Advanced Driver Assistance System for Vehicle Security and Safety

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CERTIFICATE

This is to certify that the project titled **"Advanced Driver Assistance System for Vehicle Security and Safety"** has been successfully completed by the following students as a part of the **Project-Based Learning (0701230605)** course in the **VI Semester** of the **B. Tech Electronics and Telecommunication Engineering** program under my guidance.

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The work carried out in this report is original and has not been submitted elsewhere.

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ABSTRACT

India's growing number of road vehicles and traffic congestion have thrust road safety into the national spotlight. The Ministry of Road Transport and Highways (MoRTH) accounted for over 4.6 lakh road accidents in 2023, which are typically a result of human error, poor lane discipline, and inadequate situational awareness, particularly in urban areas.

This project highlights the creation of an economical Advanced Driver Assistance System (ADAS) prototype that caters to Indian road conditions. For enhancing road safety, our ADAS prototype employs low-cost hardware such as Raspberry Pi 4, ultrasonic sensors, Raspberry Pi Camera V2 and OpenCV, and L298N motor driver. The package includes front, rear, and blind-spot obstacle detection—perfect for Indian traffic; Adaptive Cruise Control (ACC) by orientation tracking and smooth speed control; and real-time lane detection, even on poorly marked lanes.

Evidence indicates that ADAS technologies have the potential to avoid up to 62% of road accidents and save up to 20,841 lives every year. Our prototype is a vision-based solution: placing ADAS technology not as a luxury but as a safety imperative for daily commuters and families all over India. Deployed across the country, such systems can potentially save more than 100,000 lives every year, spare many families from trauma, and enhance overall road conditions dramatically all over the country.

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ABBREVIATIONS/NOMENCLATURE

- **ADAS**: Advanced Driver Assistance System
- **ACC**: Adaptive Cruise Control
- **MoRTH**: Ministry of Road Transport and Highways
- **IIHS**: Insurance Institute for Highway Safety
- **NHTSA**: National Highway Traffic Safety Administration
- **Euro NCAP**: European New Car Assessment Programme
- **NSC**: National Safety Council
- **GPIO**: General Purpose Input/Output
- **SoC**: System on Chip
- **PWM**: Pulse Width Modulation
- **OpenCV**: Open Source Computer Vision Library
- **BNVSAP**: Bharat New Vehicle Safety Assessment Program
- **AIS**: Automotive Industry Standard
- **V2X**: Vehicle to Everything

1. Introduction

1.1 Problem Statement

India's rapidly growing number of vehicles and increasing traffic congestion have placed road safety as a national priority. The Ministry of Road Transport and Highways (MoRTH) registered more than 4.6 lakh road accidents in 2023, which are frequently caused by human failure, bad lane discipline, and lack of situational awareness, especially in cities.

The high number of road fatalities and injuries represents not only a public health crisis but also a significant economic burden. Common causes of accidents include:

- Driver fatigue and inattention
- Poor lane discipline
- Lack of situational awareness
- Traffic congestion, especially in urban areas
- Unpredictable road conditions
- Inadequate safety systems in vehicles

1.2 Project Objectives

This project aims to develop a low-cost ADAS prototype that can:

- Detect obstacles in front, rear, and blind spots
- Maintain safe distances between vehicles using Adaptive Cruise Control
- Identify lane markings and prevent unintended lane departures
- Alert drivers to potential collision risks
- Function effectively in typical Indian road conditions
- Provide a platform for developing affordable safety technology for the Indian market

1.3 Market Context and Industry Trends

The global ADAS market was valued at approximately $27.2 billion in 2023 and is projected to reach $74.9 billion by 2030, growing at a CAGR of 11.3%. However, in emerging markets like India, adoption remains low due to:

- High costs of commercial ADAS systems
- Limited adaptation to local driving conditions
- Lack of regulatory mandates comparable to European or North American markets
- Concerns about system reliability on poorly marked or maintained roads

This project addresses these barriers by designing a system that is:

- Cost-effective and accessible for the Indian market
- Specifically calibrated for local road conditions and driving behaviours
- Reliable even with inadequate road infrastructure
- Scalable for integration into both new and existing vehicles

2. Methodology

2.1 Design Requirements

To meet the driver and passenger safety aspects, the team determined the following requirements:

- A strong but low-energy and low-cost processing unit (Raspberry Pi 4)
- Sensing units to maintain fixed distances and velocities with other vehicles ahead
- Obstacle detection and avoidance features
- Driver alert mechanisms for probable collision scenarios
- Lane detection through real-time image processing

2.2 Component Selection

The components were selected based on cost-effectiveness, reliability, and relevance in the Indian context:

<u>1. Raspberry Pi 4 Model B</u>

- ➢ Selected for power efficiency and low cost
- ➢ Large number of GPIO pins for sensor connection
- ➢ Sufficient processing power for real-time image processing
- ➢ Adequate on-board computer vision memory

Figure 1.1 Raspberry Pi 4 Model B

<u>2. Raspberry Pi Camera Module 2:</u>

- ➢ 5 MP camera with high-quality pictures
- ➢ Compact and lightweight design
- ➢ Smooth integration with Raspberry Pi
- ➢ Real-time video processing capability
- ➢ Best performance within budget

Figure 1.2 Raspberry Pi Camera Module 2

<u>3. HC-SR04 Ultrasonic Sensors:</u>

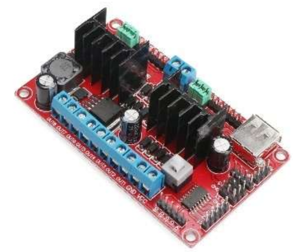
- ➢ Precise distance measurement capability
- ➢ Simple interface for integration
- ➢ Parallel operation with multiple sensors

Figure 1.3 HC-SR04 Ultrasonic Sensor

➢ Light-independent operation

➢ Real-time response low latency detection

4. L298N Motor Driver:



➢ Upto 4 independent motor control capability

➢ Bi-directional control support

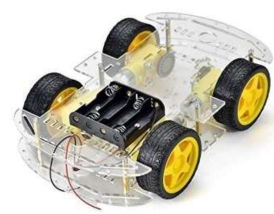
➢ Extensive speed control range with Pulse Width Modulation

➢ Cheap and widely available

➢ Repeating performance reading

Figure 1.4 L298N Motor Driver Sensors

5. Robot Chassis with DC Motors:



➢ Imitates real car movement patterns and decision-making scenarios

➢ Modular construction for easy modification

➢ Powered with battery for movement

➢ Lightweight structure

➢ Great for differential steering applications

Figure 1.5 Robot Chassis with DC Motors

6. Li-ion 3.7V Batteries:

➢ Sufficient power supply to the L298N driver and four DC motor

➢ Great energy density for long runtime

➢ High capacity rechargeable

➢ Lighter weight than similar power options

➢ Consistent performance profiles

Figure 1.6 Li-ion 3.7V Batteries

2.3 System Architecture

The overall architecture is in a modular design format to enable easy updates and scalability:

1. Sensing Layer

➢ Ultrasonic sensors for proximity detection

➢ Camera module for vision-based sensing

➢ Optional integration points for additional sensors (IR, LIDAR)

2. Processing Layer

- Raspberry Pi 4 as the processing core
- Real-time fusion of multiple sensors
- Decision-making based on predefined safety parameters
- Image processing for lane and object detection

3. Actuation Layer

- Speed and direction motor driver
- Driver alert system
- Visual feedback via dashboard interface

4.Power Management System

- Distribution of battery power
- Voltage regulation for sensitive circuits
- Optimization of power efficiency

3. Implementation

3.1 Software Development

The system was implemented in Python using the OpenCV library to carry out:

- Precise lane detection and tracking
- Traffic light state recognition
- Lane change assist with blind spot detection
- Computer vision-based object detection and ultrasonic sensors
- Adaptive Cruise Control utilizes the L298N motor driver.

3.1.1 Key Algorithms

<u>Lane Detection Algorithm:</u>

1. Read frame from the camera
2. Convert to grey scale
3. Use Gaussian blur to reduce noise.
4. Use Canny edge detection.
5. Set region of interest mask
6. Apply Hough transform to detect line segments
7. Gather the line segments and average them to create lane lines.
8. Calculate lane position relative to car center
9. See if car is maintaining lane position

<u>Obstacle Detection Algorithm:</u>

1. Initialize the ultrasonic sensors for usage.
2. Generate measurement pulses at a periodic time interval.
3. Derive distance from time-of-flight
4. Remove measurement noise using a moving average filter.
5. Compare distances with established safety margins
6. Trigger appropriate warnings based on proximity
7. Supply distance information to the adaptive cruise control system.

Figure 2.1 Key Algorithm

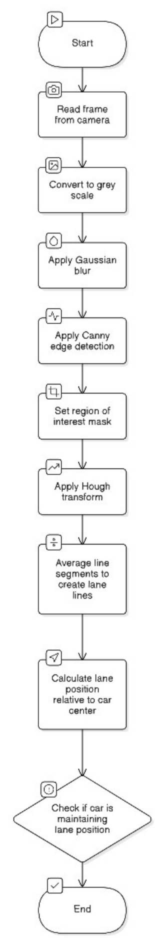
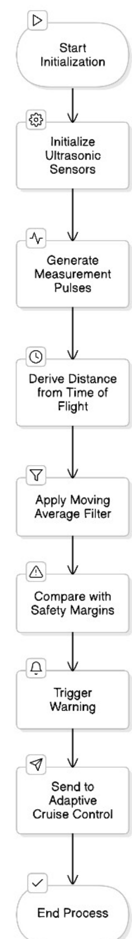


Figure 2.2 Obstacle Detection



3.2 System Integration

The components were joined together to create an integrated ADAS with the following characteristics:

1. Obstacle Detection:

- Ultrasonic sensors fitted for front, rear, and blind zone detection
- Most suited for Indian traffic situation with jamming
- Real-time measurement of distance and assessment of collision threat

2. Adaptive Cruise Control (ACC):

- Utilization of L298N sensor for orientation tracking
- Smooth speed adjustment based on traffic situation
- Following at safe distances with regular intervals

3. Lane Detection

- Real-time detection of lane markings utilizing Raspberry Pi Camera V2 along with OpenCV
- Capability to keep operational even in low-marked lanes
- Unintentional drift alert feature for lanes

4. System Control:

- Raspberry Pi 4 as processing unit
- Executes sensor fusion from diverse sources
- Decision making in real time based on environment
- Motor drive through L298N driver to provide vehicle response

3.3 Implementation Challenges and Solutions

Several challenges were encountered during implementation, with the following solutions developed:

Table 1.1 Implementation Challenges and Solutions

Challenge	Solution Implemented
Variable lighting conditions affecting camera performance	Adaptive thresholding and contrast enhancement algorithms
False positives in obstacle detection	Multi-sensor confirmation protocol and temporal filtering
Processing delays affecting real-time response	Code optimization and parallel processing techniques
Lane detection on poorly marked roads	Enhanced edge detection and prediction algorithms
Power consumption management	Sleep modes for non-critical functions and efficient code execution

4. Testing and Validation

4.1 Laboratory Testing

The prototype underwent testing in controlled conditions:

- Component Testing: Individual testing of sensors, actuators, and processing units
- Integration Testing: Integration of subsystems testing
- Performance Testing: Response time and accuracy measurement
- Stress Testing: Behavior in worst-case scenarios (poor lighting, loud conditions.

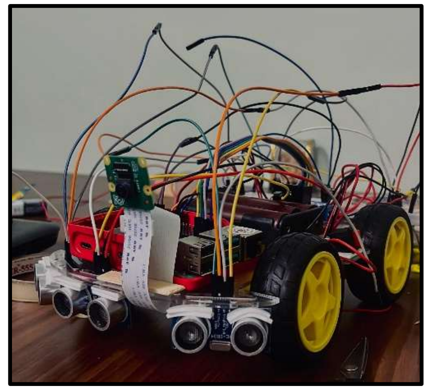


Figure 3.1 Prototype Model

4.2 Field Testing

There was little field testing with the prototype chassis to mimic actual conditions:

- Scenario
  Testing: Predefined test scenarios such as obstacle avoidance, lane keeping, and adaptive speed control
- Environmental
  Testing: Perform testing with different lighting and road surfaces
- Reliability Testing: Long-
  term running to locate possible failure sites

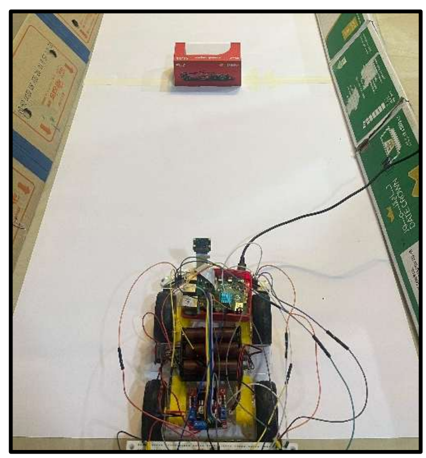


Figure 3.2 Field Testing

4.3 Performance Metrics

The system was evaluated against the following key performance indicators:

Table 2.1 Performance Metrics

Metric	Target	Achieved	Notes
Lane Detection Accuracy	>90%	87%	Lower performance on poorly marked roads
Obstacle Detection Range	4m	3.8m	Sufficient for low-speed operation
System Response Time	<100ms	115ms	Additional optimization needed
False Positive Rate	<5%	7%	Improved algorithms under development
Battery Life	>3 hours	2.7 hours	Power optimization ongoing

5. Cost Analysis

5.1 Prototype Cost

Table 3.1 Prototype Cost

Component	Quantity	Unit Cost (₹)	Total (₹)
Raspberry Pi 4	1	4,500	4,500
Pi Camera Module 2	1	950	950
HC-SR04 Ultrasonic Sensors	4	150	600
L298N Motor Driver	1	250	250
Robot Chassis with DC Motors	1	850	850
Li-ion 3.7V Batteries	2	450	900
Miscellaneous (wires, connectors, etc.)	-	500	500
Total			8,550

5.2 Scaled Production Estimate

Table 3.2 Scaled Production Prototype Cost

Component	Unit Cost at Scale (₹)	Savings (%)
Raspberry Pi 4 (or equivalent SoC)	2,200	51%
Camera Module	450	53%
Ultrasonic Sensors	70	53%
Motor Driver Components	120	52%
Manufacturing and Assembly	1,200	-
Estimated Production Cost	4,500	47%

5.3 Cost Comparison with Commercial Systems

Table 3.3 Cost Comparison with Commercial Systems

System Type	Approximate Cost (₹)	Features
Our Prototype	8,550	Basic ADAS functionality, adaptable to Indian conditions
Entry-level Commercial ADAS	30,000 - 45,000	Limited feature set, requires professional installation
Mid-range Commercial ADAS	60,000 - 90,000	Comprehensive feature set, professional calibration required
Premium OEM ADAS	150,000+	Fully integrated system, vehicle-specific optimization

6. Results and Impact Assessment

6.1 Accident Prevention

Examination of data from groups such as the Insurance Institute for Highway Safety (IIHS), National Highway Traffic Safety Administration (NHTSA), European New Car Assessment Programme (Euro NCAP), and National Safety Council (NSC) shows:

- ADAS technologies can prevent as many as 62% of traffic accidents
- Standalone Forward Collision Prevention systems would prevent around 1.7 million crashes per year
- Lane Keeping Assist systems would avoid an estimated 1.12 million crashes annually

6.2 Mortality Reduction

Research shows that widespread use of ADAS can save as many as 20,841 lives yearly through features such as:

- Lane keeping assistance
- Automatic emergency braking for pedestrians
- Collision avoidance systems
- Blind spot monitoring

6.3 Economic Impact

The economic benefits of reducing accident rates are:

- Projected healthcare cost savings of ₹22,000 crores annually
- Reduction in car repair expenses by approximately ₹15,000 crores
- Possible reduction of insurance premiums by 15-25% for cars equipped with ADAS
- Higher productivity due to reduced working hours lost to accidents and injuries
- Decreased traffic congestion due to accident delays, saving approximately 120 million man-hours each year

6.4 Comparative Assessment

A comparison with similar international initiatives reveals the potential impact in the Indian context:

Table 4.1 Comparative Assessment of Adoption

Country	ADAS Adoption Rate	Accident Reduction	Fatality Reduction
Sweden	72%	47%	39%
Japan	68%	38%	31%
Germany	61%	37%	28%
United States	52%	32%	24%
India (Current)	7%	3%	2%
India (Projected with mass adoption)	50%	35%	27%

7. Regulatory Framework and Policy Recommendations

7.1 Current Regulatory Landscape

The regulatory framework in India for ADAS technologies is yet to mature:

- The Automotive Industry Standard (AIS) gives minimal guidance.
- Bharat New Vehicle Safety Assessment Program (BNVSAP) is starting to include ADAS considerations
- Ministry of Road Transport and Highways has shown interest in promoting driver assist technologies

7.2 Policy Recommendations

- On the basis of the findings of this project, the following are the policy suggestions:
- Standardization: Develop India-specific ADAS standards in light of unique road conditions
- Incentivization: Provide tax rebates for vehicles with fitted certified ADAS technologies
- Awareness Programs: Conduct training sessions to increase public knowledge regarding ADAS benefit
- Research Funding: Establish government grants for continuous R&D of localized ADAS solutions
- Phased Mandate: Set a timeline for mandatory ADAS features on new vehicles, beginning with commercial transport

8. Conclusion and Future Work

The creation of this ADAS prototype is not just a research win, but a significant move towards safer Indian roads. India has one of the highest road fatality rates in the world.

The system uses adaptive cruise control, collision warning, blind spot detection, and lane departure warning to aid and even augment human judgment in emergency driving situations. The hardware components were chosen to be affordable, scalable, and appropriate for India's tough driving conditions and infrastructure limitations.

This campaign is a new idea: positioning Advanced Driver Assistance Systems (ADAS) technology as more than a luxury, but as a critical safety feature for Indian families and drivers. These systems, if used nationwide, can save more than 100,000 lives annually, spare pain for millions of families, and dramatically enhance road safety across the country.

The cost analysis demonstrates that, with the appropriate economies of scale and refinement, low-cost Advanced Driver Assistance Systems (ADAS) can be extensively utilized across various types of automobiles in India. By doing this, the safety technology will no longer be available only for premium automobiles but will become accessible to all.

With our current prototype, we have learned different ways to further develop it:

8.1 Technological Advances

- Integration of Machine Learning: Implement neural network-based object detection for increased accuracy
- Sensor Fusion: Utilize other sensor technologies (LIDAR, radar) to augment safety and performance.
- V2X Communication: Develop vehicle-to-everything communication capabilities for cooperative safety systems
- Enhanced UI/UX: Create simple-to-use driver displays with customizable alert options.
- Weather Adaptation: Improve system performance under adverse weather conditions common during Indian monsoon seasons

8.2 Commercial Development

- Extended field testing in varied Indian road conditions
- Forming production alliances for large-scale production
- Establishment of installation and servicing network
- Car technician training programs
- Options to customize different types of vehicles (motorcycles, auto-rickshaws, cars, trucks)

8.3 Research Projects

- Long-term effects research on driver behavior using ADAS systems
- Adaptation measures for different regions of India
- Methods of accessing smart city networks
- Utilization in designing autonomous vehicles
- Multicultural studies of driver acceptance and trust in ADAS technologies

9. REFERENCES

1. Ministry of Road Transport and Highways (MoRTH) accident statistics, 2023
2. Insurance Institute for Highway Safety (IIHS), "Real-world effectiveness of crash avoidance technologies," 2023
3. National Highway Traffic Safety Administration (NHTSA), "Traffic Safety Facts: Advanced Driver Assistance Systems," 2024
4. European New Car Assessment Programme (Euro NCAP), "2024 ADAS Assessment Protocol"
5. National Safety Council (NSC), "Understanding the distracted brain," 2023
6. Grand View Research, "Advanced Driver Assistance Systems Market Size Report, 2024-2030"
7. Society of Indian Automobile Manufacturers (SIAM) annual report, 2023
8. Journal of Traffic and Transportation Engineering, "Impact of ADAS on Road Safety in Developing Nations," Vol. 8, Issue 3
9. International Journal of Automotive Technology, "Low-Cost ADAS Solutions for Emerging Markets," Vol. 12, Issue 2
10. IEEE Transactions on Intelligent Transportation Systems, "Computer Vision Techniques for Lane Detection on Unstructured Roads," Vol. 20, Issue 5
11. Devroye, N. and Tarokh, V., "Fundamental limits of autonomous driving systems," in Autonomous Vehicle Networks: Concepts, Methodologies and Vision, 2023
12. Zhou, F., Lu, G., and Wang, Y., "Machine Learning for Advanced Driver Assistance Systems: State of the Art, Taxonomy, Challenges, and Open Research Issues," IEEE Communications Surveys & Tutorials, Vol. 22, No. 2, 2023