

Smart Blind Curve Vehicle Detection System Using Radar

Saachika S¹, D Vishnu Priya², Deepika D Pai³, Sunil Hosur⁴

^{1,2,3,4}*Electronics and communications, Vemana Institute Of Technology; India*

Abstract—Road crashes at blind curves and hairpin bends remain a safety concern because restricted sight distance can prevent drivers from perceiving opposing traffic before entering the curve. This paper presents a low-cost, stand-alone vehicle detection and warning prototype based on two radar sensors and an Arduino Uno microcontroller. The radar sensors monitor the two approaches of the curve, and the controller drives a tri-color LED indication—red for stop/danger, yellow for caution, and green for safe passage—together with a 16×2 LCD that displays text warnings. The prototype was evaluated using multiple bench-scale vehicle-approach scenarios. In the reported tests, the system detected approaching vehicles, selected the intended warning state, and updated the LCD status in real time. Because the design does not depend on Internet connectivity, it is intended for remote hilly and rural locations where communication infrastructure may be limited. The prototype demonstrates the feasibility of an economical local warning system for blind curves; however, controlled field trials, quantified detection accuracy and latency measurements, environmental robustness testing, and long-term reliability assessment are required before real-world deployment.

Keywords—Arduino Uno, blind curve, radar sensor, road safety, vehicle detection, warning system.

I. INTRODUCTION

A. Background and Motivation

Road traffic injury remains a major public-safety problem. The World Health Organization reported approximately 1.19 million road traffic deaths worldwide in 2021 [1]. In India, the Ministry of Road Transport and Highways recorded 58,626 crashes and 22,263 deaths on curved roads in 2023; curved roads, potholes, and steep grades together accounted for 14.5% of reported crashes [2]. These data underline the need for practical safety interventions at geometrically constrained road locations, including blind curves, hairpin bends, and hilly road sections.

Horizontal curves are associated with a disproportionate crash risk. The U.S. Federal Highway Administration reports that more than one-quarter of fatal crashes are associated with horizontal curves and that the average crash rate on curves is approximately three times that of tangent highway segments [3].

Conventional signs, chevrons, pavement markings, and other low-cost countermeasures remain important [4], but passive devices cannot directly indicate whether an opposing vehicle is presently approaching a blind section.

Dynamic warning systems provide a complementary approach because the warning can be activated in response to observed traffic conditions. A field evaluation by Monsere et al. reported that a dynamic advanced curve warning system reduced mean vehicle speeds by approximately 2–3 mph and shifted the speed distribution away from higher-speed bins [5]. This supports the broader premise that real-time, condition-responsive warnings can influence driver behavior at hazardous curves.

Radar is attractive for vehicle sensing because it can provide object detection and motion-related information without relying on visible-light imagery. Automotive and millimeter-wave radar technologies are widely used for range and velocity sensing, and radar can operate under lighting conditions that challenge optical systems [6], [7]. For the present prototype, radar sensing is combined with an Arduino Uno microcontroller, whose ATmega328P-based platform provides the digital input/output and embedded control capabilities required for sensor interfacing and visual warning outputs [8].

B. Research Problem and Objectives

At blind curves, drivers may enter a restricted-sight-distance section without timely knowledge of opposing traffic. The engineering problem addressed in this work is therefore to provide a simple local warning mechanism that detects approaching vehicles and communicates a clear stop/caution/proceed status without dependence on Internet connectivity or remote servers. The objective is to design, implement, and functionally test a radar-based prototype that can support safer decisions before vehicles enter the blind portion of a road.

C. Main Contributions

The study contributes a two-sided radar monitoring architecture, an Arduino-based decision controller, a tri-color LED warning interface, and a 16×2 LCD message display. The prototype is intentionally simple and uses locally available embedded hardware. Its evaluation focuses on functional behavior under the reported bench-scale detection scenarios rather than on field crash reduction, long-term reliability, or statistical safety effectiveness.

II. MATERIALS AND METHODS

A. Study Design

The work follows an experimental hardware-prototype design. Two radar sensors monitor the left and right approaches of the blind curve and provide detection inputs to an Arduino Uno. The controller executes the programmed decision logic and updates the LED and LCD outputs. The overall architecture is shown in Fig. 1. Arduino documentation was used as the platform reference for the Uno hardware and development environment [8], [9].

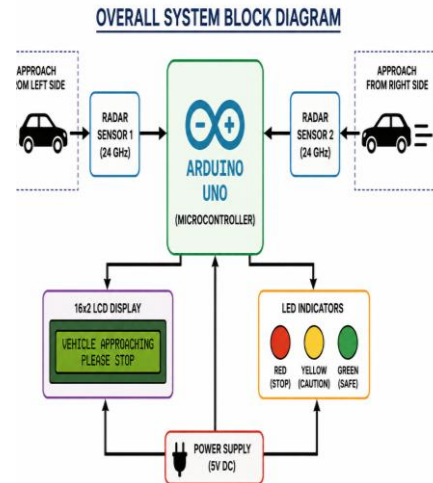
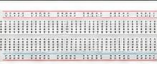


Fig. 1. Overall system block diagram.

B. Hardware Components

The prototype consists of the Arduino Uno, two 24-GHz radar modules, a 16×2 LCD, red/yellow/green LEDs, a breadboard, jumper wires, a USB cable, and a regulated 5-V supply. Table I summarizes the component set used in the prototype.

TABLE I. HARDWARE COMPONENTS USED

Sl. No.	Component	Image	Specification	Quantity	Purpose
1	Arduino Uno		ATmega328P Microcontroller	1	Acts as the central controller of the system and processes data from sensors.
2	Radar Sensor (24 GHz)		24 GHz Microwave Radar Module	2 (One for each side)	Detects approaching vehicles on both sides of the blind curve.
3	16×2 LCD Display		16×2 LCD (HD44780 Compatible)	1	Displays warning messages and system status.
4	Red LED		5 mm LED (Red)	1	Indicates danger (Stop).
5	Yellow LED		5 mm LED (Yellow)	1	Indicates caution.
6	Green LED		5 mm LED (Green)	1	Indicates safe to proceed.
7	Breadboard		Standard Breadboard	1	Used for assembling and testing the circuit connections.
8	Jumper Wires		Male to Male Jumper Wires	As required	Used for making electrical connections between components.
9	USB Cable		USB Type-B Cable	1	Used for programming the Arduino Uno.
10	Power Supply		5V DC Regulated Power Supply	1	Provides regulated power supply to the entire system.

C. Software Tools

The control program was developed and uploaded using the Arduino IDE. Embedded C/C++ was used for the control logic, and the Serial Monitor supported debugging and inspection of sensor output during prototype development [9].

TABLE II. SOFTWARE TOOLS USED

Software	Purpose
Arduino IDE	Programming and uploading code to the Arduino Uno
Embedded C/C++	Development of the control algorithm
Serial Monitor	Debugging and inspection of sensor outputs

D. System Methodology

The controller continuously evaluates the two radar inputs. If a vehicle is detected on one approach, the warning on the opposite side is set to red and the LCD displays a vehicle-approaching message. After the detected vehicle clears the monitored region, the system enters a caution state using the yellow indication. When both approaches are clear, the green indication signals safe passage. Figure 2 summarizes this control sequence.

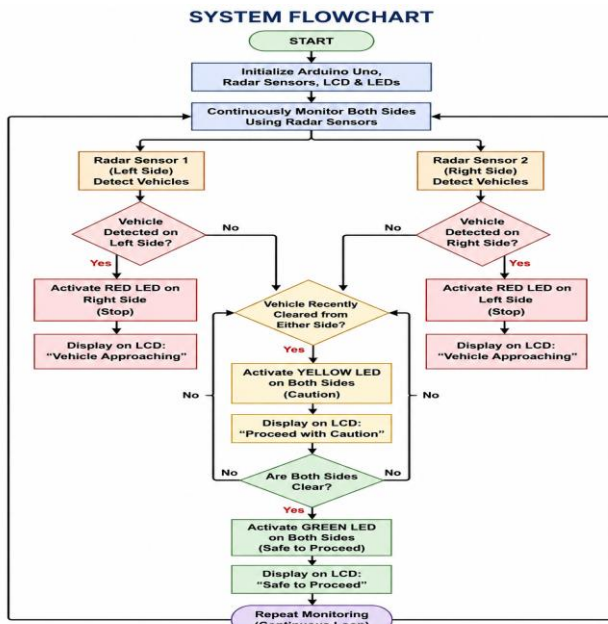


Fig. 2. System flowchart.

E. Working Procedure

The operational sequence implemented in the prototype is summarized as follows:

1. Continuously monitor both approaches using the radar sensors.
2. Transmit the vehicle-detection states to the Arduino Uno.
3. Process the two sensor states using the programmed decision logic.
4. When a vehicle is detected from one direction, activate the red warning for the opposite-side approach.
5. After the vehicle clears the monitored region, activate the yellow caution state.
6. When both approaches are clear, activate the green safe-to-proceed state.
7. Update the 16×2 LCD with the corresponding warning message.
8. Repeat the monitoring cycle continuously.

F. Circuit Implementation

The circuit integrates the radar sensors, Arduino Uno, 16×2 LCD, three LED indicators, and a regulated 5-V power supply. The radar modules act as the primary inputs, while the microcontroller interprets the input states and updates the visual outputs. The Arduino Uno provides sufficient digital I/O for this prototype-scale implementation [8]. The assembled circuit arrangement is shown in Fig. 3.

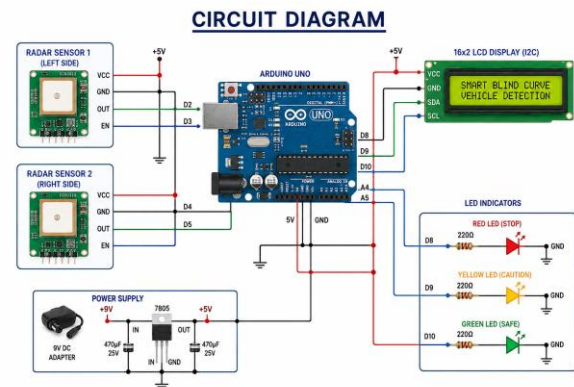


Fig. 3. Circuit diagram.

G. Prototype Development and Test Cases

A functional prototype was assembled on a breadboard and programmed using the Arduino IDE [9]. Vehicle movement was simulated from both approaches of the model blind curve, and the radar detections were used to exercise the red, yellow, and green warning states.

The evaluation recorded whether the expected LED state and LCD message were produced for the reported test cases. No Internet connection or external communication infrastructure was used during operation.

III. RESULTS AND DISCUSSION

A. Results

The prototype completed the reported functional tests and produced the expected warning outputs. When the test

The condition represented a clear roadway, the green LED and “Safe to Proceed” message were displayed. A caution condition produced the yellow LED and “Proceed with Caution” message, while an approaching-vehicle condition produced the red LED and “Vehicle Approaching” message. Figures 4 and 5 show the experimental prototype and an example LCD/LED status, respectively.



Fig. 4. Experimental prototype.



Fig. 5. LCD and LED vehicle-detection status.

Table III reproduces the three reported experimental test cases. In the test setup, the cases at 7 m, 5 m, and 2 m were associated with green, yellow, and red outputs, respectively, and each case was recorded as successful. These results demonstrate functional state switching in the prototype; they do not, by themselves, establish a calibrated real-world detection range or a distance-based control law.

TABLE III. EXPERIMENTAL TEST RESULTS

Case	Test condition	LED	LCD message / response
1	Radar at 7 m	Green	Safe to Proceed / Successful
2	Radar at 5 m	Yellow	Proceed with Caution / Successful
3	Radar at 2 m	Red	Vehicle Approaching / Successful

B. Discussion

The principal outcome is the successful integration of sensing, embedded decision logic, and visual warning outputs into a self-contained prototype. This is consistent with the broader rationale for active curve-safety treatments: drivers benefit when warnings are timely and responsive to actual traffic conditions rather than being purely static [3], [4]. Prior research on dynamic advanced curve warning has also shown measurable changes in driver speed behavior, although that work evaluated full-scale road deployments rather than a bench prototype [5].

The radar-based architecture avoids dependence on visible-light imaging and is compatible with the wider use of radar for vehicle sensing and motion-related measurements [6], [7]. The Arduino Uno provides a low-complexity embedded platform for implementing the required input processing and output control [8]. These characteristics support the intended use case of a stand-alone warning device in locations where network connectivity may be limited.

The current evaluation has important limitations. Testing was confined to a scale prototype and three reported functional scenarios. The study did not quantify probability of detection, false-alarm rate, sensor range under different vehicle types, end-to-end warning latency, operation in rain/fog/temperature extremes, electromagnetic interference, power consumption, or long-term reliability. It also did not include controlled field trials or before-and-after crash data. Accordingly, the present results should be interpreted as proof of functional feasibility rather than evidence of real-world crash reduction.

Future work should therefore include calibrated distance and speed measurements, repeated trials with statistical performance metrics, outdoor field testing, fail-safe logic for simultaneous detections and sensor faults, and weatherproof enclosures. Wireless communication between units, solar-power integration, event logging, and remote diagnostics may be considered after the stand-alone safety logic has been validated under field conditions.



IV. CONCLUSION

A Smart Blind Curve Vehicle Detection System Using Radar was designed and implemented as a low-cost embedded prototype for two-sided vehicle detection and visual warning. Two radar sensors provide approach information to an Arduino Uno, which controls red, yellow, and green LED states and a 16×2 LCD message display.

The reported bench-scale tests verified that the prototype could switch among the intended warning states and display the corresponding messages without requiring Internet connectivity.

The work establishes functional feasibility, but the available experiments are not sufficient to quantify real-world safety effectiveness. Field deployment, detection and false-alarm statistics, latency measurement, environmental testing, power characterization, and longer-duration reliability studies are required before practical roadside implementation. With these validations and appropriate weatherproofing and power-system design, the architecture may provide a useful basis for an economical warning system at blind curves and similar restricted-visibility locations.

REFERENCES

- [1] World Health Organization, Global Status Report on Road Safety 2023. Geneva, Switzerland: WHO, 2023, ISBN 978-92-4-008651-7. [Online]. Available: <https://www.who.int/publications/i/item/9789240086517>. Accessed: Aug. 26, 2026.
- [2] Ministry of Road Transport and Highways, Government of India, Road Accidents in India 2023. New Delhi, India. [Online]. Available: <https://morth.nic.in/sites/default/files/Road-Accident-in-India-2023-Publications.pdf>. Accessed: Aug. 26, 2026.
- [3] Federal Highway Administration, “Horizontal Curve Safety,” U.S. Department of Transportation, 2023. [Online]. Available: <https://highways.dot.gov/safety/rwd/keep-vehicles-road/horizontal-curve-safety>. Accessed: Aug. 26, 2026.
- [4] Federal Highway Administration, Low-Cost Treatments for Horizontal Curve Safety 2016, Rep. FHWA-SA-15-084, U.S. Department of Transportation, 2016. [Online]. Available: https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa15084rev011720_508_FINAL.pdf. Accessed: Aug. 26, 2026.
- [5] C. M. Monsere, C. Nolan, R. L. Bertini, E. L. Anderson, and T. A. El-Seoud, “Measuring the impacts of speed reduction technologies: Evaluation of dynamic advanced curve warning system,” Transportation Research Record, vol. 1918, no. 1, pp. 98–107, 2005, doi: 10.1177/0361198105191800113.
- [6] J. Hasch, E. Topak, R. Schnabel, T. Zwick, R. Weigel, and C. Waldschmidt, “Millimeter-wave technology for automotive radar sensors in the 77 GHz frequency band,” IEEE Transactions on Microwave Theory and Techniques, vol. 60, no. 3, pp. 845–860, Mar. 2012, doi: 10.1109/TMTT.2011.2178427.
- [7] Texas Instruments, “Getting Started with mmWave Sensors,” Application Report SPRADM3, Mar. 2025. [Online]. Available: <https://www.ti.com/lit/an/spradm3/spradm3.pdf>. Accessed: Aug. 26, 2026.
- [8] Arduino, “UNO R3,” Arduino Documentation. [Online]. Available: <https://docs.arduino.cc/hardware/uno-rev3>. Accessed: Aug. 26, 2026.
- [9] Arduino, “Arduino IDE 2 Documentation,” Arduino Documentation. [Online]. Available: <https://docs.arduino.cc/software/ide/>. Accessed: Aug. 26, 2026.