[An Incentive Based Dynamic Ride-Sharing System for Smart Cities](https://www.researchgate.net/publication/351077202_An_Incentive_Based_Dynamic_Ride-Sharing_System_for_Smart_Cities)

The research paper discusses a ride-sharing system based on incentives for both passengers and drivers. The objective is to reduce the number of private vehicles on urban roads by utilizing the available seats effectively. A mobile-cloud architecture-based system has been developed, enabling real-time ride-sharing. The effectiveness of the proposed system has been evaluated through microscopic traffic simulation using the Simulation of Urban Mobility (SUMO), considering the traffic flow behavior of a real smart city. Moreover, a lab-scale experimental prototype has been developed in the form of an Internet of Things (IoT) network.

**Research Questions:-**

The paper answers the following questions:-

1. How can an incentive-based (point reward) dynamic ride-sharing system be developed to address traffic congestion in a smart city?
2. What factors contribute to the effectiveness of the proposed ride-sharing system in reducing the number of private cars on the road?
3. How does the proposed ride-sharing system impact fuel consumption, CO2 and CO emissions, average speed, and waiting time in comparison to traditional transportation systems?

**Study Methodology:-**

1. **Problem Identification**: Recognizing challenges associated with traffic congestion and proposing an incentive-based ride-sharing solution. The annual cost of traffic

congestion in 471 urban areas in the U.S. in terms of extra travel time and fuel are estimated to be approximately **160 billion USD** in 2015. Furthermore, transportation contributes about **29%** of the total U.S. greenhouse gas (GHG) emissions.

1. **System Proposal**: Developing a dynamic ride-sharing system based on incentives, focusing on encouraging car occupancy and reducing the number of cars on roads. After completing a trip, both drivers and passengers will receive mutual benefits in the form of point rewards rather than monetary compensation. However, a restriction is imposed on the incentive system to prevent drivers from earning excessive reward points by offering too many rides. The goal is to encourage people to share their private vehicles to alleviate traffic congestion, rather than promoting the system as an alternative source of income for drivers. For the incentive system, the point rewards are computed based on the following criteria:-

• Base point Pb—point to be charged for taking a successful ride;

• Point per minute Pt—point to be charged for every minute of travel within the ride;

• Point per km Pd—point to be charged for every km of travel within the ride;

• Traffic scaling factor Fts—a factor that regulates reward point depending on traffic

condition and time, e.g., traffic congestion during peak hours;

• Passenger(s) scaling factor Fps—a factor that regulates reward point according to

the number of passenger(s) in each vehicle.

Hence, the point to be charged per rider Pcharge is calculated as

Pcharge = Fps(Pb + tPt + dPd)Fts

where t is the travel time and d is the travel distance. The points to be earned by a driver

Pearn is calculated as

Pearn => n=Nr

∑ Pcharge

n=1

where Nr denotes the number of riders sharing the same vehicle. The value of Fps decreases as the number of passengers sharing the same vehicle increases. The purpose is to restrain drivers from earning excessive reward points as the main goal of the proposed ride-sharing system is to overcome traffic congestion rather than creating new job opportunities.

1. **Simulation Model**: Utilized the microscopic traffic simulation software SUMO to evaluate the proposed system's performance in a virtual smart city environment. A model of the multi-lane traffic network of Sunway City is built in SUMO. The traffic flow

in the network is varied from moderate to congested, imitating the real traffic scenario of the city.

1. **Experimental Prototype**: Creating a lab-scale prototype with Arduino Mega 2560

controlled small-scale connected autonomous vehicles (AVs), wireless communication, and a central control system to validate the proposed algorithm in a controlled environment. NodeMCU is installed in every vehicle and connected to Arduino to act

as data transmitter and receiver. On top of each vehicle, an AprilTag is used for localization.

1. **Performance Evaluation**: Conducting simulations to measure the impact of the ride-sharing system on fuel consumption, emissions, average speed, and waiting time.
2. **Discussion**: Analyzing the benefits and limitations of the proposed ride-sharing system, comparing it with existing models, and addressing future challenges.
3. **Results and Conclusion**: Presenting the simulation results and concluding the paper with insights into the potential effectiveness of the proposed system.

**Findings:-**

**Simulation Results:-**

* It is found that the total fuel consumption of the traditional transportation system without ride-sharing is 16.10 L. And in the best case when 10% riders (out of 20% users) are using the ride-sharing system, the total fuel consumption is reduced by 16.40% compared to the traditional transportation system without ride-sharing.
* It is noted that the total CO2 emission of the traditional transportation system without ride-sharing (case 1) is 38.06 kg, whereas the total CO2 emission of the ride-sharing system for the best case is 32.29 kg.
* It is revealed that the average speed of cars for the best case is 23.61 km/h, which resulted in 11.74%, compared to the traditional transportation. A notable improvement has been achieved in the average speed due to reduction of traffic congestion by the proposed ride-sharing system.
* Finally, it is observed that using the incentive based ride-sharing service, a person can save approximately $9.07 per month.

**Pros:**

**Reduced Fuel Consumption**: The proposed system shows a significant reduction in total fuel consumption, contributing to potential cost savings.

**Environmental Benefits**: Lower CO2 and CO emissions demonstrate the system's positive environmental impact, aligning with sustainability goals.

**Improved Traffic Flow**: Average speed improvements suggest a potential reduction in traffic congestion, enhancing overall traffic flow.

**Realistic Prototype**: The lab-scale experimental prototype demonstrates the practical feasibility of the proposed ride-sharing system.

**Incentive Mechanism**: The point reward-based incentive system balances economic benefits, encouraging user participation without causing excessive rides.

**Cons:**

**User Participation Dependency**: The effectiveness of the system relies on a certain percentage of users joining, raising concerns about initial adoption.

**Privacy and Security Issues**: The paper acknowledges that privacy and security concerns need to be addressed, which may pose challenges in motivating and attracting users.

**Simplified Simulation Scenario**: The simulation is conducted in a simplified scenario, and real-world implementation may yield different results.

**Limited Prototype Scale**: The lab-scale prototype does not fully represent the complexities and challenges of a full-scale smart city implementation.

**Future Work Required**: The study identifies the need for further optimization based on real-world data and emphasizes the importance of addressing privacy and security concerns, indicating ongoing challenges.