Ministry of Physical Infrastructure and Transport

National Road Safety Council

Singhadurbar, Kathmandu

FABRICATION AND PERFORMANCE EVALUATION OF PROVISION OF PROXIMITY SENSOR IN BUS AND TRUCK

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FINAL REPORT

FABRICATION AND PERFORMANCE EVALUATION OF PROVISION OF PROXIMITY SENSOR IN BUS AND TRUCK

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भौतिक पूर्वाधार तथा यातायात मन्त्रालय
नेपाल सरकार
सिंहदरवार, काठमाडौं

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LIST OF ABBREVIATION

BoQ	Bill of Quantity
CPS	Centre for Pollution Studies
DOR	Department of Road
GDP	Gross Domestic Product
IOE	Institute of Engineering
MoPIT	Ministry of Physical Infrastructure and Transport
O&M	Operation and Management
QRDC	Quality Research Development Centre
PID	Proportional – Integral – Derivative
SDG	Sustainable Development Goals
SNH	Statistics of National Highway
TU	Tribhuvan University
UI/UX	User interface/user experience
VAT	Value Added Tax

ABSTRACT

This report presents the fabrication and performance evaluation of a proximity sensor system designed for installation in buses and trucks, with an initial target detection range of 60 meters. The primary objective of this study was to enhance road safety by providing early detection of obstacles and hazards. However, due to technical and environmental constraints, the feasibility of achieving a 60-meter detection range was critically assessed and found to be impractical with the current technology. Consequently, the focus shifted to developing and evaluating a sensor system with a feasible detection range of 6 meters.

The study involved a comprehensive review of various sensor technologies, including radar, lidar, ultrasonic, and camera-based systems. The limitations of each technology were analyzed, particularly in adverse weather conditions such as fog. The report also discusses the need for additional frameworks and clauses to support the integration of these sensors into existing vehicle systems.

Field tests were conducted to evaluate the performance of the 6-meter detection range sensor, with a focus on accuracy, reliability, and response time. The results demonstrated significant potential for reducing collision rates and enhancing overall road safety. The study highlights the challenges encountered during the fabrication and testing phases and provides recommendations for future research and development. These include exploring advanced sensor technologies and further pilot testing in diverse environmental conditions to validate and improve sensor performance.

This report concludes that while a 60-meter detection range sensor is not currently feasible, the implementation of a 6-meter detection range sensor offers a practical and effective solution for improving safety in buses and trucks. Future work will focus on overcoming environmental limitations and extending the detection range through advanced technologies and comprehensive feasibility studies.

CHAPTER ONE: INTRODUCTION

1.1 Background

The construction and widening of the road and its network have been a great challenge and impactful factor in the socio-economic development of the country. The development of the road network and maintenance dates back to 2007, when they constructed and maintained roads in Kathmandu Valley under an office named Botokaj Goswara. The major and memorable work in road development in Nepal done by the Public Works Department in 2007 was the construction of the Tribhuvan Rajpath, currently known as East-West Highway. To date, it is the longest highway in Nepal, running from the east and touching the west border of the country. There are 80 national highways developed in Nepal covering the road length of 14,913 km as per report SNH 2020/21.

With technological advancement and road development, different parts of the country have become accessible. Although this has decreased the time required for travel, it has increased road accidents significantly. According to the World Bank, in 2019, there were nearly 13,000 highway and road accidents, with more than 2,700 deaths and 10,000 serious injuries. In addition, the economic cost for road accidents has increased by three folds since 2007 and reached 1.5% of the GDP. While the road accidents can be attributed to many reasons including lack of proper road, old vehicles with no safety measures, design fault in vehicle, over loading, traffic violation etc. the major cause of fatal accidents is the driver related accidents contributing at 60%. In most cases due to overloading of the vehicle and lack of information regarding clearance in front and back, drivers tend to lose control and can cause severe damage to vehicles and personnel it.

To prioritize road safety, the Government of Nepal previously included the road safety in its SDG 3 Good Health and Well-Being and targeted reducing the deaths by road accident in half by 2020. While this goal was not achieved the road safety is still a major challenge of the government. In addition, Ministry of Physical Planning and Transport Management has previously prepared the Nepal Road Safety Action Plan (2013 – 2020) in 2013. In the same line with the Nepal Road Safety Action Plan (2013 – 2020), world bank has prepared, "Delivering Road Safety in Nepal", which highlight the five pillars for action which can help develop safer roads in Nepal. These pillars are

- Pillar 1: Road safety management
- Pillar 2: Safer Road and mobility
- Pillar 3: Safer vehicle
- Pillar 4: Safer Road users
- Pillar 5: Post-crash response

In regards to these five pillars the use of vehicle safer accessories can help in decreasing the road accidents like other pillars. Hence, Ministry of Physical Infrastructure and Transportation is conducting a pilot study to increase the safety of the road by installing proximity sensors within the vehicle.

1.2 Proximity sensor

A proximity sensor is a non-contact sensor that detects the presence of an object the target enters the sensor's field. Depending on the type of proximity sensor, sound, light, infrared radiation (IR), or electromagnetic fields may be utilized by the sensor to detect a target. Proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors. Proximity sensors can have a high reliability and long functional life because of the absence of mechanical parts and lack of physical contact between the sensor and the sensed object. The different type of proximity sensor long with their characteristics is shown in Table 1-1.

Table 1-1: Types of proximity sensor

Parameter	Capacitive Proximity Sensor	Inductive Proximity Sensor	Magnetic Proximity Sensor	Optical Proximity Sensor	Ultrasonic Proximity Sensor
Sensing distance (mm)	1-35mm (some sensors up to 70mm)	Up to 60 mm	Up to 80 mm	2-30mm	Up to 1000mm
Vibration tolerant	Excellent	Excellent	Excellent	Excellent	Poor
Sensitivity	Very sensitive to changes in environmental conditions such as temperature and humidity	Adaptable to harsh environments	Susceptible to magnetic interference	Sensitive to dust and lubricants	Temperature variations (since the speed of sound is dependent on temperature)
Sensing object material	The object can be made up of any material	Ferrous metal such as iron and steel. Nonferrous materials sensing range decreases	The object should be of magnetic material only	The object can be made up of any material. (Fails for a transparent object)	The object can be made up of any material. (Works for transparent object)
Cost	Medium	Low	Low	Medium	High
Sie	Small	Small	Small	Small	Small

1.3 Problem statement

Buses and trucks are integral components of urban and rural transportation networks, carrying passengers and goods over long distances. Despite their importance, these large vehicles are prone to accidents due to their size, limited maneuverability, and numerous blind spots. Traditional safety measures often fall short in preventing collisions with nearby objects, pedestrians, or other vehicles, especially in complex traffic environments and during maneuvering operations such as parking or reversing.

The existing safety mechanisms in buses and trucks do not adequately address the risks posed by limited visibility and blind spots, leading to a high incidence of accidents. Drivers often struggle with spatial awareness, particularly in congested urban areas, loading docks, and narrow streets. There is a critical need for an advanced system that can enhance the situational awareness of drivers, reduce the likelihood of accidents, and improve overall safety and efficiency.

1.4 Challenges

- Environmental Variability: Proximity sensors must function accurately in diverse weather conditions (rain, fog, snow) and varying light conditions (day/night).
- Durability and Maintenance: The sensor system must withstand the rigors of daily vehicle operations, including vibrations, dust, and potential impacts.
- False Positives/Negatives: Ensuring that the system accurately detects objects without generating false alarms or missing actual hazards.
- Driver Adaptation: Designing an intuitive interface that provides clear and actionable alerts without causing distraction or confusion for drivers.

1.5 Objective

The main objective of the study is to install proximity sensors for increasing the road safety in Nepal. The study shall be the pilot project for the demonstration of use of proximity sensor to indicate the drivers regarding the clearance within the vehicle.

The specific objectives are:

- To perform research to develop standard design for the installation of sensors in the vehicle and accordingly quantify their output for notification to the drivers
- To install the proximity sensor and hence develop the working prototype
- To demonstrate the use of proximity sensor to notify the drivers regarding the clearance in the back and front of the vehicle
- To develop the baseline for design and specification of components for installation.

1.6 Limitation

Like other projects, this project has the following limitations as given in the points as:

- Any object detected by the sensor is viewed as the vehicle in HMI screen even if that object is not vehicle.
- HMI is programmed to detect the objects or vehicle and display the respective information when they come under the range of two meters.
- There are no regulatory compliances in place for busses and trucks.

CHAPTER TWO: METHODOLOGY

The detailed methodology that shall be followed during the study "Provision of Proximity Sensor in Buses and Trucks (Fabrication and Performance Evaluation)" will be done as shown in Figure 2-1 at Vehicle Fitness Center (VFC), Teku.

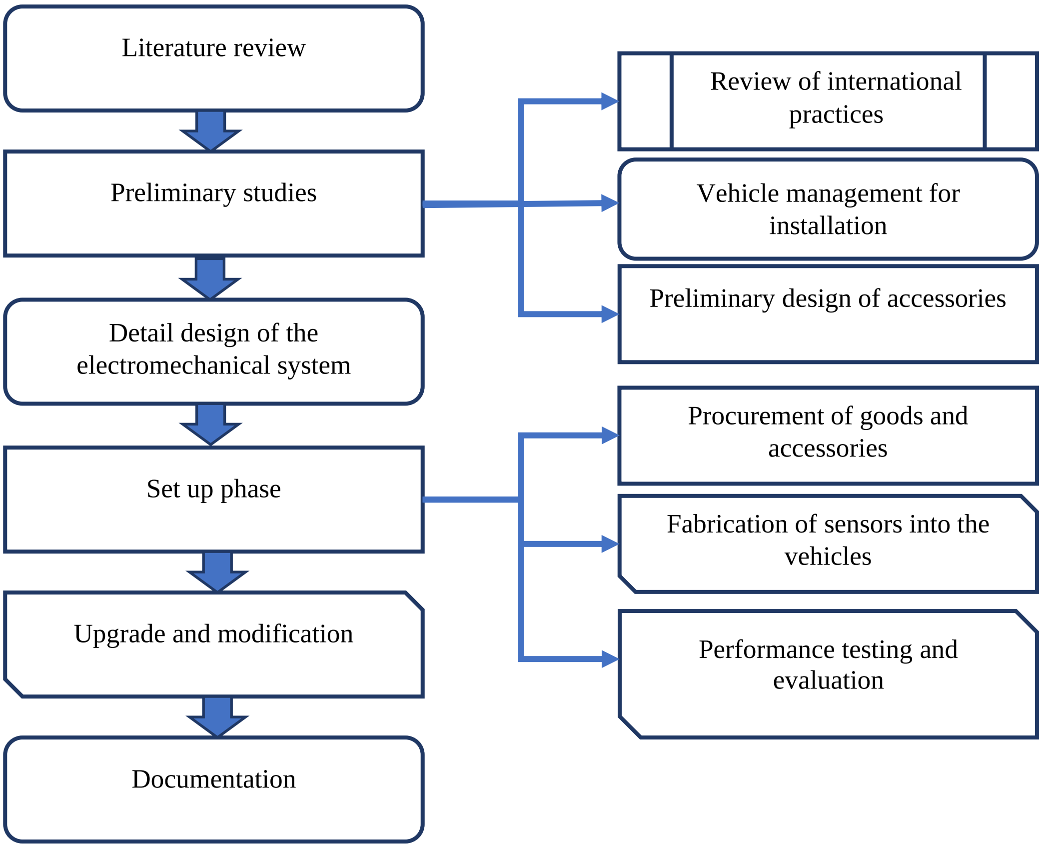

Figure 2-1: Methodological flowchart

2.1 Literature review

The study began with the literature review and continued throughout the research. Various design parameter, guidelines for the design and fabrication of proximity sensor and load sensor in public vehicles have been studied. The detailed design to measure the clearance and weight of vehicles used in different countries have thoroughly been reviewed through peer reviewed papers and journals. In addition to these various components, their specification and use that are required for the installation have been collected and thoroughly analyzed. In addition, all the necessary authorization has been managed in this phase of work.

2.1.1 Evolution of Proximity Sensors

Proximity sensors have evolved significantly since their inception, driven by advancements in technology and the increasing demand for safety and automation in various industries.

- **Early Developments**: The concept of proximity detection can be traced back to the early 20th century with the invention of basic mechanical switches and reed relays. These early devices were simple but laid the groundwork for more sophisticated technologies.

- **Advancements in Technology**: The development of electronic and semiconductor technologies in the mid-20th century led to the creation of more reliable and accurate proximity sensors. Capacitive and inductive sensors became popular for their ability to detect metallic and non-metallic objects without physical contact.
- **Modern Proximity Sensors**: In recent years, the integration of microprocessors and advanced signal processing techniques has significantly enhanced the capabilities of proximity sensors. Modern sensors now offer high precision, extended detection ranges, and robust performance in various environmental conditions.

2.1.2 Design Parameters and Guidelines for Proximity Sensors

The design parameters for proximity sensors in public vehicles are critical to ensuring their effectiveness and reliability. These parameters include detection range, environmental resistance, integration with vehicle systems, and user interface.

- **Detection Range**: The optimal detection range for proximity sensors in buses and trucks typically ranges from a few centimeters to several meters, depending on the specific application. Adjustable detection ranges are essential to accommodate various vehicle sizes and operational scenarios. For example, sensors in large trucks need to detect objects at greater distances to ensure adequate response time for braking or maneuvering. In contrast, sensors in buses might focus on shorter ranges to assist with parking and navigating tight urban environments.
- **Environmental Resistance**: Proximity sensors must be designed to operate reliably under diverse environmental conditions, including rain, fog, and extreme temperatures. This necessitates robust housing materials and protective coatings to prevent damage from moisture, dust, and temperature fluctuations. Sensors must also be able to filter out false signals caused by environmental noise, ensuring accurate detection in all conditions.
- **Integration with Vehicle Systems**: Effective integration with the vehicle's existing systems is crucial. Sensors should seamlessly communicate with vehicle control units, providing real-time data to drivers and onboard systems. This integration can involve connecting sensors to braking systems, steering controls, and driver alert systems. Proper integration ensures that sensor data is utilized effectively to enhance vehicle safety and performance.
- **User Interface**: The Human-Machine Interface (HMI) must be user-friendly and designed to integrate with the vehicle's dashboard, providing clear and intuitive feedback to the driver. The HMI should display sensor data in real-time, alerting drivers to potential hazards and allowing them to take corrective action. Customizing the HMI for each vehicle type ensures better usability and integration, enhancing the overall effectiveness of the sensor system.

2.1.3 Fabrication Techniques for Proximity Sensors

Reviewing international standards and best practices is essential to ensure the sensors' design and fabrication meet global safety and performance requirements.

- **ISO Standards**: The International Organization for Standardization (ISO) provides comprehensive guidelines for the design and testing of vehicle sensors. ISO 26262, for example, outlines functional safety requirements for automotive electronic systems. This standard ensures that sensors meet rigorous safety criteria, reducing the risk of failure and improving overall vehicle safety. Compliance with ISO standards is often required for sensors to be approved for use in various markets.
- **SAE Standards**: The Society of Automotive Engineers (SAE) publishes standards for vehicle sensors, including J1939, which specifies communication protocols for in-vehicle networks. These standards are critical for ensuring sensor compatibility and reliability. The J1939 protocol, for instance, defines how data is transmitted between sensors and vehicle control units, ensuring consistent and accurate communication. Adhering to SAE standards helps manufacturers produce sensors that can be easily integrated into existing vehicle systems, enhancing their functionality and interoperability.

2.1.4 Case Studies and Practical Applications

The successful implementation of proximity sensors requires careful selection and specification of components. Key considerations include the sensor interface, control unit, and installation mechanisms.

- **Sensor Interface (Modbus)**: The Modbus communication protocol is widely used for sensor interfaces, providing reliable and standardized data exchange. This protocol allows for easy integration of sensors with various vehicle systems, facilitating the communication between sensors and control units. Modbus is known for its simplicity and robustness, making it an ideal choice for automotive applications. It supports multiple devices on the same network, enabling comprehensive monitoring and control of the vehicle's sensor systems.
- **Control Unit with Touch Screen Display**: The control unit must be user-friendly and provide real-time data visualization. An intuitive HMI design enhances driver interaction and system usability. The touch screen display should present sensor data clearly, allowing drivers to quickly assess the situation and respond appropriately. Features such as visual and auditory alerts can further improve the effectiveness of the control unit by drawing the driver's attention to critical information.
- **Fittings, Wiring, and Assemblage Mechanisms**: Proper installation of sensors requires high-quality fittings, wiring, and assemblage mechanisms. These components ensure that the sensors are securely mounted and function reliably under various conditions. The choice of fittings and wiring should account for the vehicle's operational environment, ensuring resistance to vibration, temperature fluctuations, and moisture. Installation mechanisms should also facilitate easy maintenance and replacement of sensors, minimizing downtime and ensuring continuous operation.

2.1.5 Authorization and Compliance

Ensuring necessary authorizations and compliance with regulatory requirements is a crucial aspect of the project. Key steps include regulatory approvals and testing and certification.

- **Regulatory Approvals:** Obtaining approvals from relevant transportation and safety authorities is essential for legal compliance. This process involves demonstrating that the sensors meet all applicable safety and performance standards. Regulatory approvals ensure that the sensors are safe for use in public vehicles and comply with local and international regulations.
- **Testing and Certification:** Rigorous testing and certification are required to verify sensor performance and reliability. Testing protocols and certification procedures for automotive sensors ensure they meet the necessary standards. These tests assess various aspects of sensor performance, including accuracy, durability, and environmental resistance. Certification from recognized authorities provides assurance that the sensors are fit for purpose and can be trusted to perform reliably in real-world conditions.

2.2 Preliminary phase

In this phase of work, the team of researcher in coordination with the Ministry of Physical Infrastructure and Transport and vehicle fitness center has managed the vehicle for the installation and testing of the vehicle sensor. In addition, the researcher has thoroughly studied the design of the vehicle and checked for the spots where the sensors can be installed. As much as possible, the sensors have been installed in blind spots so that they cannot be observed directly. Finally, the preliminary design of the accessories has been developed.

2.3 Detailed design

The detailed design of the accessories has been done in this phase of work. Based on the specification of the various components and preliminary design, detail electro-mechanical design showing each and every component from different angles has been drawn using. The detailed mechanical design has been done using SolidWorks. Similarly, the positioning of sensors along with various electrical parts shall be highlighted in the design. The design has been done in such a way that each and every component are easily accessible for repair and maintenance while being kept hidden from direct field of vision. The detail design has also included the in-detail specifications of each and every component required.

Automobile-grade sensors and accessories were identified and used for the design purpose. Modbus modules were selected to transfer data easily over long distances. Modbus is selected in industrial environments for its low sensitivity to noise and ability to transfer data up to 1200 meters.

The design included the hardware component and the software component of the system. UI/UX was also developed for the controller to track and monitor testing results. This was helpful in showcasing the capabilities of the system and also in formulating further courses of action. Overall, the design involved selecting appropriate sensors, developing the necessary hardware and software, integrating the system with the vehicle, and ensuring durability and reliability under various conditions. The detailed design process is listed below:

1. Sensor Selection

For comprehensive coverage, a combination of ultrasonic, infrared, and radar sensors was used.

- Ultrasonic Sensors: Used for short-range detection, especially useful for parking and obstacle detection in tight spaces.
- Infrared Sensors: Employed for close-proximity object detection and providing redundancy for ultrasonic sensors.

2. System Architecture

The system architecture includes the following components:

- Sensors: A combination of ultrasonic, infrared, and radar sensors placed at strategic locations.
- Microcontroller: A central processing unit ATmega2560 was used to process sensor data.
- Power Supply: A stable power source with protection against voltage spikes.
- Communication Interface: CAN bus or UART for communication between the microcontroller and vehicle systems. In our case the wire length could be more than 10 meters, so MODBUS protocol based RS485 is used.
- User Interface: Display and alert system integrated into the vehicle's dashboard for driver notifications.

3. Component Specifications

Ultrasonic Sensors:

- Model: 89341C
- Range:15 cm to 6 m for targets larger than 0.5 m2
- Operating Voltage: 12V

Microcontroller:

- Model: ATmega2560
- Features: Multiple I/O pins, UART, SPI, I2C interfaces

Power Supply:

- 12V to 5V DC-DC Converter (for sensors)
- 12V to 3.3V DC-DC Converter (for radar sensor)

4. Circuit Design

Power Supply Circuit:

- Connect the vehicle's 12V battery to DC-DC converters to step down the voltage to 5V and 3.3V for sensors and microcontroller.

Sensor Connections:

- Ultrasonic Sensors: Connect trigger and echo pins to the microcontroller's digital I/O pins.
- Infrared Sensors: Connect output pins to the microcontroller's analog inputs.
- Radar Sensors: Connect data output to the microcontroller's UART or SPI interface.

Microcontroller Connections:

- Power the microcontroller using the 5V output from the DC-DC converter.
- Connect a CAN bus transceiver to the microcontroller for vehicle communication.
- Interface an LCD display and buzzer to provide visual and auditory alerts to the driver.

Alert Generation:

- Define distance thresholds for generating alerts (e.g., warning at 2 meters, critical alert at 1 meter).
- Develop algorithms to prioritize alerts based on the severity and proximity of detected objects.

User Interface:

- Display real-time sensor data and alerts on the LCD screen.
- Trigger auditory alerts using a buzzer when an object is detected within critical distance.

System Integration:

- Implement communication protocols to send processed data and alerts to the vehicle's central control unit via CAN bus.

6. Enclosure Design

- Design waterproof and dustproof enclosures for sensors to protect them from environmental conditions.
- Use materials such as ABS plastic or polycarbonate for durability.
- Ensure proper mounting brackets to securely attach sensors to the vehicle body.

7. Testing and Calibration

Laboratory Testing:

- Set up a test rig to simulate various obstacles at different distances and angles.
- Test sensor accuracy, range, and response time under controlled conditions.

Field Testing:

- Install the system on a test vehicle (bus or truck).
- Conduct tests in real-world environments, including urban areas, highways, and loading docks.
- Collect data on sensor performance, false positives/negatives, and driver feedback.

Calibration:

- Fine-tune sensor thresholds and algorithms based on test results.
- Ensure that sensors are properly aligned and mounted for optimal performance.

8. Performance Evaluation

Accuracy:

- Measure the system's ability to detect objects and avoid false alarms correctly.

Range:

- Evaluate the effective detection range of each sensor type in different conditions.

Response Time:

- Assess the time the system takes to detect objects and alert the driver.

Reliability:

- Test the system's performance under various environmental conditions (rain, fog, night driving).

Driver Feedback:

- Collect and analyze feedback from drivers on the usability and effectiveness of the alerts.

2.4 Set up phase

This was one of the most important phases of work and included all the activities related to the hardware installation and testing. After the confirmation regarding the proper working of each module, all the components were integrated. The main tasks in this phase of work are shown in Figure 2-2.

Figure 2-2: Tasks in Set up phase

2.4.1 Procurement of goods and components

Based on the specifications developed and detailed design, Bill of quantities of goods and accessories have been prepared. A market survey was conducted to determine the cost and availability of different components. In case the components were not available in the country; components had been procured from nearby countries like India and China through proper channels of distributors and suppliers. Different vendors listed in our organization were contacted to supply the required components. Based on the nature of components and phases of development two slabs were made for procurement. Few vendors were ready for supplying the components so we published public notice for the procurement. We received quotations from four different vendors and we selected the one to award the purchase order based on the price and specification of the items offered.

Fabrication experts from our team confirmed the specifications of the supplied components. We were able to acquire all the required components for the project from two different vendors in two phases. The specifications of the acquired components are listed in the Table 2-1 .

Table 2-1: Specification of procured goods and components

S.N.	Particulars	Specification	Reference Model
1.	Proximity Sensor	• Sensor type: Analog • Frequency: 40KHz +/- 10 KHz • Water proofing: IP55 or above • Static Capacitance: 2000 +/- 15% pF • Input voltage Max: 140V(p-p) at 40KHz	89341C

		• Decay time: <5ms • Echo Sensitivity: >150mV • Horizontal Angle: 45 degree or above • Vertical Angle: 50 degree or above • Detection Range: .22 mm to 22.5 meter • Working Voltage: 10 to 28 VDC	
2.	Control Unit	Controller supporting RS 485 and have extra ports for connecting data link, data download and configuration port Weight display Program, Sensor Selection feature, setting distance indication with alarm and Buzzer	Customized
3.	HMI Unit with Program	• Digital display: 7 inches with touchscreen • Color: 16.7M(16777216) colors • Panel Type : IPS • Viewing Angle: 85/85/85/85 (L/R/U/D) • Active Area (A.A.): 94.20mm (W)*150.72mm (H) • Visible Area (V.A.): 94.60mm (W)*151.12mm (H) • Resolution: 800*1280 Pixel • Backlight: LED • Brightness: 300nit	DMG12800C070_32WTC
4.	Sensor Interface	• Sensor Interface with 4 Port compatible with multiple sensor with serial communication • Low power module with integration capability with controller or stand alone as well	Customized
5.	Wireless module	• Quad-band 850/900/1800/1900MHz • GPRS class 2/10 • Input Voltage : 9V-12V DC • Control via AT commands (3GPP TS 27.007, 27.005 and SIMCOM enhanced AT command set) • Configurable baud rate • Built-in SIM Card holder • Built-in Network Status LED	SIM800A
6.	Integrated Stop Sign	• Customized to warn the vehicle approaching from behind	Customized

2.4.2 Development and accessories testing

The Software portion was divided into sensor interfacing and display module. The sensor interfacing was completed using Modbus protocol. For the display module, the UI/UX was developed in Figma and the design was later programmed into the display module using the interface provided by DWIN instruments.

The sensor interface was programmed in embedded controller with acted as a bridge between the sensor and the display unit.

The hardware was further prepared to be assembled in a single enclosure which could be mounted in the vehicle itself. Sensor calibration could be done in each vehicle since the vehicle series have not been identified for the application of the senser system. For this stage it can be programmed to be placed in any generic vehicle.

2.4.3 Fabrication and installation

The proximity sensor system was fabricated in this step. The components procured were utilized to fabricate the vehicle safety accessories within the vehicle. The fabrication and instrumentation were done by the experts in close consultation with Ministry of Physical Infrastructure and Transport and was done in one vehicle provided by the vehicle fitness center. The components were installed systematically in such a manner that that there was no obstacle in the installation and also all the components can be easily accessible for repair, maintenance and replacement.

To ensure the quality and track the progress of fabrication along with cost of project, earned value analysis have been conducted in various steps. The safety of the manpower took the priority and every measure were ensured to minimize the accidental hazards. It was also ensured that the fabrication of the vehicle safety accessories was based on design and followed various national and international standards and was suitable in context of Nepal.

2.5 Upgrade and modification

Finally, the proximity sensor system has been tested for the accuracy, reliability and durability in different conditions. The test results were then be evaluated to develop the baseline criteria for these accessories. The researcher modified and upgraded the system for better performance and reliability while reducing the cost. The modifications have been done in coordination with Ministry of Physical Infrastructure and Transport and other stakeholders.

2.6 Documentation

All the information regarding the design, testing and modification along with cost benefit analysis have been utilized to develop the final report. The revised final report shall be submitted after incorporating comments, feedbacks and suggestions from various stakeholders. The findings of the research along with demo of proximity sensor in transportation shall be presented among stake holders.

2.7 Feasibility Analysis

The feasibility analysis reveals critical insights into the practicality of implementing detection systems with varying ranges. A 60-meter detection range was evaluated and found impractical due to current technological limitations and environmental factors, such as the interference of foggy weather with Lidar performance. This analysis highlights that while the long-range detection capabilities are beyond our reach, a shorter 6-meter detection range is achievable and practical for immediate implementation. The challenges associated with integrating a fully functional computer system into the detection process require further detailed study, as the present state of technology does not support immediate feasibility. This underscores the importance of focusing on more immediate, attainable goals while continuing to advance research and development for future technological enhancements.

2.8 Sensor Technology Considerations

The analysis of sensor technology considerations highlights the strengths and limitations of various systems. Radar technology emerges as suitable for longer ranges and remains reliable in adverse weather conditions, making it a robust choice for consistent performance. Cameras for road vehicle mapping provide essential visual context, complementing other sensor technologies to enhance overall system accuracy. Ultrasonic sensors, while effective for shorter ranges, face limitations in foggy conditions, reducing their reliability in such environments. Similarly, Lidar offers precise mapping capabilities but also proves ineffective in foggy weather. This evaluation underscores the need to integrate multiple sensor technologies to mitigate individual limitations and achieve comprehensive, reliable detection in diverse operating conditions.

CHAPTER THREE: RESULTS AND DISCUSSION

3.1 Preliminary design output

Figure 3-1 shows the preliminary output of the device developed for distance sensing and alerting system. The proposed design makes use of four radar sensors which are attached to the front and back bumper of the vehicle. Two sensors are placed in forward direction and two at the back. The sensor transmits modulated waves out to the surrounding and measure the reflected waves to calculate the distance of any possible object in front of the sensor. These sensors shall help detect the objects that are located around the vehicle. The number of sensors can be added in the system to increase the coverage. The controller communicates to each of the radar sensor and updates the status in 500 milliseconds. This way the object tracking can be done accurately even for the moving objects.

Figure 3-1: Distance measurement in real time

The working of the controller, sensor and display modules are confirmed in different stages. Road testing is set to be carried out once the suitable vehicle for testing is made available. The road testing has been carried out in coordination with the vehicle testing center in Teku.

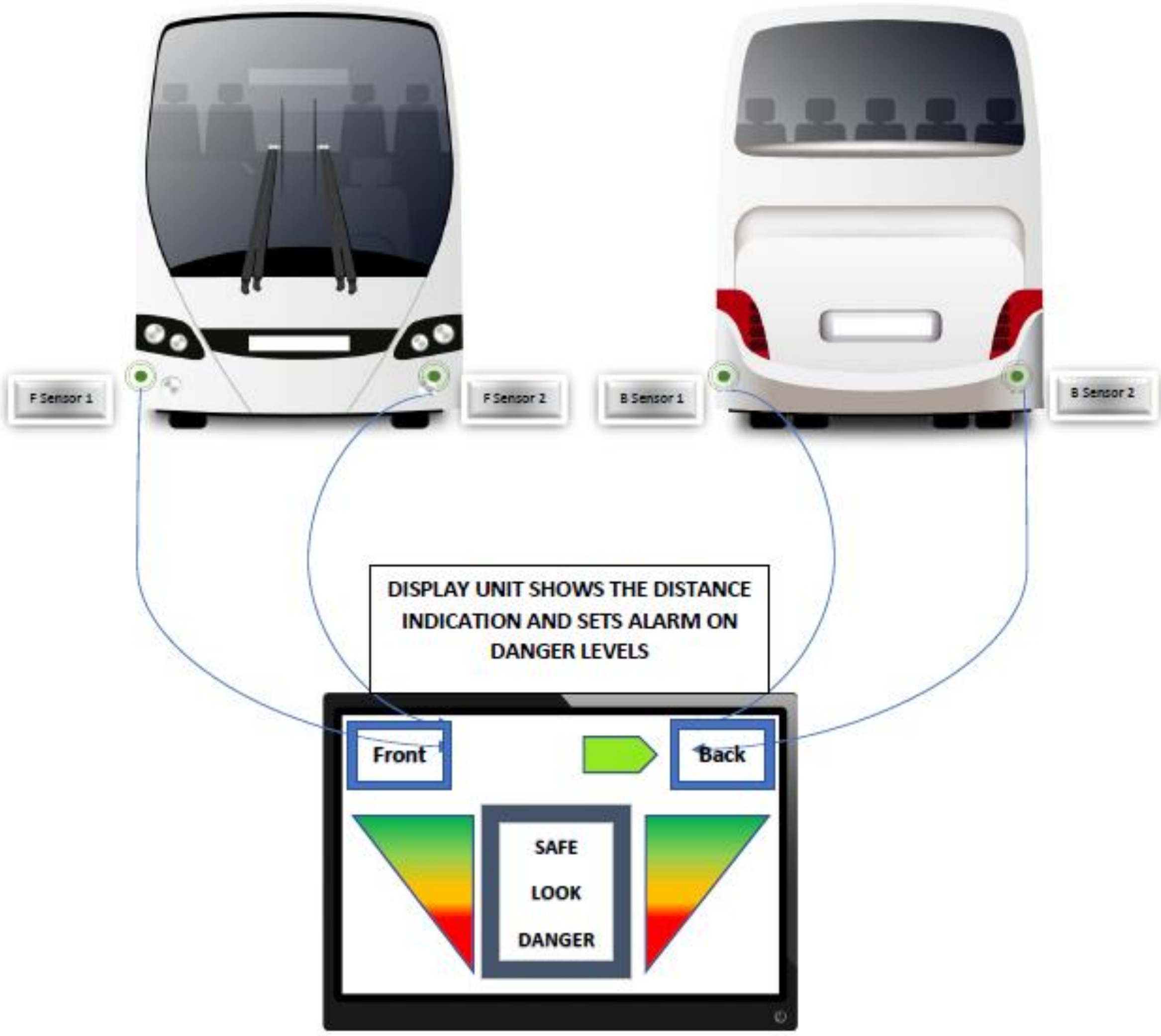

Figure 3-2: Preliminary design of the distance monitoring system

The major components of the design are:

3.1.1 Controller

This controller utilizes the feedback from the radar sensor to locate or measure the distance of obstacle in front. Since the sensor relies on the returning waves they work best for solid surface or objects. The sensor emits modulated ultrasonic waves and the receiver of the sensor also detects the same emitted signal after it bounces back of any obstacle. The sensor is designed to function between 20 centimeters to 20 meters. The sensing distance decreases if the coverage angle is increased since the signal power is dispersed in the wider distance.

The controller is equipped with a Modbus connection for sensors up to 200 meters. The controller has functionalities to be connected to other peripherals as required. Output is shown in a seven-inch HMI display which also acts as an input device through the touchpad. The casing of the controller is designed to fit all the components inside it and a connector is provided to connect the sensor which is located outside the vehicle.

Figure 3-3: Control unit used in the design

3.1.2 Modbus

Modbus RS485 is a protocol which defines the message structure and communication rules in the network. It uses differential signaling, which provides noise immunity and allows the communication over longer distances. The Figure 3-4 shows the Modbus communication testing after connecting the sensor and controller. The Modbus hardware was configured to transfer the distance signal received from the sensor into digital signal and passing the message over to the controller in RS485 protocol. One Modbus module is capable of handling multiple sensors too, which is useful in interfacing other sensors that will be placed in adjacent suspensions.

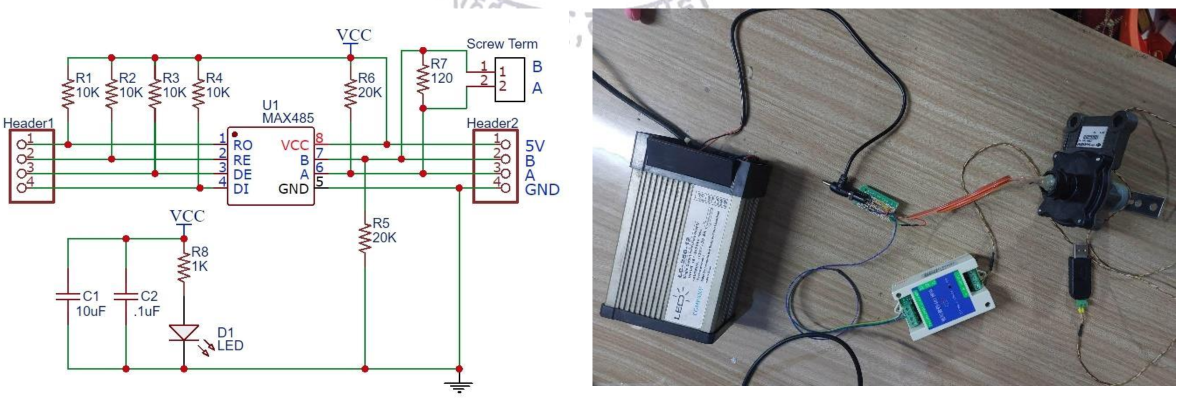

Figure 3-4: Circuit design and hardware connection of modbus

3.1.3 Control Unit/HMI

HMI stands for Human Machine Interface, which consists of the display module which may have keypads for inputs or simply touchscreen. But, the one which was used for this project is touchscreen, without keypads for any inputs. The HMI is equipped with a 7-inch display with all of the control system components encased behind it. The control covers of a signal conditioner, data logger, and storage along with the cloud communication system. The cloud communication channel is placed in the controller but the cloud connectivity is left open for further development. The display of the control unit is designed in such a way that the drivers will be able to identify the necessary data immediately. The screen displays the distance measured by the individual sensors, along with information of side from which object is approaching or located. The HMI screen is programmed to show waring message and inform the vehicle operator about the location of the sensed obstacle.

One more feature is that whenever some obstacle is detected at the back of the vehicle it activates a stop sign which is placed at the back of the vehicle. This will help indicate the vehicle behind about the close distance and will help avoid unsafe parking or stopping behind vehicles in traffic jams.

3.1.4 Cloud Connectivity

Cloud connectivity is the basic element in today's technology where Internet of Things has been the global concept. It enables the organization to have the advantages of being scalable, flexible and information or resources can be accessed from anywhere. The system has a medium for cloud communication, which can be used to transmit the vehicle position and loading condition. The data can be further analyzed as required.

3.2 Output on test vehicle

After the individual functionality of the controller was checked and verified. The device was installed on a vehicle available for test. The vehicle was provided by the Vehicle Fitness Testing Centre. The sensor covered an angle of 30 degree as per the specification. After installation it was noticed that the sensor could sense objects within that range. The Figure 3-5 shows the principle behind it.

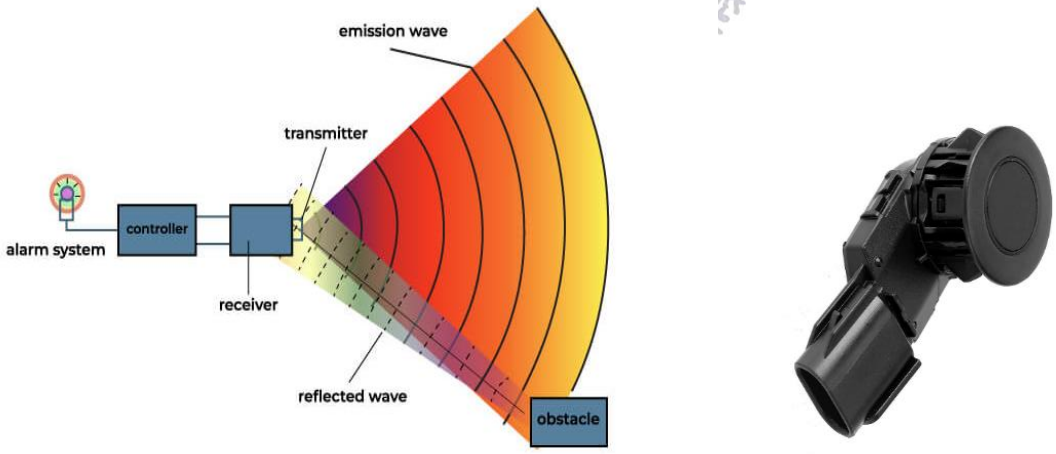

Figure 3-5: Working of proximity sensor

The sensor is waterproof (rated IP67) and the signal source and receiver are aligned concentric to one another. The vehicle under testing is described as below:

Vehicle under test: Bolero B6 car

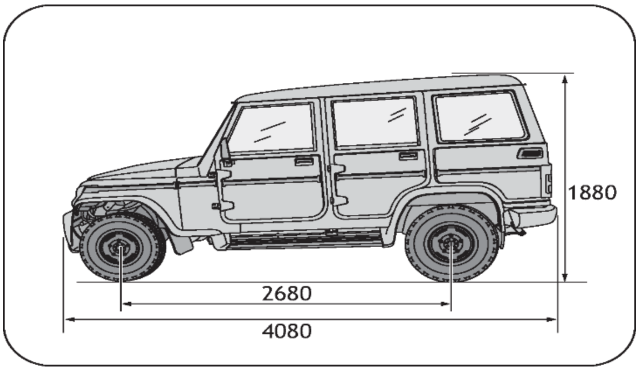

Figure 3-6: Test vehicle dimension

Figure 3-7 shows the device output when object is detected on any side. If obstacle is detected by multiple sensors, each distance is plotted in the display by the controller.

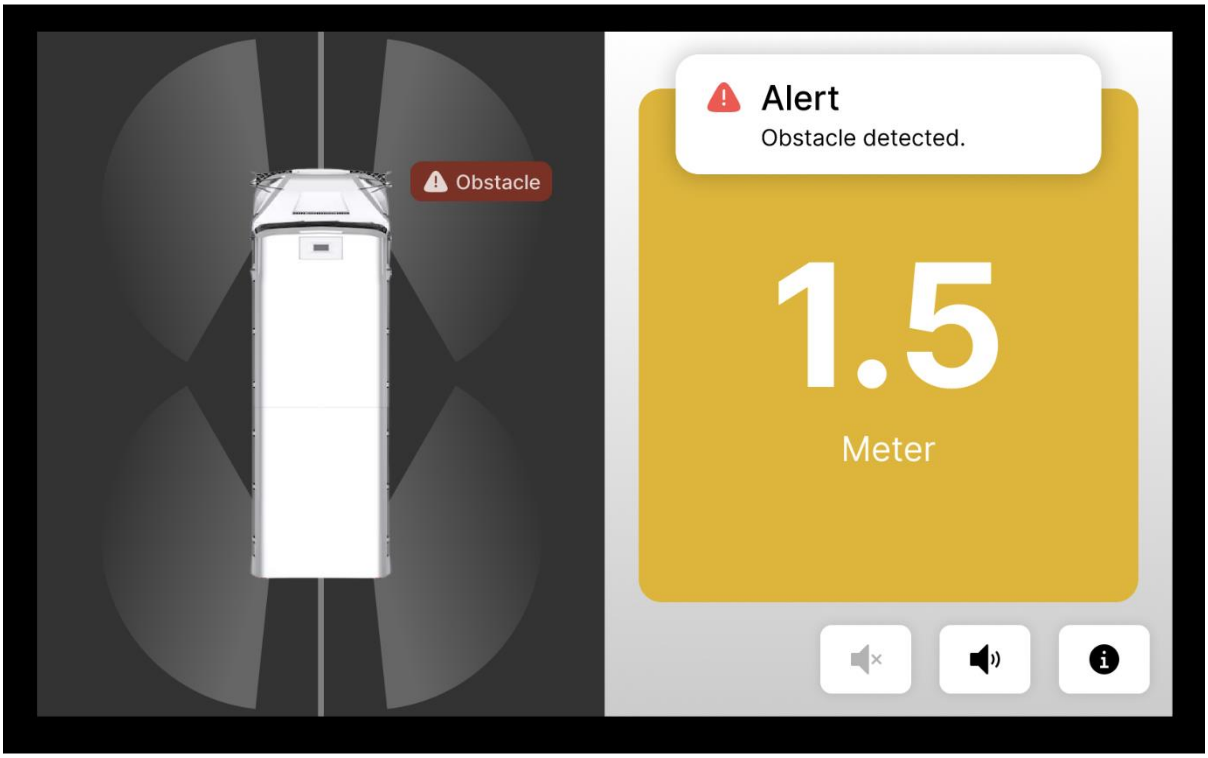

Figure 3-7: Obstacle detection by sensor

The individual sensors are operated individually and the controller shows an alert message when an obstacle reached distance lower than the marked one (threshold of the safe distance can be set). When the obstacle approaches from the rear side of the vehicle and reaches the distance of 2 meter, the rear warning board gets activated and warn the driver of the approaching vehicle. The designed and installed warning board is shown in the Figure 3-8.

Figure 3-8: Rear warning board

3.3 Working methodology

The number of proximity sensor installed in the vehicle is four, two in the front and two in the rear bumper respectively. When the sensors sense any obstacles around the vehicle, they send the signal to the control unit. inside the control unit, firstly, the received signals are filtered by the signal conditioner through the use of either a PID controller or a fuzzy logic. The micro controller/control unit is programmed to detect the objects if the distance between the vehicle and approaching vehicle is 2 meters, and the warning beeping sound is activated if the distance reaches to 1.5 meters. Here, the external noise and disturbances are filtered out and only the actual signal is passed to the next step where the signal is manipulated to get the actual distance between the vehicle and the obstacle. This data is displayed in the HMI screen and stored in the system itself as well as in a cloud storage for remote accessing. Actually, the HMI displays the warning messages about the approaching object i.e., side from which it is approaching along with distance from that vehicle. The stop sign board is also attached to the rear side of the vehicle to warn the driver if his/her vehicle approaches very near to the vehicle. It is also same if the obstacle or vehicle is in the front side of the vehicle, HMI screen displays the distance between the vehicle and obstacles with warning message except its location. The electrical circuit design for the system is shown in Annex I. The basic circuit connection between sensor and HMI screen is illustrated in the Figure 3-9.

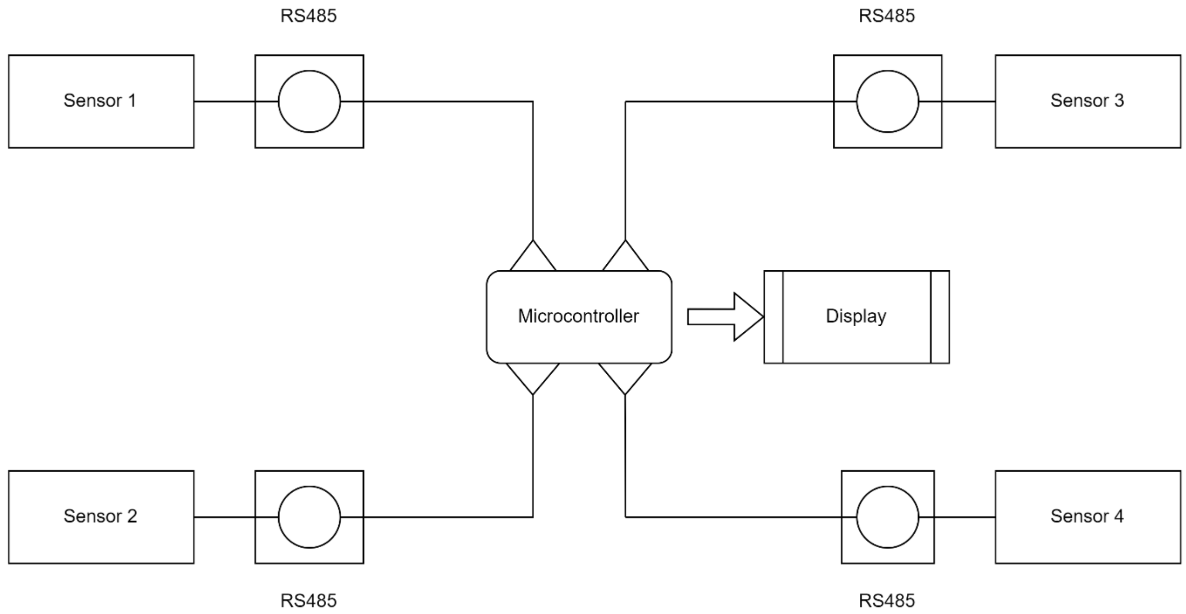

Figure 3-9: General sensor circuit representation

3.4 Selection of sensor

Among various proximity sensors, the sensors which were used in the testing vehicle are ultrasonic sensor. As the nature of project which requires to detect the object coming under the proximity of the vehicle. So, there is need of continuous sending and receiving the information which makes it suitable to choose the ultrasonic sensor for this project. Some of the advantages that chosen sensor over sensor are given in the following:

- Gives the precise distance measurement over a longer range.
- More robust in challenging environments with airborne particles, making it suitable for outdoor installation.
- Allows non – contact distance measurement and object detection.
- Can detect various wide range of objects including solid surfaces, liquids, and powders of any materials, shapes and sizes.
- Work effectively with both metallic and non – metallic materials.
- Easy to install and set up and don’t require direct line-of-sight for detection, making it more flexible in installation configuration.
- Not affected by the color or transparency of the objects.

Even though the ultrasonic sensors offer several advantages, but like other sensor, it is important to consider specific application requirement and potential limitations:

- It does have limitation in accuracy when it is used for short distance measurement.
- It is temperature sensitive i.e., extreme temperature may affect the performance of this sensor.
- Some materials can absorb the sound which can impact the accurate working of ultrasonic sensors.
- Ultrasonic sensors may have blind spot where it is unable to detect the objects. This causes the requirement of a greater number of sensors which may make it more costly.

3.5 Communicator

The raw data sensed by the sensor must be channelized to the microcontroller for the further processing. Those raw data are channelized and collected using Modbus protocol since it gives the data transmission rate of 10 Mb/sec. After the raw data reached to the microcontroller, it is processed and analyzed, giving the required output or info in HMI screen. The raw data of the sensor is analyzed in order to determine whether the objects are within the sensor range and, if detected, the distance between vehicle and objects is displayed in the HMI screen, along with side of objects in reference to vehicle. The HMI is programmed to activate the alarm with alert system when the object comes very near or designated distance. It is also equipped with warning board which warns the rear driver when they come very near to the vehicle.

3.6 Testing and validation

After the installation of sensor and HMI, along with wire connectors and warning board with alarm in the given in the provided test vehicle, the vehicle was brought in to test the working of the system. To confront the proper working of the sensor with associated HMI accessories, the test was done by tracking the obstacle after making it to come under the designed proximity area of the vehicle. Following Table 3-1 represents the data of the experiment to calculate the distance between the obstacles and vehicle sensed by the sensors as:

Table 3-1: Experimental data for proximity sensor

S.N.	HMI displayed distance (m)	Remarks (Alert messages)
1.	2	Obstacle detected and approaching from the left
2.	1.7	Obstacle detected and approaching from the left
3.	1.5	Obstacle detected and approaching from the left, and alarm and warning board activated
4.	1.4	Obstacle detected and approaching from the left, and alarm and warning board activated
5.	0.4	Obstacle detected and approaching from the left, and alarm and warning board activated
6.	0.3	Obstacle detected and approaching from the left, and alarm and warning board activated

Table 3-1 represents the data taken when the obstacle approached from the rear. When the obstacle was taken to the front of the vehicle, the HMI screen displayed the alert message “Obstacle detected” only, i.e., without the information of distance so that the driver clearly got the idea that the obstacle was in the front part of the vehicle.

3.7 Upgrades after testing and demonstration

During the demonstration of the provision of parking sensor some changes in the setup was proposed. The flowchart showcasing the steps followed for the necessary upgrades is mentioned in the Figure 3-10.

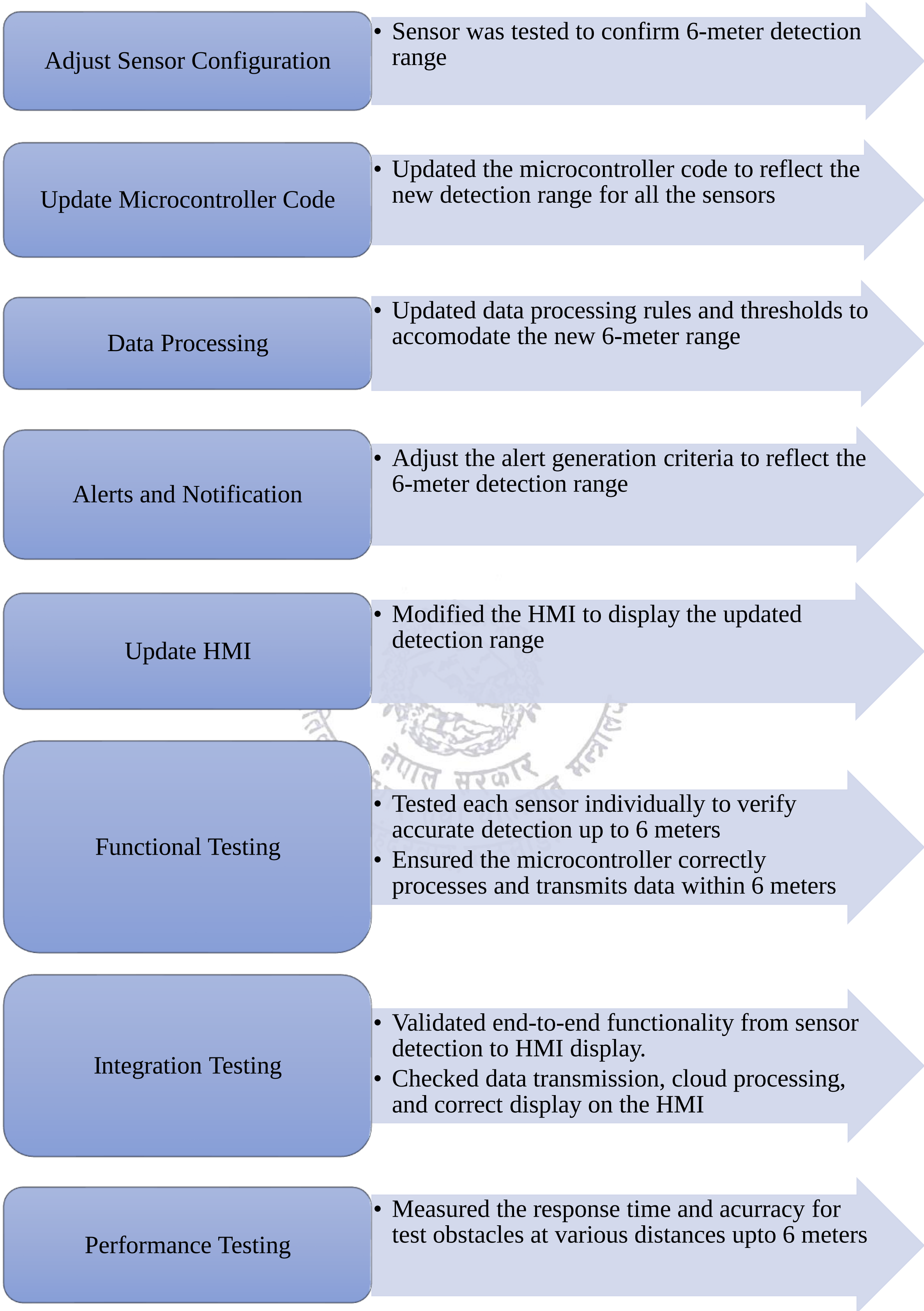

Figure 3-10 Steps for upgradation

By following these steps, the proximity sensor system was effectively updated to a 6-meter detection range, and the corresponding data will be accurately displayed on the HMI. The list of functionalities and the changes made are listed and discussed in following sections.

3.7.1 Changing the detection range of the sensors to 6 meters and displaying the same in the HMI

The distance display was programed to be visible after the vehicle reaches two meter distance. Since the sensing capacity of the ultrasonic sensor used is six meters the limit in the program was also changed to six meters. Also, front distance in display was prioritized if the sensor sensed object in both front and back. The system is capable of changing the operation range form 0-6 meters as required and setting the priority for front or back detection. The prioritization can be done based in the use case. For parking purpose, back sensor can be prioritized whereas for front object detection, different sets of seniors can be prioritized. The system gets distance reading from all the sensors so setting up functionalities can be configured from the HMI itself.

There is only one sensor to adjust the distance sensitivity. Moreover, to change the detection range of the sensors to 6 meters and display the updated range on the Human-Machine Interface (HMI), the threshold need to be updated where the distance starts popping up in the screen. There are thresholds for:

- Showing in the screen
- Alert for yellow
- Alert for orange
- Alert for Red and Beep sound

3.7.2 Possibility of detection of objects during bad weather

One the major points that came up and discussed as the possibility to detect the object ahead of vehicle during bad weather. For object detection and mapping, commonly available technologies are LIDAR and SONAR. Light based sensors will not be useful in case of poor visibility.

The detection range was expected to be 60m to 100m for which high power sonar is required and the sensor should be able to map the surrounding based on the readings form each direction focusing on the forward section. Installing such technology is not possible under the scope of our current work. But Artificial Intelligence /Machine Learning based estimation techniques are applied in combination to existing map data, vision sensor, and SONAR. This is more of a sensor fusion and localization type of problem.

We can always look forward to catch up to the latest technological trend. But the methods, resource, and complications associated with those type of research is also challenging.

3.8 Design Considerations of the system for future installations

The project requires precise design considerations for the components used. The core components of the sensor set include a Proximity Sensor, Control Unit, HMI Unit with Program, Sensor Interface, and an Integrated Stop Sign customized to warn vehicles. The development of these components as a system can be approached through two primary methodologies: Integration with Vehicle and Stand-alone Approach.

3.8.1 Integration with Vehicle

The Integration with Vehicle approach involves tailoring the sensor components specifically for each type of vehicle. This method ensures that each system is optimized for the particular protocols and standards of the vehicle manufacturer, in this case, the Mahindra Bolero Geep. Key aspects include:

- **Vehicle-Specific Protocols and Standards**: Each vehicle has unique communication protocols and operational standards. The sensor system must be designed to seamlessly integrate with these specific requirements to ensure optimal functionality.
- **Custom Proximity Sensor**: The proximity sensor needs to be calibrated to the vehicle's dimensions and operational characteristics. For example, the detection range may need to be adjusted to suit the vehicle's size and the typical operating environment.
- **Control Unit Adaptation**: The control unit should be designed to interface efficiently with the vehicle's existing electronic control systems, ensuring seamless data exchange and operation.
- **HMI Unit Customization**: The Human-Machine Interface (HMI) must be user-friendly and designed to integrate with the vehicle's dashboard layout, providing clear and intuitive feedback to the driver.
- **Sensor Interface and Stop Sign Integration**: The sensor interface should facilitate efficient communication between the sensor and control unit. The integrated stop sign needs to be customized to the vehicle's rear design, ensuring it is clearly visible to trailing vehicles.

This vehicle-specific approach ensures that the proximity sensor system is finely tuned for each vehicle type, providing maximum efficiency and safety.

3.8.2 Stand-alone Approach

The Stand-alone Approach aims to develop a universal sensor system compatible with various types of vehicles, facilitating mass production and cost efficiency. Key considerations include:

- **Universal Compatibility**: The sensor set must be designed to work with a wide range of vehicles, regardless of manufacturer-specific protocols. This requires a flexible design capable of interfacing with different vehicle systems.
- **Mass Production Benefits**: By standardizing the design, components can be mass-produced, significantly reducing costs. This also allows for the sharing of Research and Development (R&D) expenses across a broader production base.
- **Compact Integrated Controller**: Developing a more compact form of the controller, combining the Modbus, Controller, and HMI into a single unit within the HMI, streamlines installation and reduces space requirements.
- **Proximity Sensor Versatility**: The proximity sensor should have adjustable parameters to suit different vehicle sizes and operational environments, enhancing its versatility.
- **Universal Control Unit**: The control unit must be designed to interface with a variety of vehicle electronic systems, ensuring reliable performance across different models.
- **Flexible HMI Design**: The HMI unit should offer a customizable interface that can be tailored to different vehicle dashboards while maintaining ease of use and clear driver feedback.

- **Standardized Sensor Interface and Stop Sign**: The sensor interface should be standardized to facilitate easy integration with the control unit, and the integrated stop sign should be designed to fit a range of vehicle rear designs, ensuring visibility and effectiveness.

This approach focuses on creating a versatile, cost-effective solution that can be easily adapted to various vehicle types, making it ideal for large-scale implementation.

Both of the approaches offer distinct advantages for the development and implementation of proximity sensor systems in buses and trucks. The vehicle-specific method provides optimized performance linked to individual vehicle types, while the stand-alone approach emphasizes cost efficiency and universal compatibility. By considering the design and specifications of the sensor set components—Proximity Sensor, Control Unit, HMI Unit with Program, Sensor Interface, and Integrated Stop Sign—future installations can be developed to meet the diverse needs of the transportation industry, enhancing safety and operational efficiency across various vehicle platforms.

3.9 Cost and Expenses of the Project

The total expenses of the project are shown in Table 3-2.

Table 3-2: Budget and Expenses

S.N.	Components	Estimated Price (NRs.)	QTY	Amount (NRs.)
1.	Proximity Sensor	25,750	4	1,03,000
2.	Control Unit	1,97,000	1	1,97,000
3.	HMI Unit With program	1,40,000	1	1,40,000
4.	Sensor Interface	27,500	4	1,10,000
5.	Wireless module	25,000	1	25,000
6.	Integrated Stop Sign	25,000	1	25,000
Total				6,00,000
Total Quotated Amount including R&D, manpower and installment cost				6,50,000
VAT				84,500
Grand Total				7,34,500

CHAPTER FOUR: CONCLUSION AND RECOMMENDATION

4.1 Conclusion

During the conduction of this assignment, the researchers installed proximity sensor in a test vehicle with an aim of increasing the road safety of the vehicle. For the completion of the project, the researchers developed a standard design for the installation of proximity sensors which would sense the distance of obstacle from the vehicle and display the output accordingly and notify the drivers. The researchers further programmed the HMI screen for the proper display of information and the installation of sensors was done with the help of expert. As expected, the sensors were working properly, it was able to detect the objects and showed the distance between them and test vehicle with negligible error when the objects were brought in the designed range. The notification messages were displayed in HMI screen about the information of approaching vehicle with distance and the side. When approached very near, alert message was displayed and the warning board got activated, alerting the objects coming from rear end. About the front one, alert message with distance between the vehicle and obstacle were displayed and detected. The installed system worked properly and displayed the distance of the vehicle from an obstacle on the display unit, HMI. The researchers recommend the use of this system as a baseline for the future innovation in this field of studies.

A significant portion of the vehicle accidents occurring in Nepal are caused by the collision of vehicles with different obstacles, including the other vehicles. The sensor system alerts the driver of any approaching obstacle which in turn allows the drives to avoid the obstacles in time increasing the safety of the vehicle and the people inside the it. Not only this, the provision of warning board will warn the other driver approaching from rear side, which will play a great role in decreasing road accidents caused by the collisions.

4.2 Recommendation

Conducting this project, we faced various problems and challenges regarding different factors like site ground layout, etc. To have better result when conducting these types of projects, following are the recommendation as suggested by our team:

- Placement of the sensor is found to be the challenging one so if the testing was done in the vehicle with in built position for the sensor, that would provide better and uniform result from each sensor.
- HMI screen is unable to identify the object found in the proximity of the sensor as it displays the information of that objects as if the vehicle is approaching, even if it is not. The identification of object, whether it is living or non – living, would definitely help the driver to make the correct decision.
- Even the used sensor is ultrasonic sensor, it would be better to try other type of sensors and conduct a comparative study on proximity sensor. This would give us a great opportunity to consider all the factors like cost, accessibility and easiness in installation and familiarization with HMI screen and functions.

CHAPTER FIVE: REFERENCES

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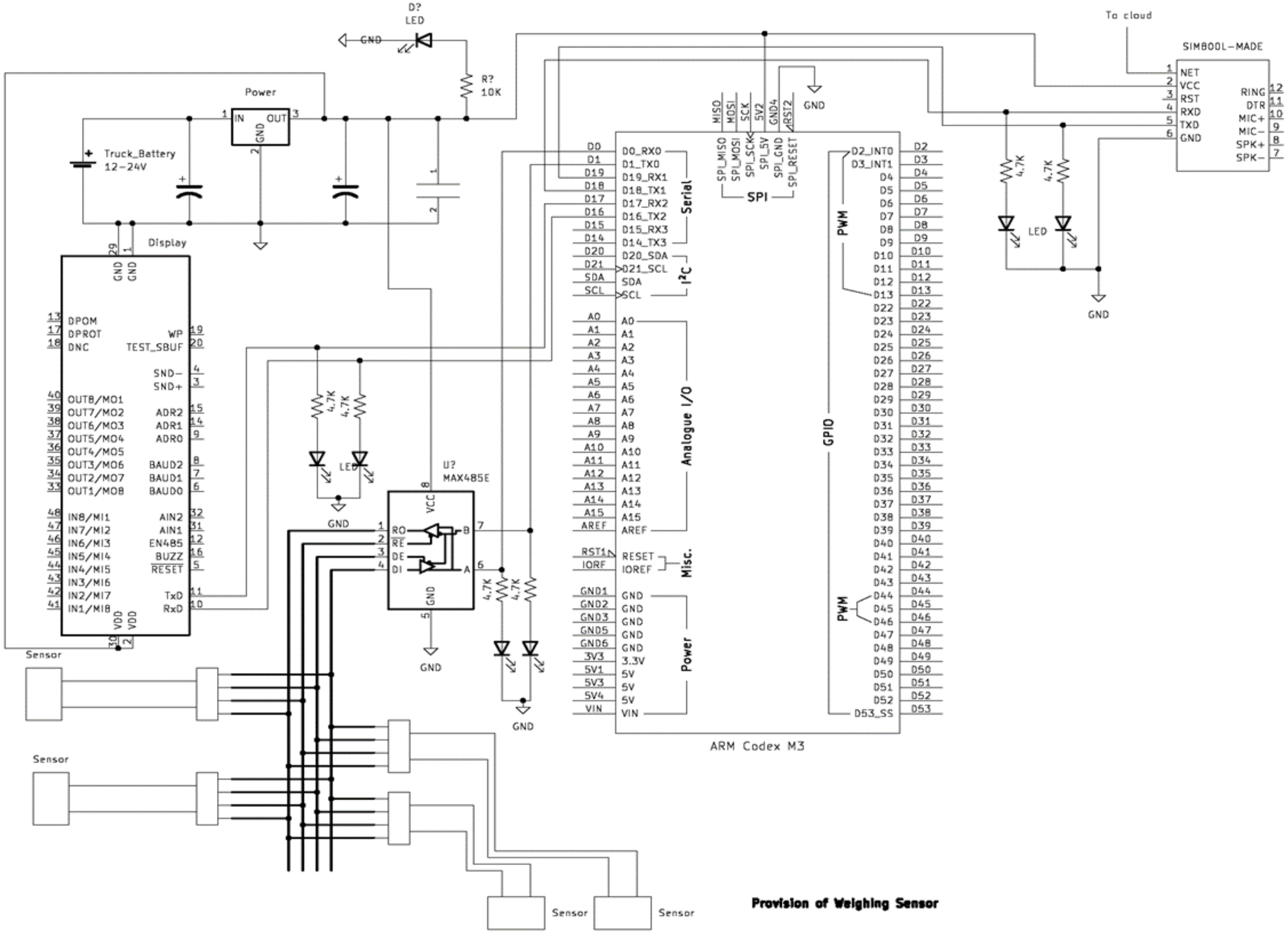
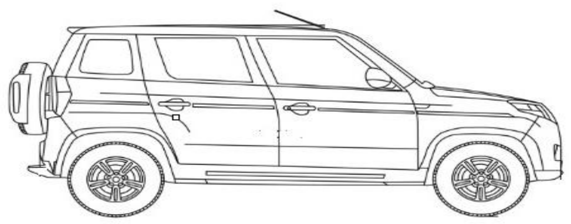
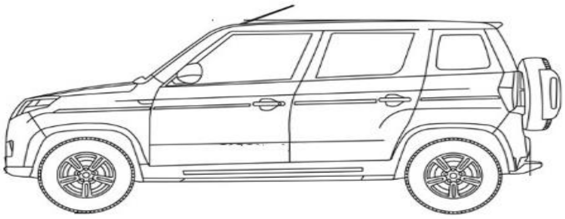
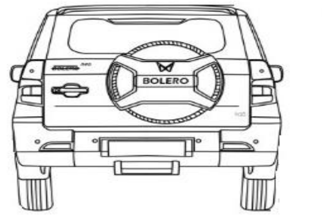
ANNEX I: CIRCUIT DESIGN



Provision of Weighing Sensor

ANNEX II: SCHEMATIC DIAGRAM OF TEST VEHICLE



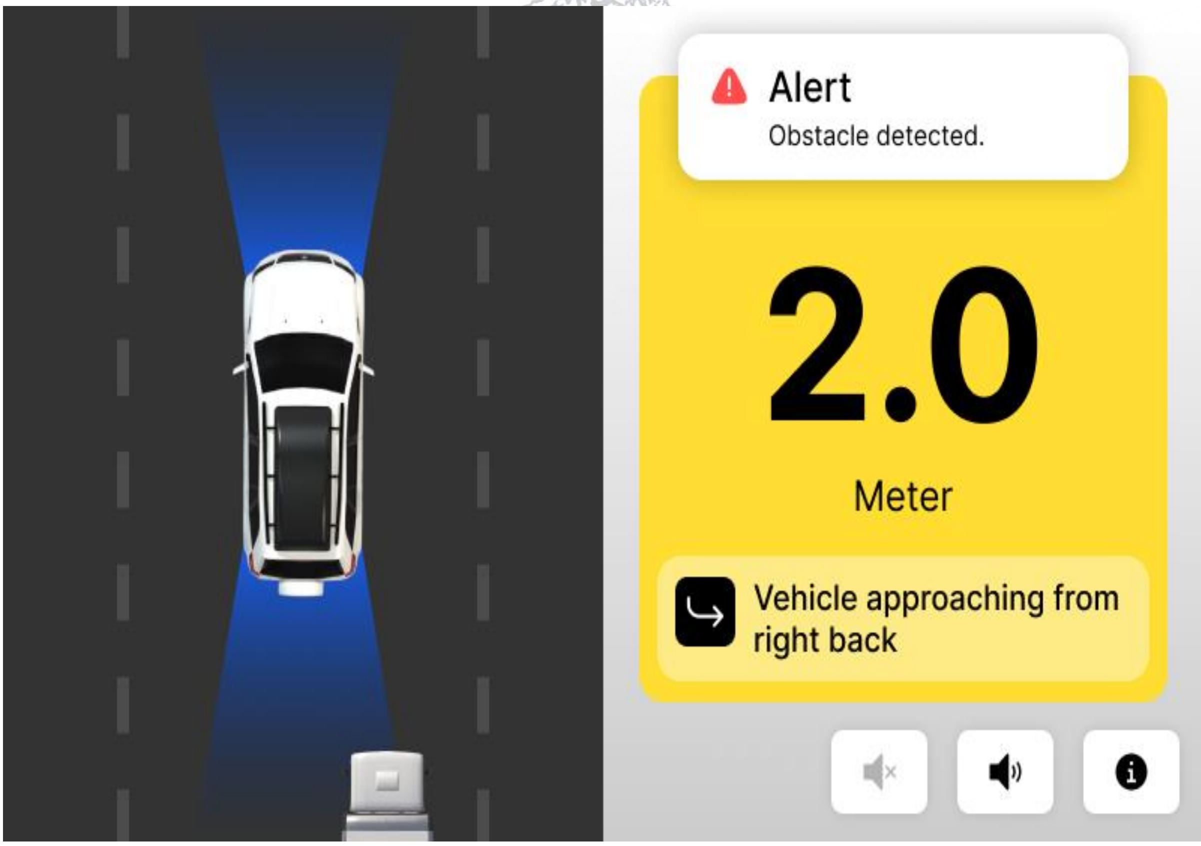



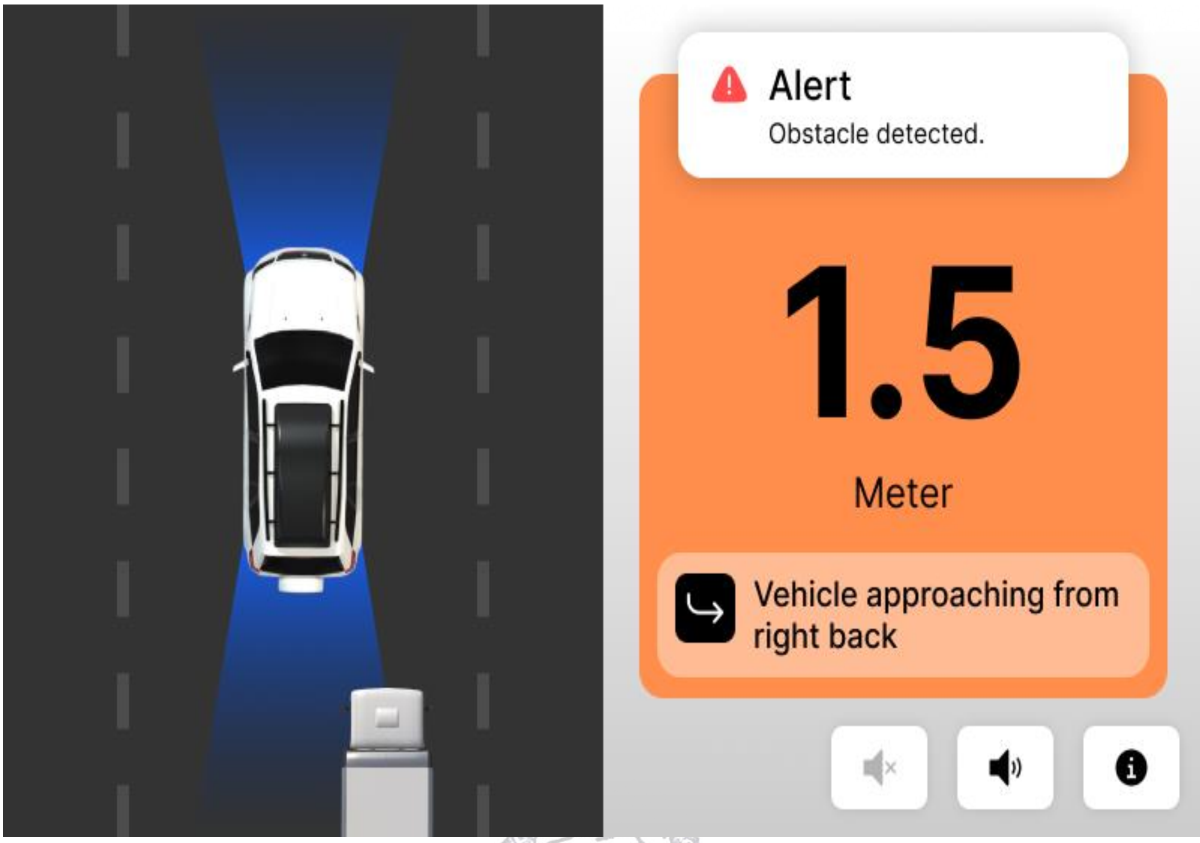


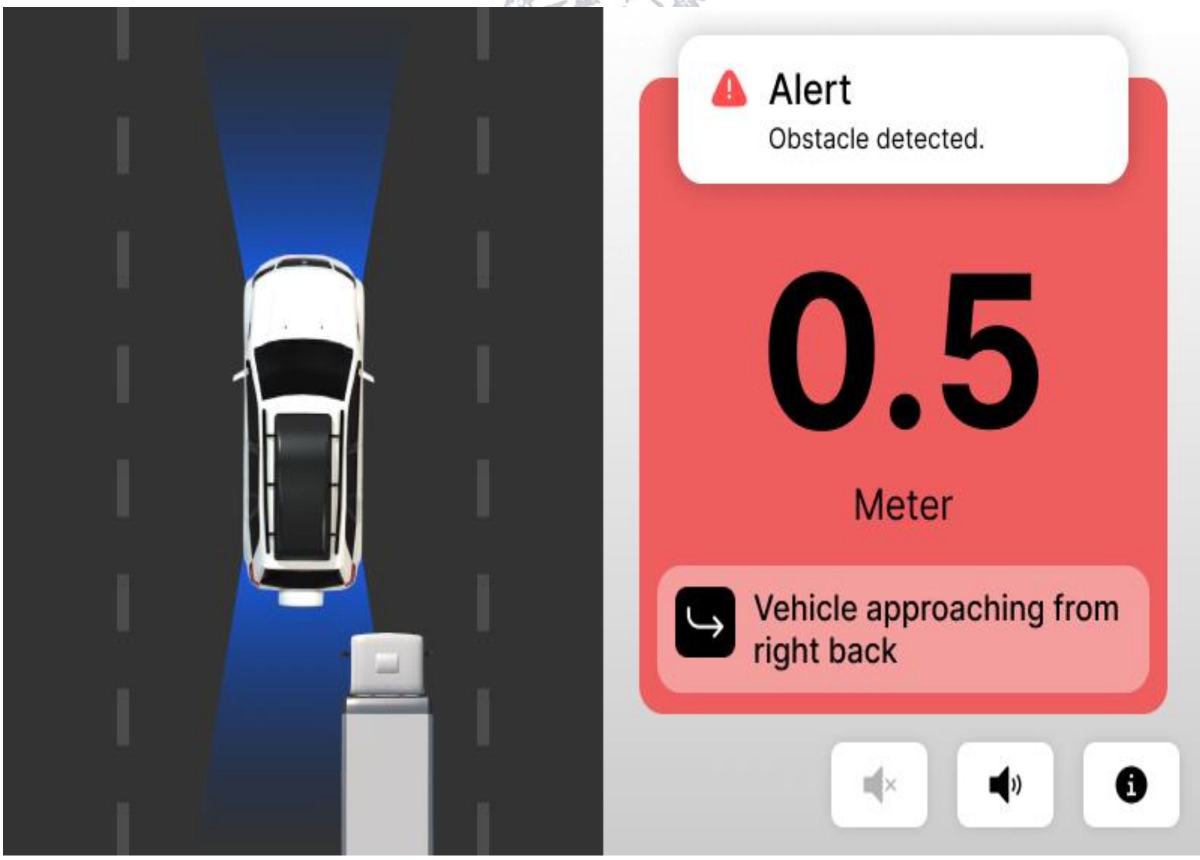
BOLERO
POWER+

ANNEX III: PROXIMITY SENSOR DISPLAY

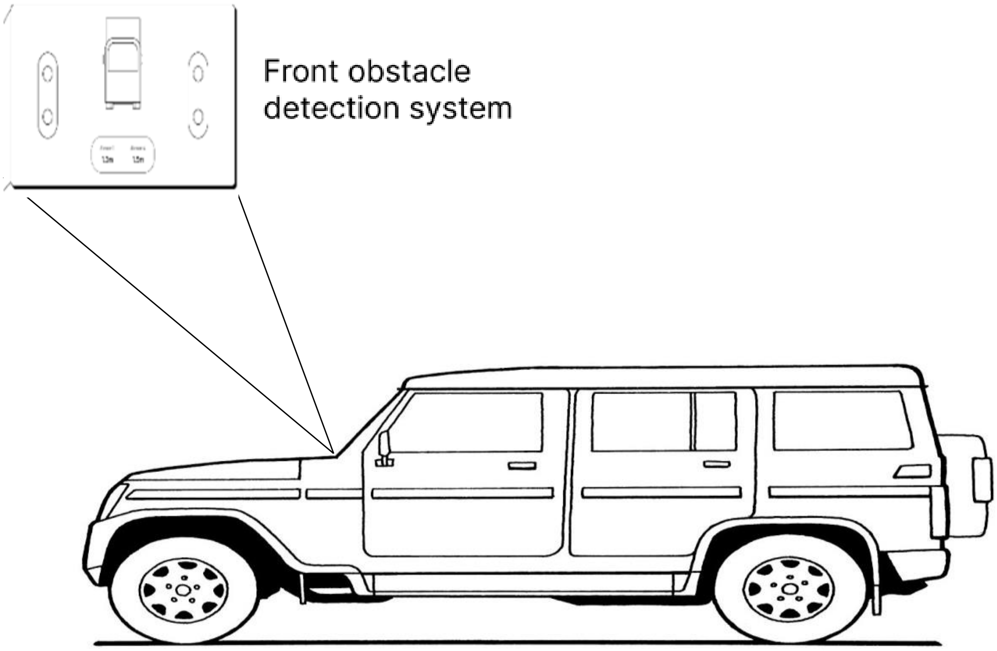

Safe
No obstacle nearby


Alert
Obstacle detected.
2.0
Meter
Vehicle approaching from right back


Alert
Obstacle detected.
1.5
Meter
Vehicle approaching from right back


Alert
Obstacle detected.
0.5
Meter
Vehicle approaching from right back

ANNEX IV: PRELIMINARY SENSOR PLACEMENT


Front obstacle
detection system


BOLERO
BAGMATI
B AA 6364

Note: The red circle shows the position of the sensor installed in the test vehicle

ANNEX V: PHOTOGRAPHS DURING SENSOR TESTING AND VALIDATION

1. Test vehicle with testing obstacle (white foam board)

2. Initial phase when the obstacle is not near sensor

3. Obstacle in the rear of the vehicle and sensor display

4. Obstacle at the 1.1 meter distance showing orange alert

5. Obstacle closer than 2 meters at the backside of the vehicle


Alert
Obstacle detected
0.5
Meter
Vehicle approaching from left back


Alert
Obstacle detected
0.4
Meter
Vehicle approaching from left back


Alert
0. 3
Meter
Vehicle approaching from left back


Alert
0. 2
Meter
Vehicle approaching from left back

6. When the obstacle is placed in the front of the vehicle

7. Photograph during draft presentation

नेपाल सरकार
भौतिक पूर्वाधार तथा यातायात मन्त्रालय
सिंहदरबार,काठमाडौं

ANNEX VI: COMMENT MATRIX

S.N.	Comments	Remarks
1.	Consider adding literature review in the draft report	Literature review section has been added in the section (2.1) (Pages: 4-8)
2.	Include the specifications developed and the detailed design for the procured goods and components in section 2.4.1	The specifications of the procured goods and components are menstioned in the section (2.4.1)(Page 10,11)
3.	Include the cost analysis of the project	Expenses and cost of the project is mentioned in the section (3.9)(Page 25)
4.	Schematic diagram of the test vehicle in Annex II doesn’t match with the actual test vehicle that has been utilized in the report	Schematic diagram of the test vehicle is now changed to match with the actual test vehicle that has been utilized in the report. Changes made are in the Annex II: Page 31 and Annex IV: Page 36
5.	Please consider addressing point no. 4 of the scope in the research agreement which states to develop the design and specifications of the system for future installations	Design Considerations of the system for future installations is mentioned briefly in section (3.8) (Pages: 23,24,25)