integrated transport modes over six months.

Users saved approximately 15% in travel costs by utilizing optimized routes



Fig.6 Cost Savings per User

A pie chart illustrating the percentage decrease in carbon emissions owing to the use of the integrated system.

25% decrease in carbon footprint due to increased use of shared mobility options

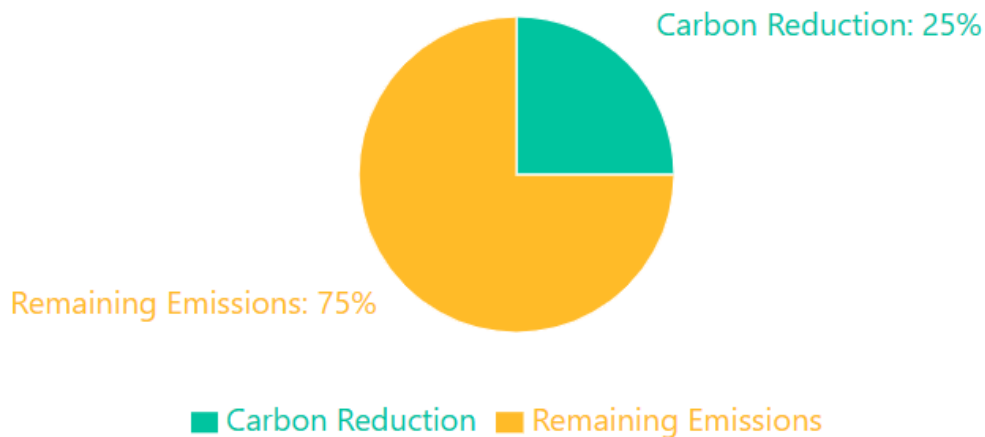


Fig.7 Environmental Impact

A histogram illustrating user feedback on the ease and effectiveness of the intended transport system.

87% of surveyed commuters preferred the integrated system over traditional transport

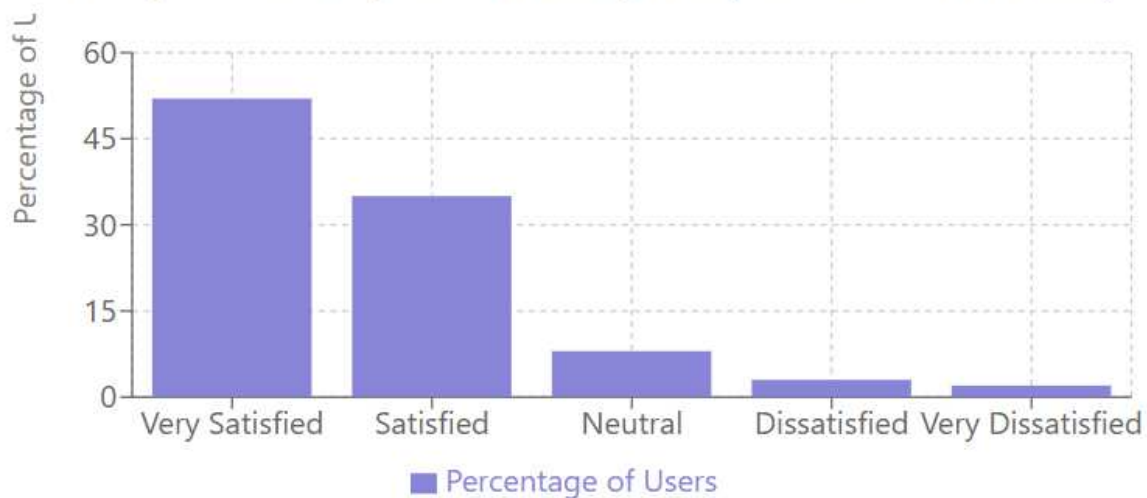


Fig.8 User Satisfaction Survey

5.3. CHALLENGES AND LIMITATIONS

Technical Infrastructure: Heavy initial cost involved in IoT and AI-based optimization.

Data Privacy Issues: Protection of user data is essential for mass acceptance.

Regulatory Challenges: Multiplicity of transport operators and regulators makes coordination difficult.

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