CODE RACE CHALLENGE 2025

– TEAM WECAN–

PROJECT NAME

"CAN-Based Emergency Stop Alert and Driver Guidance System for Highway Safety"

Members

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1 Topic Research

1.1 Business context

In recent years, traffic accidents on highways in Vietnam have remained a critical concern. One of the leading causes of severe highway incidents is vehicles coming to a sudden stop or moving abnormally slowly without timely warning to other drivers. These situations often result from mechanical failures, driver panic, or minor collisions, where the driver may be unable to activate emergency signals quickly or properly. In high-speed environments like highways, even a few seconds of delayed reaction can lead to multi-vehicle collisions with devastating consequences.

Meanwhile, most modern vehicles are equipped with Controller Area Network (CAN) systems, which continuously monitor and transmit real-time vehicle data such as wheel speed, steering angle, brake pedal status, engine RPM, gear information, and acceleration input. This internal data, if intelligently processed, presents a powerful opportunity to automatically detect abnormal driving behavior, such as abrupt stops or unusual deceleration and trigger emergency alerts without requiring driver input.

However, existing warning systems in many vehicles are either manual, delayed, or not integrated with real-time CAN-based detection. As a result, the reaction time for surrounding vehicles is significantly reduced, increasing the risk of rear-end or chain-reaction accidents.

Our proposed solution aims to bridge this safety gap by leveraging CAN data to automatically detect emergency-stop behavior and broadcast real-time alerts to both the driver's infotainment system and external communication interfaces (e.g., hazard lights, V2X channels). Additionally, the system will display contextual warnings and simple instructions on the vehicle's media screen, guiding the driver on what to do next — such as activating hazard signals, safely pulling over, or checking for system issues.

By enhancing driver situational awareness and encouraging appropriate responses during unexpected stops, the solution helps reduce the likelihood of secondary accidents, especially on high-speed roads.

1.2 Vision goal

The vision of our project is to develop a simple, effective, and low-cost solution that directly addresses the safety risks associated with sudden stops or unusually slow driving behavior on expressways. Instead of relying on complex or expensive external infrastructure, our approach aims to make intelligent use of the vehicle's existing CAN (Controller Area Network) data to deliver timely, meaningful assistance to the driver and ensure that surrounding vehicles are also promptly alerted.

We believe that advanced driver assistance does not necessarily require high-end equipment or sophisticated AI models. In many critical situations, what matters most is speed, clarity, and reliability of alerts and instructions. Therefore, our project focuses on enabling the vehicle to react quickly and autonomously when abnormal deceleration is detected, by providing in-vehicle warnings, driver guidance, and automatically triggering external alerts (such as hazard signals or V2X messages).

Our key goals are:

1. Design a lightweight detection mechanism that utilizes real-time CAN signals (e.g., wheel speed, brake status, acceleration) to identify emergency stops or abnormal slowdowns with minimal latency.

2. Provide clear and immediate feedback to the driver via the infotainment system, including warnings and suggested actions (e.g., move to the roadside, check engine status, activate hazard lights).

3. Trigger automatic external alerts to inform nearby drivers of potential hazards ahead, minimizing the risk of rear-end or secondary collisions.

4. Ensure that the solution is easy to deploy and compatible with most vehicles equipped with standard CAN architecture, without requiring additional hardware.

5. Maintain a strong focus on driver safety and surrounding awareness, ensuring that both the person behind the wheel and nearby road users receive timely and actionable information.

Ultimately, this project targets a solution that is not only intelligent and responsive, but also cost-effective, simple to implement, and adaptable to a wide range of vehicles, including those with existing CAN infrastructures.

1.3 Market research

In recent years, the automotive industry has seen a significant shift toward intelligent active safety systems, driven by rising concerns about highway collisions and stricter global regulations. One of the most common causes of multi-vehicle accidents on expressways is a vehicle coming to an abrupt stop or slowing down abnormally without sufficient warning to other drivers. These events often lead to secondary collisions due to the lack of early alerts or miscommunication in high-speed environments.

To address such challenges, car manufacturers and regulatory bodies have been adopting various safety systems, such as Emergency Stop Signal (ESS), Autonomous Emergency Braking (AEB), and Driver Assistance Alerts. For example, **Kia and Hyundai** have integrated ESS functionality, which automatically triggers brake light flashing when sudden deceleration is detected via CAN signals (Kia Owner's Manual, 2024). Meanwhile, **Mercedes-Benz** has developed more advanced solutions like Active Emergency Stop Assist, combining sensor fusion with automatic braking and emergency service communication (Mercedes-Benz Owner's Guide, 2025).

According to **Precedence Research**, the global market for automotive active safety systems was valued at **USD 116.8 billion in 2024** and is projected to reach **USD 276.4 billion by 2034**, with a compound annual growth rate (CAGR) of nearly 9%. The AEB segment alone is expected to grow from **USD 74.7 billion in 2025** to **USD 134.4 billion in 2034** (Precedence Research, 2024).

In the Asia-Pacific region, including Vietnam, the adoption of Advanced Driver Assistance Systems (ADAS) features is especially high—accounting for over 30% of global ADAS deployments—reflecting both regulatory push and market readiness (IMARC Group, 2023).

Moreover, a 2024 report by **MITRE Corporation and the U.S. National Highway Traffic Safety Administration (NHTSA)** found that AEB and Forward Collision Warning (FCW) systems have reached 94% penetration in newly manufactured vehicles in the U.S. market. However, most of these systems rely on expensive radar, lidar, or camera-based components, which limit their applicability in lower-cost vehicles, particularly in emerging markets.

This situation presents a strong opportunity for simple, intelligent, and cost-effective safety systems that utilize the existing Controller Area Network (CAN) data infrastructure in modern vehicles. Our proposed solution meets this demand by using real-time CAN signals to detect emergency-stop scenarios, provide in-vehicle visual guidance to the driver, and trigger external alerts (e.g., hazard lights, V2X warnings)—all without requiring additional hardware.

The feasibility of this solution is supported by proven practices in the automotive industry (e.g., Kia's ESS), as well as the growing global interest in scalable ADAS features for mass-market deployment. By focusing on core safety use cases—emergency stop detection, driver instruction, and external communication—our project offers a practical and affordable improvement to vehicle safety that is well-suited for highway environments.

1.4 Scientific research - Overview of CAN Bus

The **Controller Area Network (CAN)** is a robust, real-time communication protocol developed by **Bosch** in 1983 specifically for automotive applications. It is designed to allow microcontrollers and Electronic Control Units (ECUs) within a vehicle to communicate efficiently over a shared bus, without the need for a central host computer. Today, CAN is widely adopted as the standard for in-vehicle networking, and its impact extends beyond automotive to sectors such as industrial automation, aerospace, and robotics.

CAN operates on a message-based, multi-master protocol, where any node can initiate communication, and all nodes on the network receive every message. A typical CAN message contains an *identifier*, which determines the priority during arbitration, and up to *8 bytes of data* in Classical CAN (or up to 64 bytes in CAN-FD). The bus itself consists of a *two-wire differential pair* (CAN_H and CAN_L), enabling high noise immunity and simple wiring.

One of CAN's most significant technical strengths is its built-in **error detection and fault confinement**, which includes CRC checks, acknowledgment, and retransmission mechanisms. This makes it exceptionally reliable in the electrically noisy environment of vehicles. In addition, the protocol supports **non-destructive bitwise arbitration**, ensuring real-time message delivery and deterministic behavior—critical for safety-related ECUs such as braking, steering, and powertrain systems.

There are several common CAN configurations in modern vehicles:

- **High-speed CAN** (ISO 11898-2): Up to 1 Mbps, used for real-time systems (e.g., engine control, transmission, ABS).
- **Low-speed fault-tolerant CAN** (ISO 11898-3): Up to 125–500 kbps, used for body control (e.g., windows, mirrors).
- **CAN-FD (Flexible Data-rate)**: Introduced by Bosch in 2012, supports higher data rates and payloads up to 64 bytes for modern data-heavy ECUs.

According to Dewesoft (2024), CAN bus remains foundational due to its simplicity, cost-efficiency, and robust architecture, which reduces wiring complexity and supports scalable network design. Meanwhile, Bosch Mobility (2024) emphasizes that CAN and CAN-FD are key enablers for Advanced Driver Assistance Systems (ADAS), Battery

Management Systems (BMS), and Vehicle-to-Everything (V2X) connectivity in next-generation vehicles.

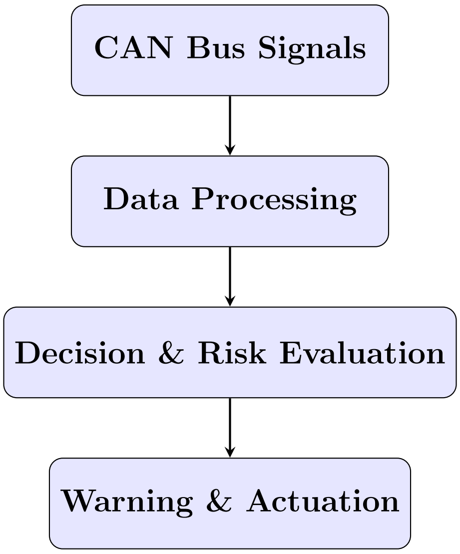
In the context of our project, the CAN bus serves as the primary data source for detecting emergency-stop scenarios. Critical parameters such as *brake pedal status*, *accelerator input*, *wheel speed*, *gear position*, and *steering angle* are broadcast in real time over the vehicle's CAN network. By tapping into this existing infrastructure, we eliminate the need for additional sensors or communication layers, making the system **cost-effective, fast to deploy, and compatible with a wide range of vehicle models**.

This technical foundation not only supports the core algorithmic logic of the solution (event detection, alert generation) but also ensures that our architecture can be integrated with future expansions, including V2X alerts, cloud logging, or infotainment-based driver guidance.

To ensure the feasibility of our proposed emergency alert system, our team conducted detailed research on available hardware platforms compatible with Controller Area Network (CAN) communication and safety-critical vehicle functions. We identified specific components that are not only cost-effective and accessible but also directly support the required functionalities of our system, including wheel speed monitoring, GPS-based highway detection, hazard light control, and infotainment output.

This section presents the hardware architecture we propose, along with justifications for each selected component.

2 Software Design



2.1 CAN Bus Signals

The system relies solely on wheel speed and GPS data as its primary inputs. Wheel speed provides real-time information about the vehicle's actual motion, while GPS delivers linear velocity and geographic position. By correlating these two data sources, the system can detect abnormal movement patterns, such as the vehicle moving at high speed with no change in position (suggesting loss of traction or control), or sudden acceleration from a stationary state. This approach eliminates the need for additional hardware, making it easily deployable on mass-market and commercial vehicles via the OBD-II port.

2.1.1 Overview of Hardware Modules for CAN-Based Input and Output Integration

To support the practical implementation of our CAN-based emergency stop detection and driver guidance system, we conducted a targeted review of hardware components that are not only technically compatible with automotive CAN networks but also feasible for real-world integration. The goal is to propose hardware options that can realistically be deployed in test vehicles or commercial platforms, focusing on capturing essential inputs (e.g., vehicle speed and GPS location) and enabling critical outputs (e.g., hazard light activation and in-vehicle driver alerts). The following hardware modules have been selected based on availability, reliability, and relevance to actual automotive deployment scenarios.

1. Wheel Speed Input: ABS ECU via CAN Bus

Wheel speed is typically broadcast through the Anti-lock Braking System (ABS) Electronic Control Unit (ECU) on the vehicle's CAN bus, using standard CAN IDs and message frames defined by ISO 11898 and proprietary OEM standards.

- These signals are updated at high frequency (typically 10–50 Hz), ensuring real-time feedback.
- Most modern vehicles publish this data across four wheels, enabling accurate braking or deceleration detection.
- Access to wheel speed data can be achieved using OBD-II tools or directly via CAN sniffing with appropriate permissions.

2. GPS Position Input: Adafruit Ultimate GPS or u-blox NEO-M8N

Highway detection is based on real-time positioning and geofencing logic. We recommend using:

- **Adafruit Ultimate GPS** – 10Hz update rate, NMEA output via UART, cost-effective and widely supported.
- **u-blox NEO-M8N** – multi-GNSS support, industry-grade, high accuracy (within 2.5m), supports I2C/SPI/UART.
- Optionally, integrated GPS from an OBD-II dongle (e.g., **Freematics OBD Kit 4**) can combine GPS + CAN access.

GPS data will be used to determine if the vehicle is currently on a highway segment through geofencing and speed context matching.

3. Hazard Light Output: Body Control Module (BCM) via CAN or Relay Control

The system requires the ability to trigger hazard warning lights during emergency stop scenarios. There are two primary approaches:

- **CAN Message Injection to BCM:**
  - Professional-grade tools such as **Vector CANoe/CANalyzer** or **Kvaser CAN interfaces** can be used to identify and replicate the correct CAN frame for hazard light control.
  - Requires access to DBC files or reverse-engineering CAN message mappings.

- **Relay-Based Control (Prototyping):**
  - A simple relay module may simulate hazard light activation by switching the hazard switch circuit directly.
  - Suitable for lab setups or vehicles without secure CAN access.

4. Driver Guidance Output: Vehicle Infotainment Display or External Screen

Visual feedback and driving instructions are a core part of this system. Depending on vehicle platform, there are several ways to provide this output:

- **OEM Infotainment Integration:**
  - Systems like **Android Automotive**, **Ford SmartDeviceLink**, or **Bosch IVI** SDKs allow 3rd-party app integration and alerts.
  - Requires access to developer APIs and possibly head unit firmware cooperation.
- **Aftermarket Screens or HMI Modules:**
  - Infotainment simulation for prototyping can be achieved via HDMI/DIS displays and microcontrollers with GUI capabilities.
  - Examples include touchscreens connected to Raspberry Pi or **AutoPi TMU Pi Dongle** which integrates CAN, GPS, and visual output.

Summary

The combination of GPS receivers, wheel speed inputs, CAN-controllable hazard lights, and infotainment display output provides a fully functional foundation for the proposed driver support system. These components enable:

- Accurate emergency stop detection based on CAN data.
- Context-aware driver alerts based on geolocation.
- Timely visual guidance on in-vehicle display systems.
- Hazard light activation for signaling to surrounding vehicles.

By focusing on widely available, modular hardware already used in production or testing vehicles, the project ensures maximum feasibility, integration potential, and adaptability to different vehicle platforms.

2.2 Data Processing

The data processing module analyzes the time-series patterns of both wheel speed and GPS-derived speed to identify inconsistencies. The system checks for sustained discrepancies between the two sources (e.g., spinning wheels with no forward movement, or GPS speed changes without corresponding wheel speed). Such mismatches may indicate scenarios like loss of traction, wheel lock, or driver unresponsiveness. The data is preprocessed—filtered, timestamp-synchronized, and normalized—to improve reliability and accuracy in detecting critical events.

2.3 Decision & Risk Evaluation

Based on detected anomalies, the system evaluates the risk level in real time. If specific conditions are met—such as prolonged lack of GPS movement despite increasing wheel speed, or the vehicle staying stationary in an unsafe location—the system concludes that the driver may have lost control or is incapacitated. Once this threshold is exceeded, the system transitions to an emergency response mode. Risk assessment is calibrated to avoid false positives by allowing brief delays before action is taken, ensuring genuine emergencies are targeted.

2.4 Warning & Actuation

When a hazardous condition is detected, the system initiates two key responses:

- Activates hazard lights to alert surrounding vehicles.
- Displays a visual warning on the vehicle's dashboard screen, informing the driver and passengers—or nearby responders—of the detected emergency.

These actions aim to increase visibility, promote rapid intervention, and reduce the risk of further incidents or harm.

3 Algorithm Development

This algorithm is designed to promptly detect and respond to situations in which a vehicle decelerates suddenly or comes to an unexpected stop on the highway – particularly when the hazard lights are not activated.

It processes data from the CAN bus and GPS signals to support the driver and alert surrounding vehicles of potential danger.

3.1 Flowchart Design

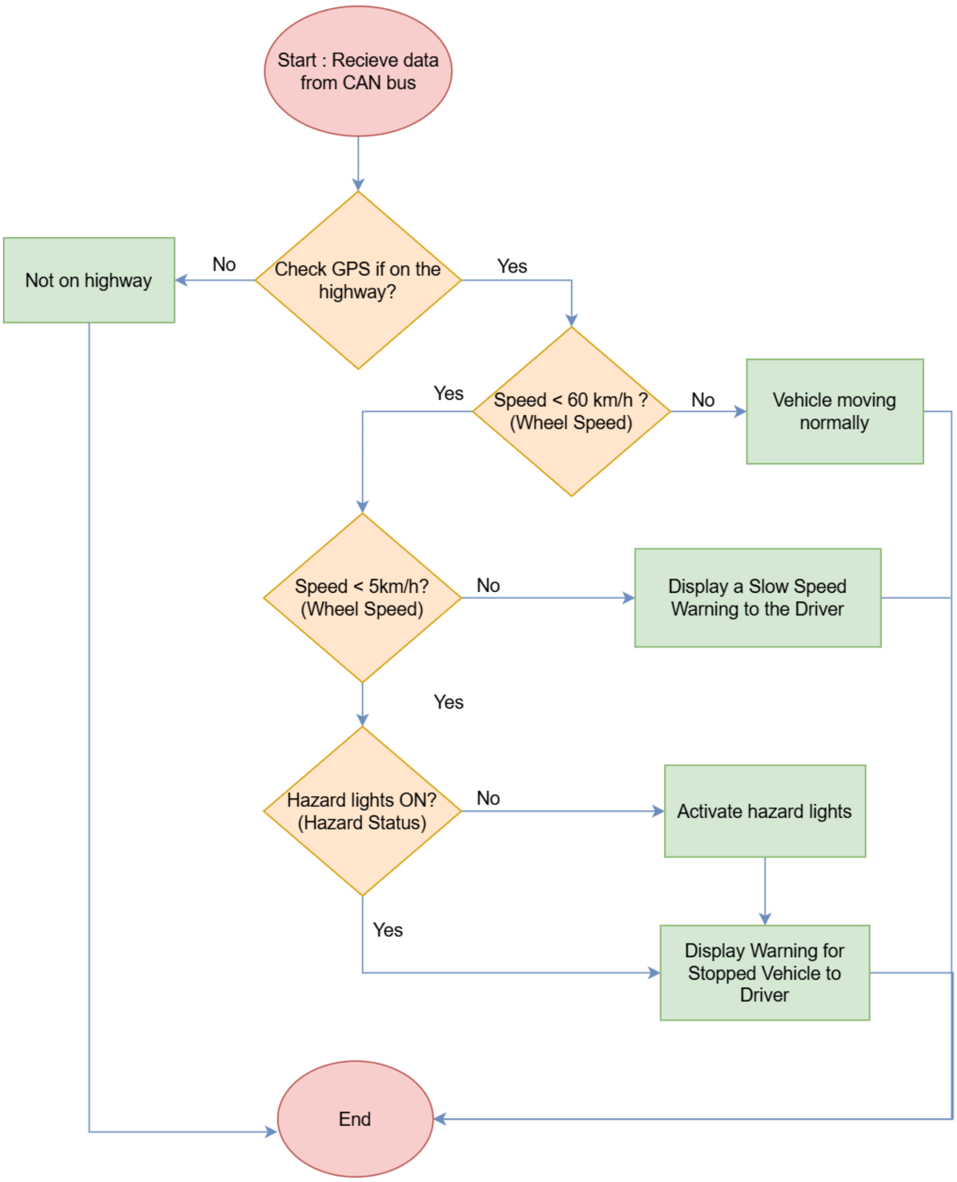


Figure 1: Flowchart of Vehicle Stop Detection on Highway

3.2 Logic Design

1. **System Start**
   The system receives real-time CAN bus data every **5 seconds**, including:
   - Wheel Speed
   - Hazard Light Status
   - GPS location and heading
   - etc.
2. **Highway Detection**
   The system uses GPS data to determine whether the vehicle is currently on a highway.
   - If the vehicle is **not on a highway**, the system deactivates further checks and exits, as the situation is out of scope.
   - If the vehicle **is on the highway**, the system proceeds to evaluate the current speed.
3. **Sudden Deceleration Detection**
   The system compares the vehicle's speed with the defined highway minimum speed limit (default: **60 km/h**).
   - If the vehicle's speed remains above 60 km/h:
     - The vehicle is considered to be operating normally.
     - The algorithm terminates
   - If the speed drops below 60 km/h, this may indicate a case of sudden deceleration.The system then moves to monitor the duration and stability of this low-speed condition.
4. **Low-Speed and Stop Detection**
   The system monitors the vehicle's speed over a time window to distinguish between slow movement and stop:
   - If speed is between between 5 and 60 km/h:
     - A **slow speed warning** on the vehicle's dashboard display.
     - The warning remains visible for **at least 5 seconds** or until the speed returns above 60 km/h.

- If the speed drops below 5 km/h:
  - The system identifies the vehicle as being **stopped**.
  - The system then checks whether the vehicle is safely stopped, such as by verifying if the hazard lights are activated.

5. **Hazard Light Check**
   When the vehicle stopped, the system will check the hazard light status:

   - If the hazard lights are **OFF**:
     - The system automatically activates the hazard lights.
     - A **stop warning** is displayed to the driver and remains visible for 5 seconds or until acknowledged.
   - If the hazard lights are **already ON**:
     - Only the **stop warning** is displayed.

6. **Algorithm Termination**
   After all conditions have been evaluated and appropriate actions have been executed, the algorithm terminates.

Note:

Slow speed warning: *"Your car is moving below the regulated speed of 60 km/h. If you are experiencing an issue, turn on the hazard lights and move to the emergency lane."*

Stop warning: *"Hazard lights have been activated. Your car has stopped unexpectedly. Please remain calm and contact traffic police for assistance."*

3.3 Test Case Demonstrations

Case 1: Sudden Stop Due to Tire Burst

Problem: The vehicle is traveling at 90 km/h on a highway. A tire bursts unexpectedly, and the driver performs an emergency brake. As a result, the speed drops rapidly to 5 km/h within 4 seconds. The driver forgets to activate the hazard warning lights.

System Response:

- Check GPS = true $\rightarrow$ on highway.
- Speed $<$ 60 km/h $\rightarrow$ continue monitoring
- Speed $<$ 5 km/h $\rightarrow$ vehicle is classified as stopped
- Hazard lights = OFF $\rightarrow$ system automatically activates the hazard warning lights and displays a warning to the driver.

Case 2: Slow Driving Due to Traffic Jam – No Hazard Light Activated
Problem: There is a traffic jam in a highway. The speed is remain between 10 and 20km/h for over 1 minute. The driver does not activate the hazard warning lights.

System Response:

- Check GPS = true $\rightarrow$ on highway.
- The system detects that Speed $<$ 60 km/h, but it does not drop below 5 km/h.
- A slow speed warning is displayed.
- The system does not automatically activate the hazard warning lights.

Case 3: Vehicle Not on Highway – Stopped at Traffic Light
Problem: The vehicle is stopped at an intersection in an urban area, and the GPS confirms it is not on a highway. Check GPS = false $\rightarrow$ the vehicle not on highway. The speed is 0 km/h. The driver does not activate the hazard warning lights.

System Response:

- Check GPS = false $\rightarrow$ the vehicle not on highway
- No warnings displayed
- Hazard lights remain OFF

Exceptional Case

Case 1: GPS Signal Loss or Uncertain Position
The algorithm is designed to use GPS to check whether the vehicle is on a highway. However, in real driving conditions, GPS may sometimes be unreliable, such as when the

car is in a tunnel, under a bridge, or in an area with weak signal. In these cases, the system may not get accurate or timely location data.

Problem:

- Missing real danger situations
- Triggering warnings by mistake

Solutions:

- If GPS is unavailable for more than 5 seconds, the system will switch to a fallback mode.
- In fallback mode, if the vehicle is moving faster than 70 km/h for at least 15 seconds, we can safely assume it's on a highway.
- If we're still unsure of the vehicle's location, the system will display a warning to the driver instead of turning on the hazard lights automatically

Case 2: Driver Turns Off Hazard Lights After Auto-Activation
After the system automatically turns on hazard lights during an emergency stop, the driver might manually disable them.

Problem: This action will compromise safety if the vehicle is still in a dangerous state

Solutions: If the driver turns it off within 30 seconds and the danger persists, the system will:

- Re-activate the hazard lights
- Display a warning to the driver explaining the reason

4 Innovation vs. Current Systems

4.1 Some Existing Emergency Stop Systems on the Market

4.1.1 Mercedes-Benz Active Emergency Stop Assist

Advantages:

- **Deep ADAS Integration**: Combines multiple sensor inputs—driver-facing camera, radar, steering, and lane-keeping—to detect driver incapacity and surrounding context accurately.

- **Smooth & Coordinated Response**: Executes a sequence of safety actions including controlled deceleration, lane centering, hazard light activation, and eCall initiation.
- **Proven in Practice**: Successfully deployed on European highways, with validation in commercial high-end vehicles.

Limitations:

- **Hardware-Dependent**: Relies heavily on high-end hardware (camera, radar, LIDAR, advanced ECUs), which drives up cost.
- **Limited to Premium Vehicles**: Not available on mid-range, economy, or older models.
- **Dependent on Infrastructure**: Requires clear lane markings and good road conditions—often lacking in developing countries.
- **Closed-System Architecture**: Cannot be retrofitted or extended by third parties, limiting flexibility for fleet operators or local integrators.

4.1.2 KIA's Driver Attention Warning (DAW) & Lane Following Assist (LFA)

Advantages:

- **Cost-Effective Integration**: Uses front-facing camera and steering sensors to detect fatigue and initiate emergency stop under specific conditions.
- **Widely Available**: Deployed across several mid-range models in KIA's global portfolio.
- **User-Friendly Alerts**: Provides visual and audio warnings before action is taken.

Limitations:

- **Limited Behavior Understanding**: Focuses mainly on steering patterns and lacks depth in assessing driver behavior dynamically.
- **Still Hardware-Based**: Requires at least a forward-facing camera and lane sensors.
- **No Standalone Stop Logic**: Emergency stop only triggers under specific ADAS scenarios, not as a dedicated module.

- **Lane Dependence**: Requires visible lane markings, reducing reliability on poorly maintained or rural highways.

4.2 What's New in Our System

1. Hardware-Free Deployment

Our system eliminates the need for cameras, radars, or additional sensors by relying only on wheel speed and GPS—both accessible via the CAN bus or standard OBD-II port. This minimizes cost and complexity while enabling retrofit across:

- Regular passenger cars
- Taxis and ride-hailing fleets
- Trucks and commercial transport vehicles

It is a truly scalable solution for both developed and developing markets.

2. Privacy-Respecting Behavior Monitoring

Instead of recording the driver's face or eye movements, our system analyzes vehicle behavior patterns:

- Wheel speed vs. GPS speed correlation
- Sudden motion anomalies (e.g., spinning wheels but no movement)
- Inactivity over time at highway speed

This approach avoids privacy concerns, works in vehicles without driver-monitoring cameras, and can learn adaptive thresholds to reduce false positives.

3. Tailored for Emerging Markets like Vietnam

Unlike traditional systems that rely on well-maintained infrastructure, our system:

- Works without lane markings, map data, or traffic sign recognition
- Remains functional even under poor road conditions
- Adapts to local driving behavior and infrastructure limitations

This infrastructure-independent design ensures reliability in real-world, imperfect conditions common in countries like Vietnam.

5 Work Package Breakdown

This section outlines the structure and division of labor within the team, providing an overview of the project milestones, deadlines, and responsibilities. The project is divided into three major work phases aligned with our technical development timeline.

5.1 Identifying Key Milestones and Deadlines

The table below summarizes the key deliverables and estimated deadlines for each phase. Specific dates can be added as the team finalizes the working schedule.

Phase	**Deliverable / Milestone**	**Deadline**
Phase 1: Design and Analysis	- Complete topic research (CAN basics, safety trends) - Design system flowchart and data flow - Define input/output hardware specifications - Draft technical design document - Initial algorithm logic design	[**30/6/2025**]
Phase 2: Implementation	- Parse CAN/GPS data and detect abnormal stop - Implement signal logic and hazard response - Handle output actions (hazard light, display alert)	[**17/7/2025**]
Phase 3: Testing and Finalization	- Build test scenarios and test cases - Debug and validate system behavior - Compile technical report and prepare presentation - Finalizes system integration into the Bosch-provided model, ensures stable end-to-end operation.	[**21/7/2025**]

5.2 Assigning Tasks and Responsibilities within Team

Each team member is assigned a specific role according to their strength and contribution to different project stages.

Phase 1 – Design and Analysis

- **Hạnh**: Topic research on CAN, active safety systems, and hardware.
- **Huy**: Responsible for system architecture, flowcharting, and technical design documentation.
- **Huấn**: Develops algorithm logic for emergency stop detection.

Phase 2 – Implementation

- **Hạnh**: Implements code for input signal processing (CAN, GPS).
- **Huấn**: Develops the core logic for emergency detection and response.
- **Huy**: Implements output control, including hazard light activation and display alerts.

Phase 3 – Testing and Finalization

- **Hạnh**: Designs test scenarios and builds test cases.
- **Huấn**: Runs system tests and handles debugging and issue resolution.
- **Huy**: Finalizes system integration into the Bosch-provided model, ensures stable end-to-end operation, and assists in compiling the technical report and final presentation.

This structured division ensures efficiency, parallel progress across tasks, and a clear accountability framework for timely delivery of project outcomes.

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