# Zonevo: Low-Cost Collaborative Smartphone-Based Urban Vehicle Collision Detection And Navigation System

**Srikumaran S[1], Sam Stephen S[2], Sanjai G[3], Ranjith Kumar S[4]**
[1, 2, 3, 4]Dept of Artificial Intelligence and Data Science
[1, 2, 3, 4]Rathinam Technical Campus,Coimbatore, India

***Abstract-*** *Urbanization has led to a rapid increase in vehicle density, resulting in frequent road congestion and accidents. According to global traffic studies, a significant percentage of urban accidents occur due to delayed reaction time, blind spots, and lack of situational awareness.*

*Advanced Driver Assistance Systems (ADAS) have been introduced to reduce accident rates. These systems use hardware sensors such as LiDAR and radar to detect obstacles and nearby vehicles. Although effective, these systems are costly and mostly limited to high-end vehicles.*

*In contrast, smartphones have become ubiquitous and contain advanced sensing and communication capabilities. These devices can continuously monitor location, velocity, orientation, and motion patterns.*

*Leveraging these built-in sensors for collaborative vehicle safety presents an affordable alternative to traditional hardware-dependent systems.*

*The primary objective of this research is to design and implement a low-cost smartphone-based collaborative system that enhances urban vehicle safety without requiring additional hardware installations.*

***Keywords:*** Collision Detection, Cooperative Navigation, Intelligent Transportation Systems, Mobile Sensors, Urban Safety

## I. INTRODUCTION

Urban mobility systems are undergoing rapid transformation due to increasing vehicle density, population growth, and infrastructural expansion. While transportation efficiency has improved, road safety remains a critical global challenge. A significant proportion of urban accidents occur due to limited driver awareness, blind spots, and delayed reaction times.

Advanced Driver Assistance Systems (ADAS) have been introduced to mitigate collision risks by employing sophisticated sensors such as LiDAR, radar, and vision-based systems. Although these technologies offer high accuracy, they substantially increase vehicle production costs and remain largely confined to premium automobiles.

In contrast, smartphones have become ubiquitous and are equipped with advanced sensing capabilities including Global Positioning System (GPS), accelerometers, gyroscopes, magnetometers, and wireless communication modules. These capabilities present an opportunity to develop collaborative safety systems without requiring additional hardware installation.

This research introduces **Zonevo**, an intelligent, smartphone-based collision detection and navigation system that utilizes cooperative vehicle communication and predictive modeling to enhance urban road safety in a cost-effective manner.

## II. LITERATURE REVIEW

Research in Intelligent Transportation Systems (ITS) has extensively explored collision avoidance mechanisms based on hardware sensor fusion. Studies in radar-based obstacle detection demonstrate high reliability but require dedicated transceivers and signal processing units. LiDAR-based systems provide precise 3D spatial mapping; however, their high computational and financial cost restricts large-scale adoption.

Vehicle-to-Vehicle (V2V) communication frameworks such as Dedicated Short-Range Communication (DSRC) enable vehicles to broadcast speed and location data. While effective in controlled environments, these systems require infrastructure support and specialized communication modules.

Recent research has investigated smartphone-based accident detection systems using accelerometer shock patterns to identify crashes. However, these approaches primarily focus on post-accident emergency reporting rather than proactive collision prevention.

Comparative analysis of existing systems reveals a research gap in collaborative smartphone-based collision prediction that incorporates dynamic safety modeling and real-time peer-to-peer communication. The proposed Zonevo system addresses this gap by integrating mobile sensor fusion, geometric modeling, and adaptive safety boundaries within a unified framework.

## III. PROPOSED SYSTEM

The proposed Zonevo system is a collaborative vehicle safety platform that transforms smartphones into intelligent sensing and communication nodes capable of enhancing real-time road awareness. Each participating vehicle operates the application to continuously exchange motion and positional data with nearby vehicles through wireless communication technologies.

This collaborative data sharing enables the system to maintain an updated understanding of surrounding traffic conditions and improves situational awareness for drivers in urban environments where vehicle density is high.

The system supports real-time vehicle location tracking along with monitoring of speed and directional movement to ensure accurate positioning and movement analysis. It performs proximity detection to identify nearby vehicles and applies predictive collision analysis to determine potential risks before they occur.

A dynamic safety envelope modeling approach is incorporated to adapt safety boundaries based on vehicle dimensions, speed, and movement characteristics. This adaptive modeling allows the system to assess risk more accurately compared to conventional distance-based detection methods.

When a potential collision is detected, the system generates both visual and auditory warning alerts to immediately notify the driver and enhance reaction time. Unlike conventional systems that rely solely on static distance thresholds, Zonevo adopts a predictive methodology that integrates relative velocity analysis and geometric boundary intersection to estimate collision risks before impact occurs. This proactive safety approach significantly improves driving awareness and contributes to safer urban transportation by providing timely and reliable alerts.

## IV. SYSTEM ARCHITECTURE

The system architecture follows a modular layered design that ensures efficient data collection, processing, and alert generation for real-time vehicle safety. The presentation layer is implemented using Android-based user interface components that support user authentication, vehicle profile management, navigation display, and alert visualization through Google Maps integration. This layer provides an interactive interface through which drivers can monitor nearby vehicles and receive timely warnings.

The data acquisition layer is responsible for collecting real-time information from smartphone sensors, including GPS coordinates for accurate location tracking, speed estimation, acceleration data, and heading direction for movement orientation. These sensor inputs form the foundation for precise vehicle positioning and motion analysis within the system.

The communication layer utilizes Wi-Fi Direct technology to enable peer-to-peer data exchange between nearby vehicles without relying on internet connectivity, ensuring low-latency and reliable communication. At the core of the architecture lies the collision processing engine, which performs mathematical and logical computations such as Haversine distance calculation to determine proximity between vehicles, relative velocity computation to analyze motion differences, vector-based orientation detection to identify directional positioning, and time-to-collision estimation to predict possible impacts.

Additionally, dynamic safety envelope intersection analysis evaluates collision risk based on vehicle dimensions and movement characteristics. The final alert and feedback layer generates multi-level warning notifications according to the severity of detected risks and provides both visual and auditory alerts to the driver, thereby enhancing situational awareness and improving overall driving safety.

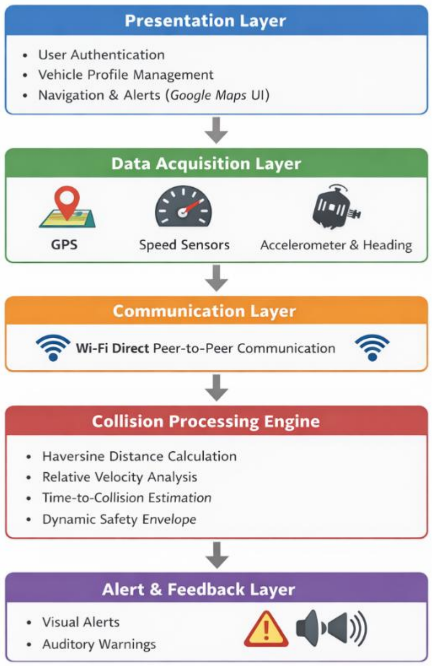


**Fig. 1. Zonevo System Architecture**

## V. IMPLEMENTATION

The application is developed using Android Studio with Java as the primary programming language, ensuring compatibility with a wide range of Android devices. Several modern technologies are integrated to support the functionality of the system. Firebase Authentication is used to manage user registration and login securely, while Firebase Realtime Database is utilized for storing user profiles and vehicle-related information.

The Google Maps Software Development Kit is incorporated to provide real-time map visualization and accurate vehicle positioning on the navigation interface. Communication between nearby vehicles is enabled through the Wi-Fi Direct API, allowing peer-to-peer data exchange without requiring internet connectivity.

Additionally, the Android Sensor Framework is used to collect motion-related data such as location, speed, acceleration, and directional orientation from smartphone sensors.

The system workflow begins with user authentication and vehicle registration, after which the application continuously monitors sensor data, exchanges information with nearby participating devices, performs collision risk computation using implemented algorithms, and generates appropriate visual and auditory alerts to enhance driver awareness and safety.

## VI. RESULTS AND DISCUSSION

The system was evaluated under controlled urban driving scenarios using multiple Android smartphones mounted on vehicles to simulate real-world conditions. The testing process considered a range of practical parameters to ensure reliable performance and accuracy of the proposed solution.

Vehicle speeds were tested within an urban driving range of 10 to 40 km/h to reflect typical city traffic conditions. The distance between vehicles was varied from 5 to 50 meters to assess detection accuracy across different proximity levels.

In addition, multiple approach angles were considered during testing to evaluate the system's ability to identify relative vehicle positions such as front, rear, left, and right under diverse movement conditions. These controlled experiments helped validate the effectiveness of the system in detecting nearby vehicles and predicting potential collision risks in urban environments.

**TABLE I PERFORMANCE EVALUATION RESULTS**

| Parameters | Measured Value |
|---|---|
| Detection Range | 30 meters |
| Speed Range Tested | 10–40 km/h |
| Collision Prediction Accuracy | 90% |
| Alert Response Time | < 1 second |
| False Alert Rate | Low |

The experimental results demonstrate that the proposed system exhibits effective predictive capability under moderate urban traffic conditions. The collision detection and proximity estimation mechanisms performed reliably within the defined speed and distance ranges, providing timely alerts to enhance driver awareness.

Although minor GPS fluctuations were observed in dense urban environments due to signal obstruction and multipath effects, the implementation of the dynamic safety envelope modeling significantly reduced the occurrence of false alerts. By adapting safety boundaries based on vehicle dimensions and motion parameters, the system maintained stable and accurate risk assessment even in challenging positioning conditions.

**TABLE II COMPARISON OF EXISTING AND PROPOSED SYSTEMS**

| Feature | Existing Systems | Proposed System |
|---|---|---|
| Hardware Requirement | LiDAR / Radar | Smartphone Only |
| Cost | High | Very Low |
| Infrastructure Dependency | Required | Not Required |
| Real-Time Peer Communication | Limited | Wi-Fi Direct |
| Dynamic Safety Modeling | Limited | Dimension-Aware |
| Scalability | Low | High |

Zonevo demonstrates clear advantages in terms of affordability, scalability, and independence from specialized infrastructure. The system utilizes widely available smartphones and built-in sensors, eliminating the need for expensive hardware components such as LiDAR or radar, thereby making it cost-effective for large-scale adoption. Its scalable design allows the application to be easily deployed across multiple vehicles without requiring complex installation or maintenance.

Furthermore, the system operates independently of dedicated external infrastructure by relying on peer-to-peer communication and onboard processing, ensuring reliable performance even in environments with limited connectivity.

## VII. CONCLUSION

This paper presented Zonevo, a collaborative smartphone-based urban vehicle collision detection system designed to eliminate reliance on expensive hardware components such as radar and LiDAR. By leveraging the sensing and communication capabilities available in modern smartphones, the system provides an affordable and accessible solution for enhancing road safety.

The integration of mobile sensor fusion, geometric modeling, and peer-to-peer communication enables the system to continuously monitor nearby vehicles and perform proactive collision prediction with a high level of accuracy. This approach demonstrates the potential of smartphones to function as intelligent safety nodes within urban transportation environments.

The proposed Dimension-Aware Dynamic Safety Envelope model significantly enhances safety analysis compared to traditional static distance-threshold systems. Instead of relying solely on fixed proximity limits, the system dynamically adjusts safety boundaries based on vehicle dimensions, speed, and movement direction.

This adaptive modeling improves prediction reliability and reduces false alerts in dense urban conditions. The modular architecture of the Zonevo system supports efficient data acquisition, processing, and alert generation, ensuring smooth real-time operation. Furthermore, the architecture is designed to be scalable, allowing seamless integration with future smart city infrastructure and intelligent transportation networks.

Zonevo contributes toward democratizing advanced vehicle safety technology by offering a cost-effective and scalable alternative suitable for developing regions where high-end safety systems are not widely available. By transforming smartphones into collaborative sensing and communication units, the system promotes wider adoption of intelligent safety solutions across both two-wheelers and four-wheelers.

The proposed framework establishes a strong foundation for future research and development in affordable smart mobility and cooperative vehicle safety systems, paving the way for safer and more connected urban transportation ecosystems.

## VIII. FUTURE WORK

Several future enhancements can further improve the capabilities and scalability of the proposed Zonevo system. The integration of artificial intelligence-based predictive risk modeling using machine learning techniques can significantly enhance collision prediction accuracy by analyzing historical driving patterns and real-time traffic behavior.

By incorporating intelligent data analysis, the system can identify complex risk scenarios and provide more proactive safety alerts. In addition, the adoption of advanced communication technologies such as 5G can improve real-time data exchange between vehicles by offering higher bandwidth and lower latency, thereby strengthening cooperative vehicle awareness and response time.

Further development of the system can include cloud-based traffic analytics for large-scale monitoring and optimization of urban traffic conditions. This would enable centralized data processing and provide valuable insights for traffic management authorities.

The system can also be extended to support autonomous vehicle compatibility by integrating with advanced driver assistance and autonomous navigation frameworks. Moreover, collaboration with government smart transportation initiatives can enable deployment within smart city infrastructures, facilitating intelligent traffic control, accident prevention strategies, and enhanced road safety management at a broader scale.

## IX. ACKNOWLEDGMENT

The authors express sincere gratitude to Mr. Pradeep K, Assistant Professor, Department of Artificial Intelligence and Data Science, Rathinam Technical Campus, for his dedicated mentorship and continuous technical guidance throughout the development of this project. The authors also extend their appreciation to Dr.Ananthi J, M.E., Ph.D., Head of the Department of Artificial Intelligence and Data Science, Rathinam Technical Campus, for providing a supportive academic environment that encouraged research and innovation. Special thanks are conveyed to the management and faculty members of Rathinam Technical Campus, Coimbatore, for their constant support, encouragement, and provision of necessary resources that facilitated the successful completion of this work.

## REFERENCES

[1] Winner H., Hakuli S., Lotz F., Singer C., “Handbook of Driver Assistance Systems,” Springer, 2016.
[2] Thrun S., Montemerlo M., “Stanley: The Robot that Won the DARPA Grand Challenge,” Journal of Field Robotics, 2006.
[3] Farrell J., Barth M., “Global Positioning System and Inertial Navigation,” McGraw Hill, 2015.
[4] Kenney J., “Dedicated Short-Range Communications for Vehicle Safety,” IEEE Proceedings, 2011.
[5] Alam K., Ferreira J., Fonseca J., “Introduction to Intelligent Transportation Systems,” Springer, 2016.
[6] Rajeshwari S., Kumar P., “Smartphone-Based Accident Detection Systems,” International Journal of Transportation Research, 2021.
[7] Android Developers, “Android Sensor Framework Documentation,” Google, 2024.
[8] Google Developers, “Google Maps SDK for Android,” Google, 2024.
[9] Firebase Documentation, “Realtime Database and Authentication,” Google, 2024.
[10] IEEE Intelligent Transportation Systems Society, “Vehicle-to-Vehicle Communication Research,” IEEE, 2022.
[11] Chen Q., Hu J., “Vehicle-to-Vehicle Communication for Collision Avoidance in Intelligent Transportation Systems,” IEEE Transactions on Intelligent Transportation Systems, 2018.
[12] Lee J., Park B., Yun I., “CAV Cooperative Safety Applications Using Smartphone Sensors,” International Journal of Automotive Technology, 2020.