# SMART CAR SYSTESM DESIGN

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**Abstract**

In recent years, commuting time has increased as people secure jobs far away from where they live. In many cases, people live in the suburban areas and use their personal vehicles to commute to the cities where professional jobs are abundant. An average one way commuting time is about 30 minutes and can vary depending on road conditions and number of vehicles. Drivers would prefer to use their commuting time wisely by working, sleep, read, talk, playing games and many other non driving activities.
Smart car has been speculated as one way to reduce and possibly eliminate driver functions during commuting.

The purpose of this design project was to develop a Smart Car (SC) vehicle system which would be integrated into a 2009 Honda Civic and shall enable the vehicle to be operated in a preexisting Modified HOV Lane System with little to no user intervention.

Smart car project was divided into three major parts namely conceptual design, detail design and system integration or final production.

The presentation will focus on the conceptual design which explores different options available to implement driverless car. The conceptual design is expected to find best ways to enable the vehicle to attain a maximum speed of 85 miles per hour safely and efficiently.

The team that was responsible for the smart car project was comprised of three graduate students from Penn State Great Valley, Malvern, PA.

During conceptual design, two major parts were explored. The actual mechanical portion (2009 Honda Civic) and the smart car kit (a collection of mechanical, electrical, hardware and software). The smart car kit will be installed in the vehicle and would enable it to use modified HOV lane as a smart car.

The team was able to complete a conceptual design which included a number of sub-system components tradeoff studies and an operational scenario.
At the end of the conceptual design, the team presented its work to the stake holders who were responsible to approve the design and appropriate funds needed to proceed to a detail design.

Key words: DARPA, GSM, MHOVLS, RFID, SCS, SCM

## 1. Introduction

The Smart Car System (SCS) is a system which is intended to modify a 2009 Honda Civic for the purpose of automating the control of the vehicle therefore eliminating human interaction while operating within a Modified HOV Lane System (MHOVLS)

The SCS will resolve many of the complaint commuters have regarding long commutes and the time "wasted" driving each day. According to U.S. Census of 2004, people who live/work in major U.S. cities have approximately a half hour commute to work, on average. For many people, their commute is actually longer and it is not uncommon to hear people commuting over an hour to work, or two hours total commute. This system is designed to allow people to use a portion of their commute time differently. One could read a book or newspaper, sleep, talk on the phone, or work virtually without the potential for causing an accident. In essence this vehicle will allow people to travel in their own personal vehicles while having the vehicle navigate them from their starting location to their destination.

The SCS is intended to be used with a preexisting Modified HOV Lane System. The vehicle will have the ability to operate in either Manual Mode or Smart Car Mode (SCM). The purpose of the system is to allow drivers to perform other tasks safely and efficiently during times that would otherwise be used to commute. A general block diagram is shown in Figure 1.

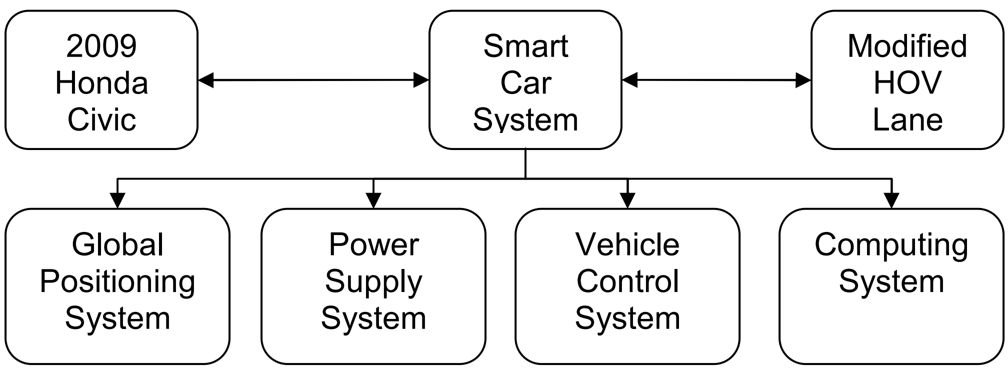


**Figure 1 – General Smart Car System Block Diagram**

## 2. Statement of Need

The purpose of this design project was to develop a Smart Car (SC) vehicle system which shall be integrated into a 2009 Honda Civic and shall enable the vehicle to be operated in a preexisting Modified HOV Lane System with little to no user intervention.

### 2.1. Stake Holders

Smart Car System was developed for automotive manufactures and consumers in the California region due to the preexisting HOV lanes and performance vehicle manufactures.

## 3. Background

The need to reduce or eliminate the functions of the driver of the vehicle has been researched by a number of automotive manufactures for many years. Recently, the U.S. Department of Defense (DARPA) has also been involved with finding a way to produce unmanned vehicles to be used on the front lines of war zones in order to reduce number of causalities. The DARPA program began a competition between universities to construct a system that will be installed on existing vehicles and use latest technologies to navigate the vehicle on a deserted route. This design team proposed a project to design a system which will reduce or eliminate driver functions during a commute. This system will be installed on an existing vehicle and will allow a driver to select between two (2) modes of operation: Manual and Smart Car.

## 4. Systems Design

To design this system, the design team initially listed all the required actions of a driver in order to safely navigate a vehicle through traffic. The team then attempted to understand the main requirements of the system, as given below.

The System must operate:

- Within the MHOVLS.
- Among other Smart Cars.
- With little to no driver interaction.
- In manual mode so that the driver could operate the vehicle outside the MHOVLS.

The Smart Car System shall be installed on a 2009 Honda Civic to create a Smart Car. The vehicle shall operate in either Manual or Smart Car Mode.

**Manual Mode:**

This mode is intended for the vehicle to operate similar to vehicles without Smart Car modifications. The driver controls acceleration, braking, follows road signs and observes road conditions in order to safely operate the vehicle.

**Smart Mode:**

This mode will be available after installation of the Smart Car System. For the vehicle to operate in this mode the driver must navigate the vehicle to an entrance of the Modified HOV Lane System (MHOVLS) at which point the MHOVLS will identify the vehicle and permit entrance into the System. To start Smart Mode operation, the driver shall stop the vehicle on the entrance ramp into the System, shift the transmission into neutral and select Smart Mode from the LCD screen. Once the SCM is activated, the driver will select an exit from a list displaced on the LCD screen. The Smart Car System then navigates the vehicle through the MHOVLS. As the vehicle approaches the selected exit, and audible alert as well as a message on the LCD screen will notify the driver that the vehicle is approaching the exit.

Smart Car Mode operation will control the acceleration, braking, position of the vehicle as well as alert the driver of a hazard condition and any system malfunctions.

In order for the SCM to function properly, the system shall rely on a number of sensors on the vehicle. These sensors will send information to the vehicle's Main Control System to safely operate the vehicle to the desired exit.

### 4.1. Product Breakdown Structure (PBS)

The Smart Car System is installed on a 2009 Honda Civic and interfaces with the MHOVLS.

#### Vehicle-2009 Honda Civic

This vehicle shall be modified with the installation of the Smart Car System.

#### Modified HOV Lane System

The MHOVLS consists of the physical lane with concrete barriers on either side, 18 feet apart. This allows for a single lane of traffic through the system. It has a communication system with consists of two (2) sets of transmitters and receivers. The one set sends and receives data to Smart Cars while the other system sends and receives data from the Department of Transportation (DOT).

#### Smart Car System

A series of block diagrams for the Smart Car System are shown in the following pages.

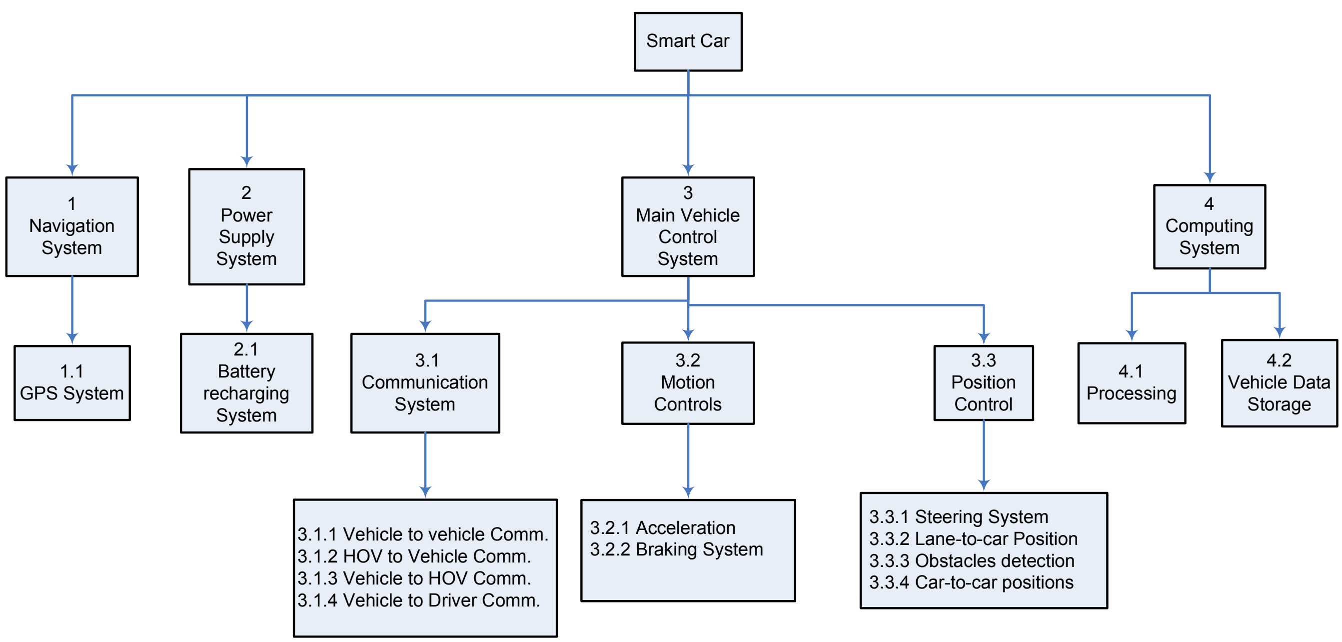


**Figure 2 – Overall Smart Car System Block Diagram**

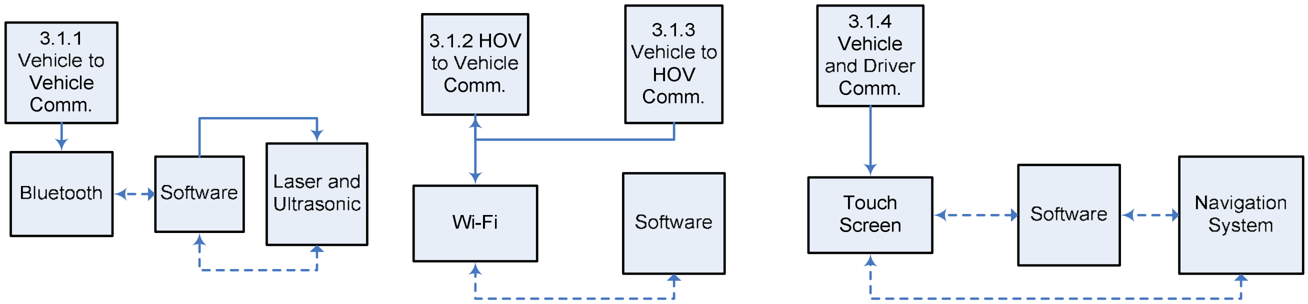


**Figure 3 – (a) Vehicle – Vehicle Communication (b) MHOVLS – Vehicle Communication (c) Vehicle – Driver Communication**

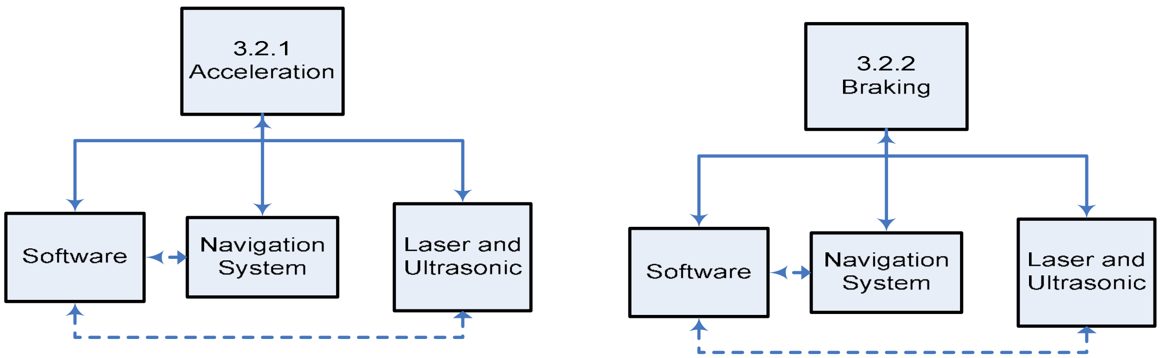


**Figure 4 – (a) Acceleration System (b) Braking System**

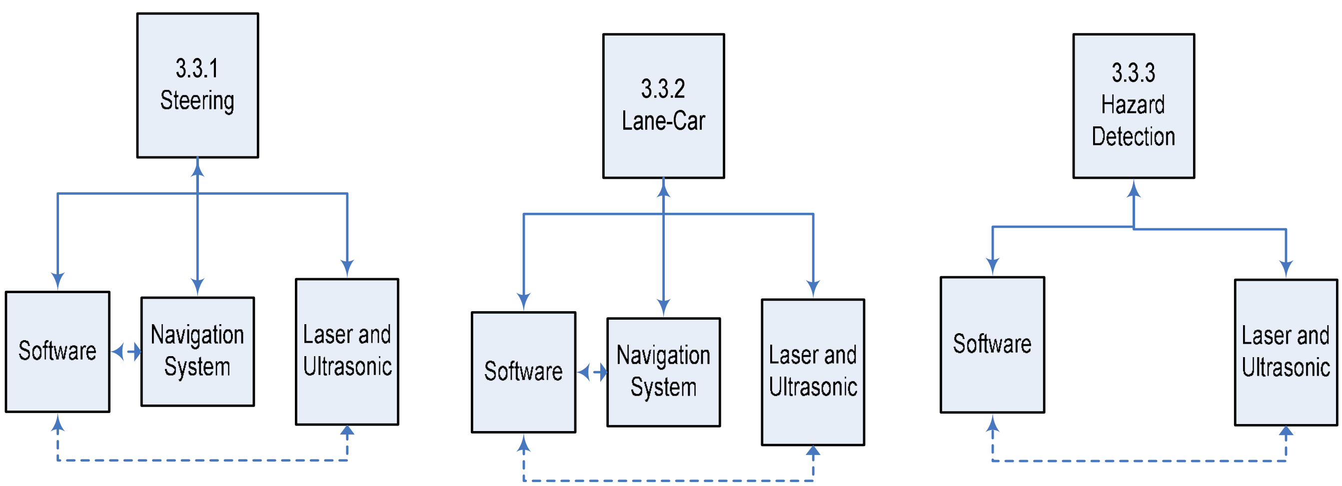


**Figure 5 – (a) Steering (b) Lane – Vehicle (c) Hazard**

### 4.2. Functional analysis

The functional analysis of this design report describes the overall functions and options the Smart Car System encounters during an operational scenario. Each function has a color codes designation as shown in Figure 6. Figure 7 shows a high level operational scenario.

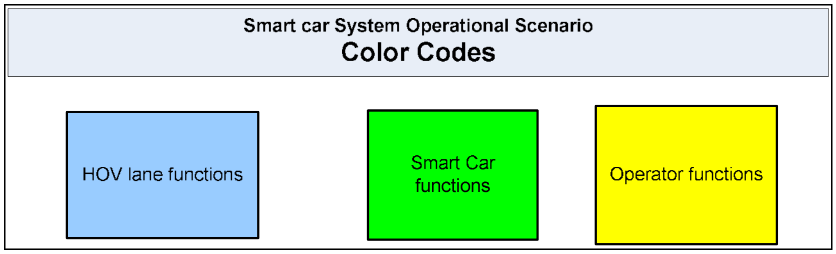


**Figure 6 – Smart Vehicle System Color Code Key**

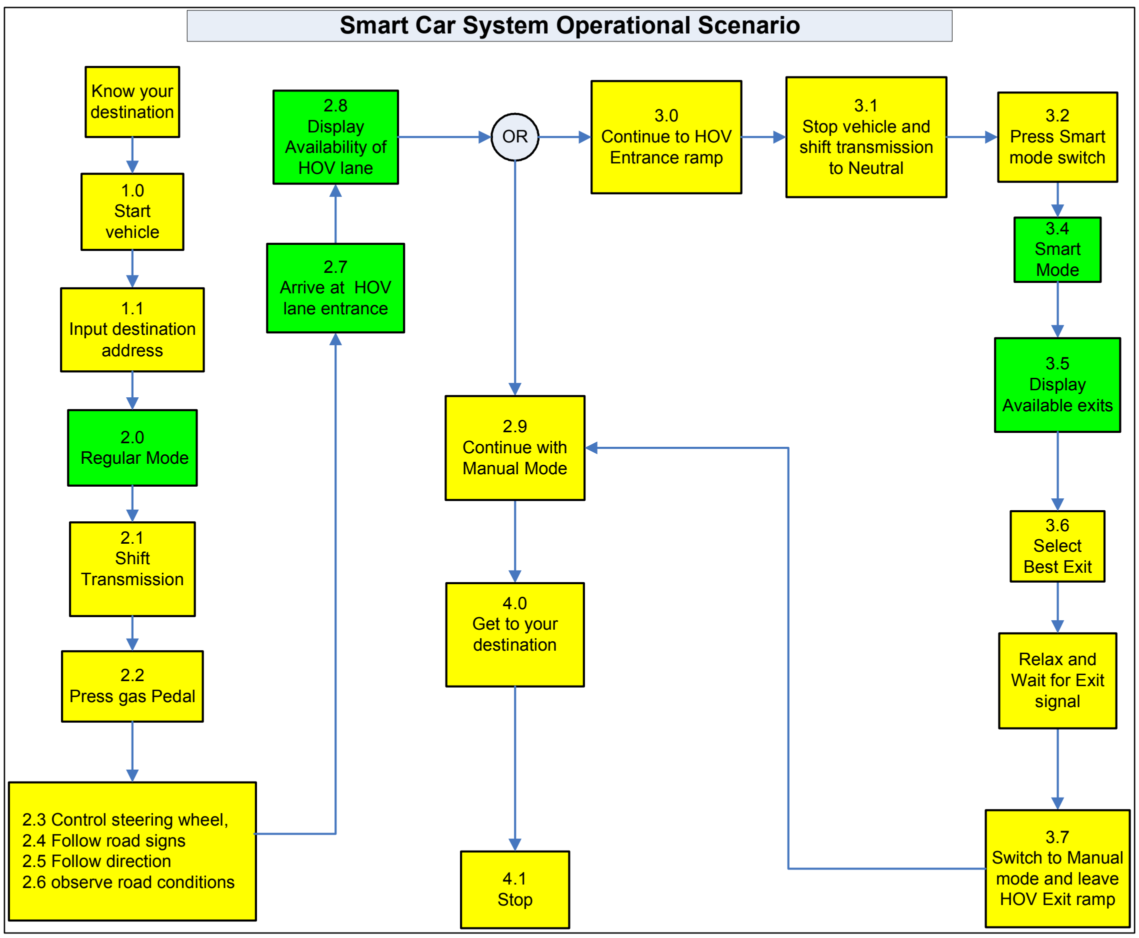


**Figure 7 – Smart Car System Operational Scenario**

Figure 8 shows how the MHOVLS detects a Smart Car at the entrance of the system.

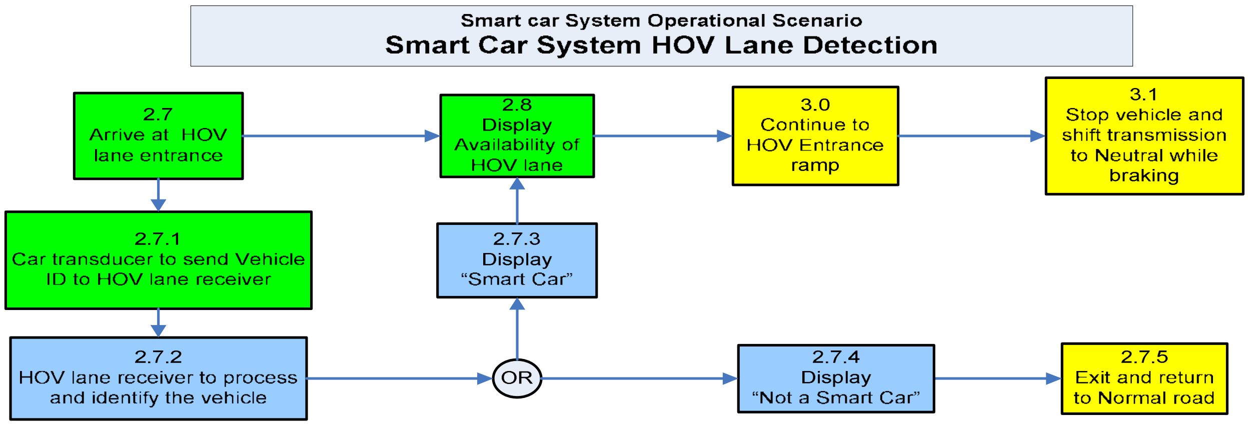


**Figure 8 – Smart Car System HOV Lane Detection**

Figure 9 is a more detailed operational scenario which includes subsystem functions.

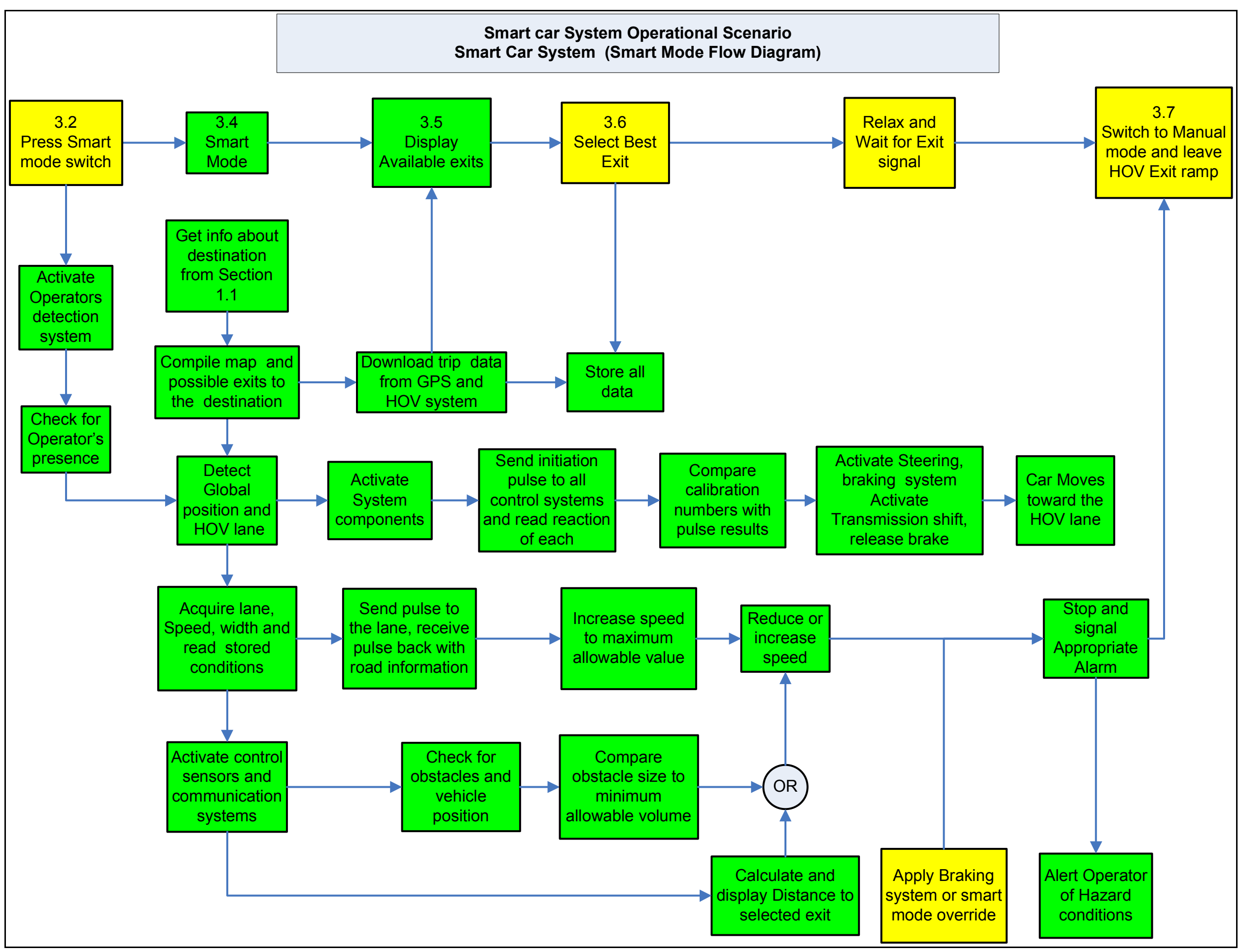


**Figure 9 – Smart Car System Smart Mode Flow Diagram**

### 4.3. Derived Requirements

- Ultrasonic sender transducers shall transform incoming voltages from the main vehicle control system to appropriate signals or energy needed by the SCS to measure distances and position.
- Ultrasonic receiver transducers shall receive appropriate signals or energy and transform them into voltages that can be understood by the main vehicle control system which can be transmitted to the processing system in order to make a decision.
- Main control system shall send voltages to the computing system to determine course of action for a particular situation.
- Vehicle main control shall be able to determine the vehicle's wheels turning angles which can be used by the processing system to send appropriate correction on the steering wheel motors.
- Braking actuators shall be able to transform the voltages into mechanical motion that can press or release the vehicle's brake pedal to reduce or stop the vehicle, or allow the acceleration system to increase the vehicle's speed.
- Accelerator actuators shall be able to transform the voltages into mechanical motion that can press or release the vehicle's foot pedal to increase or decrease acceleration.
- Laser and ultrasonic sender transducers shall be able transform incoming voltages to signals or energy to be used to measure hazard sizes in front of the SC.
- Laser and ultrasonic receiver transducers shall be able to transform reflected energy or waves that come from hazard detection into appropriate voltages to be used by the main vehicle control system and the processing to calculate the hazard size.
- Navigation system shall be able to send appropriate data to the processing system for the display to show the driver the exact location and distance to the selected exit.
- System shall utilize a 64-bit ARM Cortex-R4F CPU with 64k cache.
- System shall utilize FreeBSD UNIX operating system.
- System shall have a minimum of 256mb of RAM.
- Smart vehicle operational data transfer will be encrypted at 128 bit to protect unauthorized access.
- The vehicle operating system has software preprogrammed to produce outputs for the all of the SC subsystems.
- SCS shall be able to receive Wi-Fi signals from the MHOVLS.
- SCS shall be able to receive and send RFID signals to and from the MHOVLS entrances and exits.
- The Honda Civic alternator system will be modified so that it recharges both the Honda Civic battery and the SCS Battery.

### 4.4. Allocation matrix

Table 1 lists the requirements per the separate requirements document and the subsystems which fulfill those requirements. One requirement may be fulfilled by more than one subsystem.

**Table 1 – Smart Car System Allocation Matrix**

| Section | Description | Navigation System | Rechargeable Battery | Communication System | Motion Control System | Position Control System | Processing System | Vehicle Data Storage System |
|---|---|---|---|---|---|---|---|---|
| 3.3.2. | Functional Requirements | | | | | | | |
| 3.3.2.1. | Functional Requirements | • | • | • | • | • | • | • |
| 3.3.2.2. | Functional Requirements | | | • | • | • | • | |
| 3.3.2.3. | Functional Requirements | • | • | • | • | • | • | • |
| 3.3.2.4. | Functional Requirements | | | • | | | • | |
| 3.3.2.5. | Functional Requirements | | | | • | • | | |
| 3.3.2.6. | Functional Requirements | | | | | • | • | |
| 3.3.2.7. | Functional Requirements | | | | • | | • | |
| 3.3.2.8. | Functional Requirements | | | • | • | • | • | |
| 3.3.2.9. | Functional Requirements | • | | • | | | | |
| 3.3.2.10. | Functional Requirements | | | • | • | • | • | |
| 3.3.2.11. | Functional Requirements | | | | • | | • | |
| 3.3.2.12. | Functional Requirements | | • | | | | | |
| 3.3.2.13. | Functional Requirements | | | | | | • | • |
| 3.3.2.14. | Functional Requirements | | | | | | • | • |
| 3.3.2.15. | Functional Requirements | | | | | | • | • |
| 3.3.3. | Performance Requirements | | | | | | | |

### 4.5. Requirements Verification Matrix

The requirements shall be verified via four (4) verification methods:

- Test
- Demo
- Inspection
- Analysis

The requirements may be verified by one or more methods. Table 2 shows how each requirement is verified.

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