**Self-Driving Car System**

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**DATE OF COMPLETION: 16/09/2024**

**WORD COUNT: 2614**

# Scenario

AutoDrive, a globally recognized leader in the automotive industry, is at the forefront of innovation in autonomous driving technology. In response to the growing demands for safer, more efficient, and environmentally-friendly transportation solutions, the company is developing a cutting-edge fully autonomous driving system (ADS) aimed at transforming the future of personal and commercial transportation.

With road safety being a critical issue, AutoDrive seeks to address the fact that human error is responsible for the vast majority of traffic accidents globally. The ADS aims to significantly reduce these incidents by eliminating common human mistakes such as distracted driving, speeding, and improper decision-making in high-pressure situations. Furthermore, AutoDrive’s system is designed to alleviate the increasing congestion in urban areas, which not only causes significant delays but also contributes to environmental pollution due to excessive fuel consumption.

By leveraging a combination of advanced sensors (LIDAR, cameras, and radar), artificial intelligence (AI), and machine learning, AutoDrive’s ADS will enable vehicles to navigate complex road scenarios autonomously. This includes interactions with other vehicles, pedestrians, cyclists, and infrastructure in real-time. The system will operate efficiently in various driving environments such as congested city streets, open highways, suburban roads, and parking lots, offering drivers a seamless and convenient experience.

# Problem and Vision Statement

## Problem Statement

AutoDrive, a leading car manufacturer, is facing growing pressure to address critical issues related to road safety, traffic congestion, and environmental impact. With human error accounting for the vast majority of traffic accidents, the demand for safer and more efficient transportation systems is at an all-time high. In urban areas, congestion leads to significant delays, increased fuel consumption, and higher levels of pollution, while individuals with mobility challenges struggle to find reliable transportation options. Although autonomous driving technology holds the potential to address these challenges, existing solutions often lack the sophistication needed to handle complex road conditions, such as unpredictable traffic patterns and adverse weather. This situation highlights the need for a fully autonomous driving system that can provide safe, efficient, and environmentally-friendly transportation across diverse environments, ensuring accessibility and convenience for all users.

## Vision statement

For urban commuters, delivery services, and individuals with mobility challenges who seek a safer, more efficient, and convenient transportation solution, AutoDrive's fully autonomous driving system offers real-time navigation and control in diverse driving environments, from city streets to highways. Unlike other autonomous systems, AutoDrive leverages advanced AI, LIDAR, and radar technology to ensure optimal safety, adaptability, and environmental sustainability, providing users with a seamless and reliable driving experience.

# Challenges

Standard requirement analysis techniques, such as use cases, user stories, and functional decomposition, are not sufficient for capturing the complex, dynamic nature of autonomous systems. Key challenges include:

**Real-time Decision-Making**: The ADS must make split-second decisions in unpredictable environments. Standard techniques lack the depth to capture the complexity of these decisions.

**Safety and Risk Management**: Autonomous systems must handle risk in a way that is often not adequately addressed by traditional methods. For instance, prioritizing the safety of passengers versus pedestrians in an unavoidable accident scenario presents ethical and legal challenges.

**Human-Systems Interaction**: The interaction between autonomous vehicles and human drivers or pedestrians requires advanced behavioural modelling that is often overlooked in traditional requirement methods.

**Compliance and Regulations**: Autonomous systems must comply with various regional and international laws, which is difficult to account for using basic requirement techniques.

# Proposed Techniques

To address these challenges, several alternative approaches can be used to supplement the requirement analysis:

## Scenario-Based Requirements Engineering

This technique focuses on creating detailed scenarios that explore how the system behaves in different situations. For self-driving cars, this could involve simulating complex traffic situations or adverse weather conditions to better understand the required system behavior.

## Safety-Critical Systems Requirements

For critical systems like ADS, techniques such as Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA) can be employed to identify potential hazards and their root causes. These approaches help in capturing the risks and formulating requirements to mitigate those risks.

## Ethical and Legal Requirement Modelling

ADS development must consider ethical decision-making in case of unavoidable accidents. Methods such as ethical matrix modeling or employing decision-making trees based on ethical AI frameworks can supplement traditional requirement techniques to ensure the system makes ethically sound decisions.

## Formal Methods

Using formal methods to mathematically specify and verify system behavior can ensure consistency, correctness, and reliability. Techniques like model checking and theorem proving can be used to prove that certain safety properties hold under all conditions.

## Risk Analysis

To handle risks, a combination of Hazard and Operability Study (HAZOP) and risk classification techniques can help analyze risks at various system levels. This will aid in deriving risk-mitigating requirements.

# Requirements Specification

## Requirement 1

**Requirement**: The system must maintain the vehicle within its designated lane at all times, ensuring smooth lane transitions when necessary.

**Rationale**: Lane-keeping is crucial for the safe operation of autonomous vehicles. By maintaining the vehicle within its lane, the system minimizes the risk of accidents caused by veering into adjacent lanes or off the road. Ensuring lane discipline also contributes to the flow of traffic and overall road safety. A failure to reliably maintain lane position could result in traffic violations, collisions, or other dangerous situations.

## Requirement 2

**Requirement**: The system must detect obstacles and take appropriate action (e.g., stop, slow down, or maneuver around) to avoid collisions.

**Rationale**: Detecting and responding to obstacles is essential for the safety of passengers and other road users. Without this capability, the autonomous vehicle could collide with objects, pedestrians, or other vehicles, leading to accidents. Accurate obstacle detection will allow the system to take preventive action, thereby avoiding incidents and maintaining a high level of trust from users and regulators.

## Requirement 3

**Requirement**: The system must autonomously plan and follow optimal navigation routes using real-time traffic data.

**Rationale**: Efficient route planning reduces travel time and fuel consumption, contributing to both user convenience and environmental sustainability. By leveraging real-time data, the system can avoid traffic congestion, accidents, and road closures, ensuring that the user reaches their destination in the shortest possible time. Failure to optimize routes could result in inefficient travel, user frustration, and increased environmental impact.

## Requirement 4

**Requirement**: The system must identify and avoid pedestrians in or near the vehicle’s path to prevent accidents.

**Rationale**: Pedestrian safety is a critical concern for autonomous vehicles. By detecting pedestrians and responding accordingly, the system helps reduce the risk of accidents involving pedestrians, which can result in injury or death. Ensuring this capability will also contribute to compliance with legal and ethical standards for road safety, especially in urban environments.

## Requirement 5

**Requirement**: The system must autonomously park the vehicle in available parking spots, including parallel parking.

**Rationale**: Parking is a key aspect of driving, and automating this task enhances user convenience while ensuring efficient use of space in busy urban areas. By autonomously handling parking, the system will eliminate the potential for human error during parking maneuvers, such as collisions or misjudging space. This also improves accessibility for users with limited mobility.

## Requirement 6

**Requirement**: The system must adapt its driving behavior in response to changing weather conditions, such as rain, snow, or fog.

**Rationale**: Adverse weather conditions can significantly affect driving safety. By adjusting the vehicle’s speed, braking, and lane-keeping behavior, the system will minimize risks associated with reduced visibility or slippery roads. Failure to do so could lead to dangerous situations, such as hydroplaning or collisions, which would undermine the system’s reliability and user trust.

## Requirement 7

**Requirement**: The system must prioritize the minimization of harm in situations where a collision is unavoidable, based on predefined ethical guidelines.

**Rationale**: Ethical decision-making in unavoidable accidents is one of the most challenging aspects of autonomous vehicle design. By integrating ethical frameworks, the system will be able to make decisions that minimize overall harm to passengers, pedestrians, and other road users. This feature is essential to ensuring public trust and acceptance of autonomous vehicles, as well as for regulatory compliance.

## Requirement 8

**Requirement**: The system must protect user data by adhering to relevant data protection laws, such as GDPR.

**Rationale**: Autonomous vehicles collect significant amounts of data, including user preferences, routes, and personal information. Ensuring the privacy and security of this data is essential for compliance with global regulations and for maintaining user trust. Data breaches or misuse could result in legal consequences and loss of customer confidence in the system.

## Requirement 9

**Requirement**: The system must detect and respond to vehicle malfunctions or external accidents by bringing the vehicle to a safe stop.

**Rationale**: Detecting emergencies is critical for maintaining safety in autonomous vehicles. Whether due to internal system failures or external accidents, the system must be able to recognize danger and respond appropriately. Bringing the vehicle to a safe stop will prevent further damage or harm and ensure passenger safety. Failure to do so could lead to catastrophic results, both for the vehicle’s occupants and other road users.

## Requirement 10

**Requirement**: The system must comply with local, national, and international regulations governing the operation of autonomous vehicles.

**Rationale**: Legal compliance is mandatory for the deployment of autonomous vehicles. Without adhering to traffic laws and regulations, the system cannot be legally deployed on public roads. This includes compliance with speed limits, signalling, and right-of-way rules. Regulatory violations could result in penalties, legal challenges, and delays in adoption.

## Requirement 11

**Requirement**: The system must communicate with other autonomous vehicles to share real-time information about traffic, hazards, and road conditions.

**Rationale**: Vehicle-to-vehicle communication enhances safety and efficiency by allowing autonomous cars to share critical information about their surroundings. This collaboration can prevent accidents, reduce traffic congestion, and optimize route planning. A failure to implement this feature could result in missed opportunities for efficiency and increased risk of collisions or traffic delays.