U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

1200 New Jersey Avenue SE.
Washington, DC 20590

May 8, 2020

The Honorable Roger F. Wicker
Chairman, Committee on Commerce, Science,
and Transportation
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

Enclosed is a report of the National Highway Traffic Safety Administration (NHTSA) "on the feasibility of a technical system that would operate in each new motor vehicle to indicate when the vehicle is subject to an open recall." This report is submitted in accordance with Section 24113 of the Fixing America's Surface Transportation (FAST) Act, Pub. L. 114-94.

The report explores three in-vehicle concept systems according to the type of wireless connectivity the system uses to send recall messages to the vehicle. There are three types of wireless connectivity: embedded, tethered, and integrated connectivity. These three connectivity approaches are not mutually exclusive and can be used in tandem, as appropriate. Furthermore, these approaches are likely to continue to exist in the future. The three different in-vehicle concept systems—i.e., options to connect vehicles to the mobile communication network—described in this report are:

1. Concept in-vehicle recall notification system 1 (Embedded): Both the connectivity (subscriber identity module (SIM) card and modem) and intelligence are built directly into the vehicle without the need of other devices. All data are transmitted via the original equipment manufacturer. Data transmission and wireless communication in the vehicle are done via a telematic control unit. The system is capable of exchanging messages (i.e., data) over the air, via a cellular network or Wi-Fi, between the vehicle and the original equipment manufacturer network operation center (i.e., servers and databases).

2. Concept in-vehicle recall notification system 2 (Tethered): External modems and/or a SIM card provide(s) the connectivity while the intelligence remains embedded in the vehicle. Data transmission and wireless communication in the vehicle are done via an aftermarket device or dongle that plugs into the OBD-II port. Connectivity is provided through an external modem.

3. Concept in-vehicle recall notification system 3 (Integrated): The smartphone and the vehicle form an integrated communication system. and all communication modules and intelligence remain strictly on the smartphone. This approach to connectivity is not connected to the vehicle controller area network bus. The system relies on the owner's mobile device for wireless connectivity and sometimes for human machine interface (if not included in the vehicle). The system requires a Bluetooth-enabled telematic control unit in the vehicle and does not have access to the vehicle on-board diagnostics system.

Although this report did not assess costs, benefits, or effectiveness to inform a regulatory outcome, it concludes that in-vehicle recall concept systems may be functionally capable of notifying owners of an open recall.

A similar letter has been sent to the Ranking Member of the Senate Committee on Commerce, Science, and Transportation; to the Chairman and Ranking Member of the House Committee on Energy and Commerce; and to the Chairman and Ranking Member of the House Committee on Transportation and Infrastructure.

Sincerely,

James C. Owens
Deputy Administrator

Enclosure

U.S. Department of Transportation
National Highway Traffic Safety Administration

1200 New Jersey Avenue SE.
Washington, DC 20590

May 8, 2020

The Honorable Maria Cantwell
Ranking Member, Committee on Commerce,
Science, and Transportation
United States Senate
Washington, DC 20510

Dear Senator Cantwell:

Enclosed is a report of the National Highway Traffic Safety Administration (NHTSA) "on the feasibility of a technical system that would operate in each new motor vehicle to indicate when the vehicle is subject to an open recall." This report is submitted in accordance with Section 24113 of the Fixing America's Surface Transportation (FAST) Act, Pub. L. 114-94.

The report explores three in-vehicle concept systems according to the type of wireless connectivity the system uses to send recall messages to the vehicle. There are three types of wireless connectivity: embedded, tethered, and integrated connectivity. These three connectivity approaches are not mutually exclusive and can be used in tandem, as appropriate. Furthermore, these approaches are likely to continue to exist in the future. The three different in-vehicle concept systems—i.e., options to connect vehicles to the mobile communication network—described in this report are:

1. Concept in-vehicle recall notification system 1 (Embedded): Both the connectivity (subscriber identity module (SIM) card and modem) and intelligence are built directly into the vehicle without the need of other devices. All data are transmitted via the original equipment manufacturer. Data transmission and wireless communication in the vehicle are done via a telematic control unit. The system is capable of exchanging messages (i.e., data) over the air, via a cellular network or Wi-Fi, between the vehicle and the original equipment manufacturer network operation center (i.e., servers and databases).

2. Concept in-vehicle recall notification system 2 (Tethered): External modems and/or a SIM card provide(s) the connectivity while the intelligence remains embedded in the vehicle. Data transmission and wireless communication in the vehicle are done via an aftermarket device or dongle that plugs into the OBD-II port. Connectivity is provided through an external modem.

3. Concept in-vehicle recall notification system 3 (Integrated): The smartphone and the vehicle form an integrated communication system, and all communication modules and intelligence remain strictly on the smartphone. This approach to connectivity is not connected to the vehicle controller area network bus. The system relies on the owner's mobile device for wireless connectivity and sometimes for human machine interface (if not included in the vehicle). The system requires a Bluetooth-enabled telematic control unit in the vehicle and does not have access to the vehicle on-board diagnostics system.

Although this report did not assess costs, benefits, or effectiveness to inform a regulatory outcome, it concludes that in-vehicle recall concept systems may be functionally capable of notifying owners of an open recall.

A similar letter has been sent to the Chairman of the Senate Committee on Commerce, Science, and Transportation; to the Chairman and Ranking Member of the House Committee on Energy and Commerce; and to the Chairman and Ranking Member of the House Committee on Transportation and Infrastructure.

Sincerely,

James C. Owens
Deputy Administrator

Enclosure

U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

1200 New Jersey Avenue SE.
Washington, DC 20590

May 8, 2020

The Honorable Frank Pallone, Jr.
Chairman, Committee on Energy
and Commerce
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed is a report of the National Highway Traffic Safety Administration (NHTSA) "on the feasibility of a technical system that would operate in each new motor vehicle to indicate when the vehicle is subject to an open recall." This report is submitted in accordance with Section 24113 of the Fixing America's Surface Transportation (FAST) Act, Pub. L. 114-94.

The report explores three in-vehicle concept systems according to the type of wireless connectivity the system uses to send recall messages to the vehicle. There are three types of wireless connectivity: embedded, tethered, and integrated connectivity. These three connectivity approaches are not mutually exclusive and can be used in tandem, as appropriate. Furthermore, these approaches are likely to continue to exist in the future. The three different in-vehicle concept systems—i.e., options to connect vehicles to the mobile communication network—described in this report are:

1. Concept in-vehicle recall notification system 1 (Embedded): Both the connectivity (subscriber identity module (SIM) card and modem) and intelligence are built directly into the vehicle without the need of other devices. Data transmission and wireless communication in the vehicle are done via a telematic control unit. The system is capable of exchanging messages (i.e., data) over the air, via a cellular network or Wi-Fi, between the vehicle and the original equipment manufacturer network operation center (i.e., servers and databases).

2. Concept in-vehicle recall notification system 2 (Tethered): External modems and/or a SIM card provide(s) the connectivity while the intelligence remains embedded in the vehicle. Data transmission and wireless communication in the vehicle are done via an aftermarket device or dongle that plugs into the OBD-II port. Connectivity is provided through an external modem.

3. Concept in-vehicle recall notification system 3 (Integrated): The smartphone and the vehicle form an integrated communication system, and all communication modules and intelligence remain strictly on the smartphone. This approach to connectivity is not connected to the vehicle controller area network bus. The system relies on the owner's mobile device for wireless connectivity and sometimes for human machine interface (if not included in the vehicle). The system requires a Bluetooth-enabled TCU in the vehicle and does not have access to the vehicle on-board diagnostics system.

Although this report did not assess costs, benefits, or effectiveness to inform a regulatory outcome, it concludes that in-vehicle recall concept systems may be functionally capable of notifying owners of an open recall.

A similar letter has been sent to the Ranking Member of the House Committee on Energy and Commerce; to the Chairman and Ranking Member of the House Committee on Transportation and Infrastructure; and to the Chairman and Ranking Member of the Senate Committee on Commerce, Science, and Transportation.

Sincerely,

James C. Owens
Deputy Administrator

Enclosure

U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

1200 New Jersey Avenue SE.
Washington, DC 20590

May 8, 2020

The Honorable Greg Walden
Ranking Member, Committee on Energy
and Commerce
U.S. House of Representatives
Washington, DC 20515

Dear Congressman Walden:

Enclosed is a report of the National Highway Traffic Safety Administration (NHTSA) "on the feasibility of a technical system that would operate in each new motor vehicle to indicate when the vehicle is subject to an open recall." This report is submitted in accordance with Section 24113 of the Fixing America's Surface Transportation (FAST) Act, Pub. L. 114-94.

The report explores three in-vehicle concept systems according to the type of wireless connectivity the system uses to send recall messages to the vehicle. There are three types of wireless connectivity: embedded, tethered, and integrated connectivity. These three connectivity approaches are not mutually exclusive and can be used in tandem, as appropriate. Furthermore, these approaches are likely to continue to exist in the future. The three different in-vehicle concept systems—i.e., options to connect vehicles to the mobile communication network—described in this report are:

1. Concept in-vehicle recall notification system 1 (Embedded): Both the connectivity (subscriber identity module (SIM) card and modem) and intelligence are built directly into the vehicle without the need of other devices. Data transmission and wireless communication in the vehicle are done via a telematic control unit. The system is capable of exchanging messages (i.e., data) over the air, via a cellular network or Wi-Fi, between the vehicle and the OEM network operation center (i.e., servers and databases).

2. Concept in-vehicle recall notification system 2 (Tethered): External modems and/or a SIM card provide(s) the connectivity while the intelligence remains embedded in the vehicle. Data transmission and wireless communication in the vehicle are done via an aftermarket device or dongle that plugs into the OBD-II port. Connectivity is provided through an external modem.

3. Concept in-vehicle recall notification system 3 (Integrated): The smartphone and the vehicle form an integrated communication system, and all communication modules and intelligence remain strictly on the smartphone. This approach to connectivity is not connected to the vehicle controller area network bus. The system relies on the owner's mobile device for wireless connectivity and sometimes for human machine interface (if not included in the vehicle). The system requires a Bluetooth-enabled telematic control unit in the vehicle and does not have access to the vehicle on-board diagnostics system.

Although this report did not assess costs, benefits, or effectiveness to inform a regulatory outcome, it concludes that in-vehicle recall concept systems may be functionally capable of notifying owners of an open recall.

A similar letter has been sent to the Chairman of the House Committee on Energy and Commerce; to the Chairman and Ranking Member of the House Committee on Transportation and Infrastructure; and to the Chairman and Ranking Member of the Senate Committee on Commerce, Science, and Transportation.

Sincerely,

James C. Owens
Deputy Administrator

Enclosure

U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

1200 New Jersey Avenue SE.
Washington, DC 20590

May 8, 2020

The Honorable Peter A. DeFazio
Chairman, Committee on Transportation
and Infrastructure
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed is a report of the National Highway Traffic Safety Administration (NHTSA) "on the feasibility of a technical system that would operate in each new motor vehicle to indicate when the vehicle is subject to an open recall." This report is submitted in accordance with Section 24113 of the Fixing America's Surface Transportation (FAST) Act, Pub. L. 114-94.

The report explores three in-vehicle concept systems according to the type of wireless connectivity the system uses to send recall messages to the vehicle. There are three types of wireless connectivity: embedded, tethered, and integrated connectivity. These three connectivity approaches are not mutually exclusive and can be used in tandem, as appropriate. Furthermore, these approaches are likely to continue to exist in the future. The three different in-vehicle concept systems—i.e., options to connect vehicles to the mobile communication network—described in this report are:

1. Concept in-vehicle recall notification system 1 (Embedded): Both the connectivity (subscriber identity module (SIM) card and modem) and intelligence are built directly into the vehicle without the need of other devices. Data transmission and wireless communication in the vehicle are done via a telematic control unit. The system is capable of exchanging messages (i.e., data) over the air, via a cellular network or Wi-Fi, between the vehicle and the original equipment manufacturer network operation center (i.e., servers and databases).
2. Concept in-vehicle recall notification system 2 (Tethered): External modems and/or a SIM card provide(s) the connectivity while the intelligence remains embedded in the vehicle. Data transmission and wireless communication in the vehicle are done via an aftermarket device or dongle that plugs into the OBD-II port. Connectivity is provided through an external modem.

3. Concept in-vehicle recall notification system 3 (Integrated): The smartphone and the vehicle form an integrated communication system, and all communication modules and intelligence remain strictly on the smartphone. This approach to connectivity is not connected to the vehicle controller area network bus. The system relies on the owner's mobile device for wireless connectivity and sometimes for human machine interface (if not included in the vehicle). The system requires a Bluetooth-enabled telematic control unit in the vehicle and does not have access to the vehicle on-board diagnostics system.

Although this report did not assess costs, benefits, or effectiveness to inform a regulatory outcome, it concludes that in-vehicle recall concept systems may be functionally capable of notifying owners of an open recall.

A similar letter has been sent to the Ranking Member of the House Committee on Transportation and Infrastructure; to the Chairman and Ranking Member of the House Committee on Energy and Commerce; and to the Chairman and Ranking Member of the Senate Committee on Commerce, Science, and Transportation.

Sincerely,

James C. Owens
Deputy Administrator

Enclosure

U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

1200 New Jersey Avenue SE.
Washington, DC 20590

May 8, 2020

The Honorable Sam Graves
Ranking Member, Committee on Transportation
and Infrastructure
U.S. House of Representatives
Washington, DC 20515

Dear Congressman Graves:

Enclosed is a report of the National Highway Traffic Safety Administration (NHTSA) "on the feasibility of a technical system that would operate in each new motor vehicle to indicate when the vehicle is subject to an open recall." This report is submitted in accordance with Section 24113 of the Fixing America's Surface Transportation (FAST) Act, Pub. L. 114-94.

The report explores three in-vehicle concept systems according to the type of wireless connectivity the system uses to send recall messages to the vehicle. There are three types of wireless connectivity: embedded, tethered, and integrated connectivity. These three connectivity approaches are not mutually exclusive and can be used in tandem, as appropriate. Furthermore, these approaches are likely to continue to exist in the future. The three different in-vehicle concept systems—i.e., options to connect vehicles to the mobile communication network—described in this report are:

1. Concept in-vehicle recall notification system 1 (Embedded): Both the connectivity (subscriber identity module (SIM) card and modem) and intelligence are built directly into the vehicle without the need of other devices. Data transmission and wireless communication in the vehicle are done via a telematic control unit. The system is capable of exchanging messages (i.e., data) over the air, via a cellular network or Wi-Fi, between the vehicle and the OEM network operation center (i.e., servers and databases).

2. Concept in-vehicle recall notification system 2 (Tethered): External modems and/or a SIM card provide(s) the connectivity while the intelligence remains embedded in the vehicle. Data transmission and wireless communication in the vehicle are done via an aftermarket device or dongle that plugs into the OBD-II port. Connectivity is provided through an external modem.

3. Concept in-vehicle recall notification system 3 (Integrated): The smartphone and the vehicle form an integrated communication system, and all communication modules and intelligence remain strictly on the smartphone. This approach to connectivity is not connected to the vehicle controller area network bus. The system relies on the owner's mobile device for wireless connectivity and sometimes for human machine interface (if not included in the vehicle). The system requires a Bluetooth-enabled telematic control unit in the vehicle and does not have access to the vehicle on-board diagnostics system.

Although this report did not assess costs, benefits, or effectiveness to inform a regulatory outcome, it concludes that in-vehicle recall concept systems may be functionally capable of notifying owners of an open recall.

A similar letter has been sent to the Chairman of the House Committee on Transportation and Infrastructure; to the Chairman and Ranking Member of the House Committee on Energy and Commerce; and to the Chairman and Ranking Member of the Senate Committee on Commerce, Science, and Transportation.

Sincerely,

James C. Owens
Deputy Administrator

Enclosure

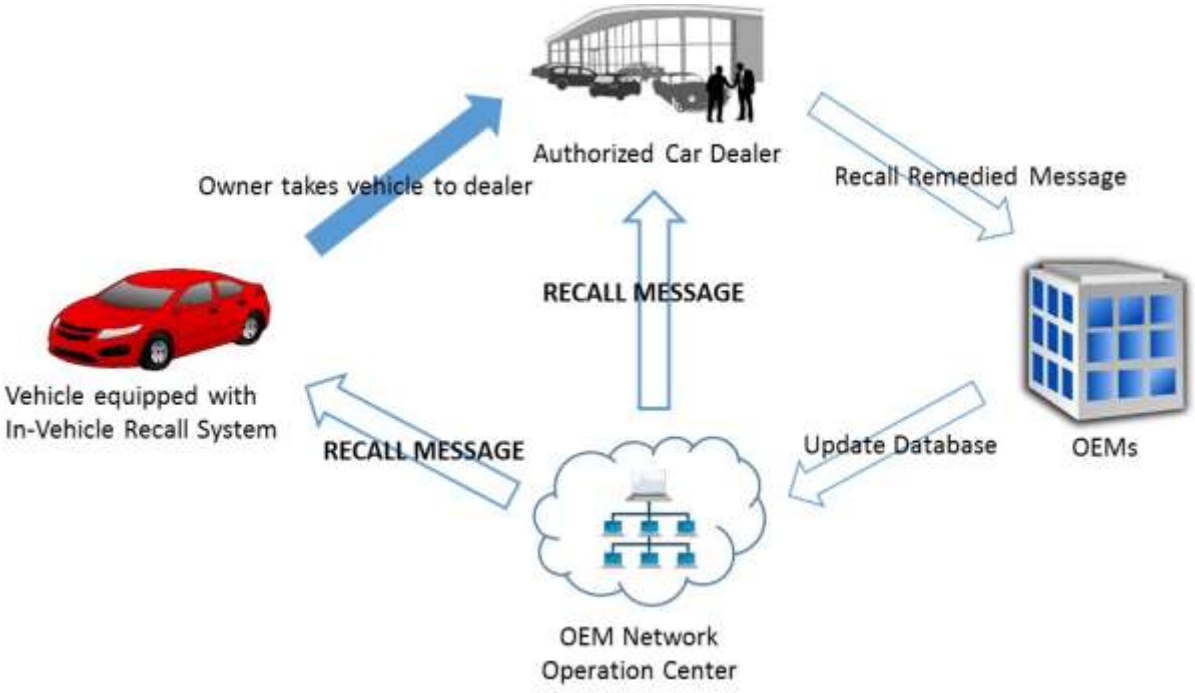
Department of Transportation

**National Highway Traffic Safety**

**Administration**

www.nhtsa.gov

# Feasibility of In-Vehicle Recall Notifications




**Final Report – May 2020**

# Table of Contents

## List of Figures



## List of Tables

## List of Acronyms

| | |
|---|---|
| **CAN** | Controller Area Network |
| **4G LTE** | Fourth-Generation Long Term Evolution |
| **CFR** | Code of Federal Regulations |
| **FAST Act** | Fixing America's Surface Transportation Act |
| **GAO** | Government Accountability Office |
| **GPS** | Global Positioning System |
| **GSMA** | Global System for Mobile Communications Association |
| **HMI** | Human-Machine Interface |
| **NHTSA** | National Highway Traffic Safety Administration |
| **OBD** | On-Board Diagnostics |
| **OEM** | Original Equipment Manufacturer |
| **SIM** | Subscriber Identity Module |
| **SME** | Subject Matter Expert |
| **TCU** | Telematics Control Unit |
| **USB** | Universal Serial Bus |
| **VIN** | Vehicle Identification Number |

## Executive Summary

The Fixing America's Surface Transportation Act (FAST Act), Pub. L. No. 119-14, in Sec. 24113, Direct Vehicle Notification of Recalls, requires the Secretary of Transportation to "issue a report on the feasibility of a technical system that would operate in each new motor vehicle to indicate when the vehicle is subject to an open recall."[1]

**Although this report did not assess costs, benefits, or effectiveness to inform a regulatory outcome, it concludes that in-vehicle recall concept systems may be functionally capable of notifying owners of an open recall.**

The National Highway Traffic Safety Administration (NHTSA), in collaboration with the John A. Volpe National Transportation Systems Center (Volpe), has performed an exploratory study to assess the feasibility to determine the functional capability of a messaging system and potential cost of vehicle-based concept systems that would operate in new light motor vehicles to indicate to drivers when the vehicle is subject to an open recall.

This effort examined the technology architecture, security considerations, and privacy implications of in-vehicle systems.[2] This study revealed that in-vehicle and aftermarket systems capable of communicating an open recall message to the vehicle exist today, and current telematics systems allow original equipment manufacturers (OEMs) to have constant access to vehicle data and typically include a human-machine interface (HMI) where drivers have access to a variety of services. OEM telematics systems use wireless connectivity to exchange data over the air between the vehicle's internal system to off-site computers where it can be stored, processed, and converted into usable information. This data is sent via the telematics control unit (TCU), a special electronic control unit connected to the vehicle data bus. Table 6 and Table 8 of Appendix A list and review current OEM telematics systems and their capabilities.

In addition to OEM telematics systems, aftermarket telematics systems are also available to vehicle owners. Aftermarket telematics systems use a device ("dongle") that connects to the On-Board Diagnostics (OBD)-II port and provides access to vehicle data. The device also includes a built-in modem allowing it to communicate with both the customer and the service provider. Aftermarket system manufacturers do not have access to the in-vehicle HMI, and must either rely upon the user's mobile device or provide their own separate interface device that can be mounted on the car dashboard. Table 5 and Table 7 of Appendix A list and review current aftermarket telematics systems and their capabilities.

Volpe devised three in-vehicle concept systems according to the type of wireless connectivity the system uses to send recall messages to the vehicle. There are three types of wireless connectivity: embedded, tethered, and integrated connectivity.[3] These three connectivity approaches are not mutually exclusive and can be used in

[1] The term "open recall" is defined as "a recall for which a notification by a manufacturer has been provided under section 30119 of title 49, United States Code, and that has not been remedied under section 30120 of that title." Sec. 24113(b).

[2] For the purpose of this report, in-vehicle systems are systems embedded in the vehicle or devices inside the vehicle that can create a consolidated communication system with the vehicle.

[3] There are three different options to connect vehicles to the mobile communication network, according to the Global System for Mobile Communications Association (GSMA): Embedded, Tethered and Integrated. In embedded

tandem, as appropriate. Furthermore, these approaches are likely to continue to exist in the future. A tandem approach might be used, for example, when the technology employed for the embedded system is likely to be inappropriate for newer generation or higher bandwidth services. Each concept system includes the following components to connect the vehicles with the OEMs: telematics system, HMI, communication technology, and OEM network operation center. The three in-vehicle concept systems are:

1. Concept in-vehicle recall notification system 1 (Embedded): Data transmission and wireless communication in the vehicle are done via a TCU. The system is capable of exchanging messages (i.e., data) over the air, via a cellular network or Wi-Fi, between the vehicle and the OEM network operation center (i.e., servers and databases).
2. Concept in-vehicle recall notification system 2 (Tethered): Data transmission and wireless communication in the vehicle are done via an aftermarket device or dongle that plugs into the OBD-II port. Connectivity is provided through an external modem.
3. Concept in-vehicle recall notification system 3 (Integrated): The smartphone and the vehicle form an integrated communication system. The system relies on the owner's mobile device for wireless connectivity and sometimes for HMI (if not included in the vehicle). The system requires a Bluetooth-enabled TCU in the vehicle and does not have access to the vehicle on-board diagnostics system.

All concept systems can connect the vehicle with an OEM network operation center that has access to recall databases (e.g., OEM databases with open safety recalls). Concept systems are capable of exchanging messages over the air between the OEM network operation center and the vehicle. Concept systems include an HMI to display recall messages to the driver. The HMI display could show required recall message content specified by 49 Code of Federal Regulations (CFR) part 577 and subsequently, owners/drivers would be able to see recall messages on the HMI display until the recall is remedied.

The recall process with the concept systems may involve four simple steps:

1. The system displays a recall message sent by the OEM network operation center.[4]
2. The owner takes the vehicle to the authorized dealer for repair.
3. The authorized dealer remedies the vehicle at no charge and notifies the OEM that the vehicle has been remedied.
4. The OEM updates the recall database and asks the OEM network operation to end the in-vehicle recall process.

The following are potentially-significant considerations when implementing in-vehicle recall systems within the recall process:

connectivity, both the connectivity (subscriber identity module (SIM) card and modem) and intelligence are built directly into the vehicle without the need of other devices. All data are transmitted via the OEM. In tethered connectivity, external modems and/or SIM card provide the connectivity while the intelligence remains embedded in the vehicle. Integrated connectivity is based upon integration between the vehicle and the owner's mobile device, in which all communication modules and intelligence remain strictly on the smartphone. This approach to connectivity is not connected to the vehicle Controller Area Network (CAN) bus.

[4] The system will display recall message regardless of dealer readiness to remedy.

- All concept systems are periodically subject to security control and implementation. They are protected from unauthorized access. OEMs protect the vehicle network and secure recall databases.
- Owners are responsible for taking the vehicle to an authorized dealer for repair.
- Dealers inform the OEM that the vehicle has been remedied.
- OEMs stop the recall message when the vehicle has been repaired.
- OEM network operation center keeps an up-to-date recall database.

Results from the analysis of the concept systems show that the costs depend on the level of involvement or roles played in the recall process, which differs across the three concept systems. An example is the mechanism for conveying the message to the owners (telematics unit screen, phone application, etc.) and how the car owner acknowledges them. In general, OEM-embedded units are typically built in the price of the vehicle; hence, the cost for the consumer is minimal. The average consumer cost of OEM dongle/devices and Bluetooth devices range between $60 and $100. In terms of consumer subscription costs, embedded systems and integrated systems are closely similar and range between $200 and $250 annually.[5] Tethered connectivity has the lowest subscription cost but also depends on a mobile data plan. OEM costs are much more difficult to estimate, for two reasons: (1) such information is not publicly available and (2) OEMs are highly dependent on telematics value chain, which is dynamic and differs across the three concept systems.

Subject matter experts (SMEs) interviewed for this study agreed that the wireless technology of the concept systems currently exists and is a reasonable way to send recall messages to owners. The caveat is that vehicles need to be connected to the mobile communication network to receive recall messages, which raises concerns about connectivity in areas with no cellular coverage. The SMEs also expressed several concerns about the implementation of a recall process using in-vehicle recall systems, including the following:

- Recall message frequency
- Driver distraction
- Time lags in the recall process loop

All SMEs agreed that the concept systems would be able to reach owners of vehicles throughout the vehicle lifecycle (i.e., owners of new vehicles and subsequent owners thereof), if the vehicles were connected to the mobile communication network. It is still yet to be determined how such systems could improve the recall process and completion rates. SMEs also agreed that system effectiveness depends on how motivating the recall notifications are and on owner risk assessment of the recall and how important it is to their safety.

**Although this study did not assess costs, benefits, or effectiveness to inform a regulatory outcome, it concludes that concept in-vehicle recall systems may be functionally capable of notifying owners of an open recall. More research may be needed to understand how these systems could improve the recall process and completion rates.**

[5] In the current market, in-vehicle recall notification prototype is a subscription type of service. In this report – while neither approving nor disapproving of the approach – we assume the consumer will have to pay a subscription cost. This assumes that OEMs are not required to provide the service without a subscription cost – if this happens, then the OEM is likely to integrate the cost of the lifetime of subscription into the overall cost to purchase the vehicle.

# 1. Introduction

The Fixing America's Surface Transportation Act (FAST Act), Pub. L. No. 119-14, in Sec. 24113, Direct Vehicle Notification of Recalls, requires the Secretary of Transportation to "issue a report on the feasibility of a technical system that would operate in each new motor vehicle to indicate when the vehicle is subject to an open recall."[6]

**Although this report did not assess costs, benefits, or effectiveness to inform a regulatory outcome, it concludes that concept in-vehicle recall systems may be functionally capable of notifying owners of an open recall.**

NHTSA, in collaboration with the Volpe National Transportation Systems Center (Volpe), has performed an exploratory study to assess the feasibility to determine the functional capability of a messaging system and potential cost of vehicle-based concept systems that would operate in new light motor vehicles[7] to indicate to drivers when the vehicle is subject to an open recall.

This report summarizes the findings in this effort and it is organized as follows:

- Summary of the recall process and its challenges
- Review of existing technical systems
- Review of security and privacy implications of the systems
- Design of three concept in-vehicle recall notification systems
- General cost evaluation of the concept systems
- Feasibility assessment of the systems based on interviews with industry subject matter experts (SMEs).

This chapter includes the recall process, NHTSA's actions to improve recall completion rates, and the challenges to improving the process.

## 1.1. The Recall Process

The Motor Vehicle Safety Act (Title 49 of the United States Code) generally prohibits the sale or lease of defective or noncompliant vehicles or equipment without first being remedied. The Act requires manufacturers to conduct safety recalls and notify consumers that a motor vehicle or item of equipment they purchased contains a safety-related defect or does not comply with an applicable motor vehicle safety standard, and as well as that manufacturers remedy such defects and noncompliance without charge.[8] When a manufacturer issues a safety recall, Parts 573 and 577 of the Code of Federal Regulations (CFR) require, among other things, the manufacturer to:

- Notify NHTSA through a Part 573 Information Report that identifies the recalled vehicle or equipment, summarizes the defect or noncompliance, and details the manufacturer's plans for remedying the defect or noncompliance.

[6] The term "open recall" is defined as "a recall for which a notification by a manufacturer has been provided under section 30119 of title 49, United States Code, and that has not been remedied under section 30120 of that title." Sec. 24113(b).
[7] Light motor vehicles encompass passenger cars, vans and minivans, sport utility vehicles, and light pickup trucks with gross vehicle weight rating under 10,000 pounds.
[8] *See* 49 U.S.C. §§ 30118–30120.

- Notify owners and purchasers, by first class mail, of the recall and the available free remedy to address the defect or noncompliance.
- Report to NHTSA, among other things, for six consecutive quarters, the number of recalled vehicles or items of equipment that have been inspected and remedied.

Figure 1 illustrates various steps of the recall process.

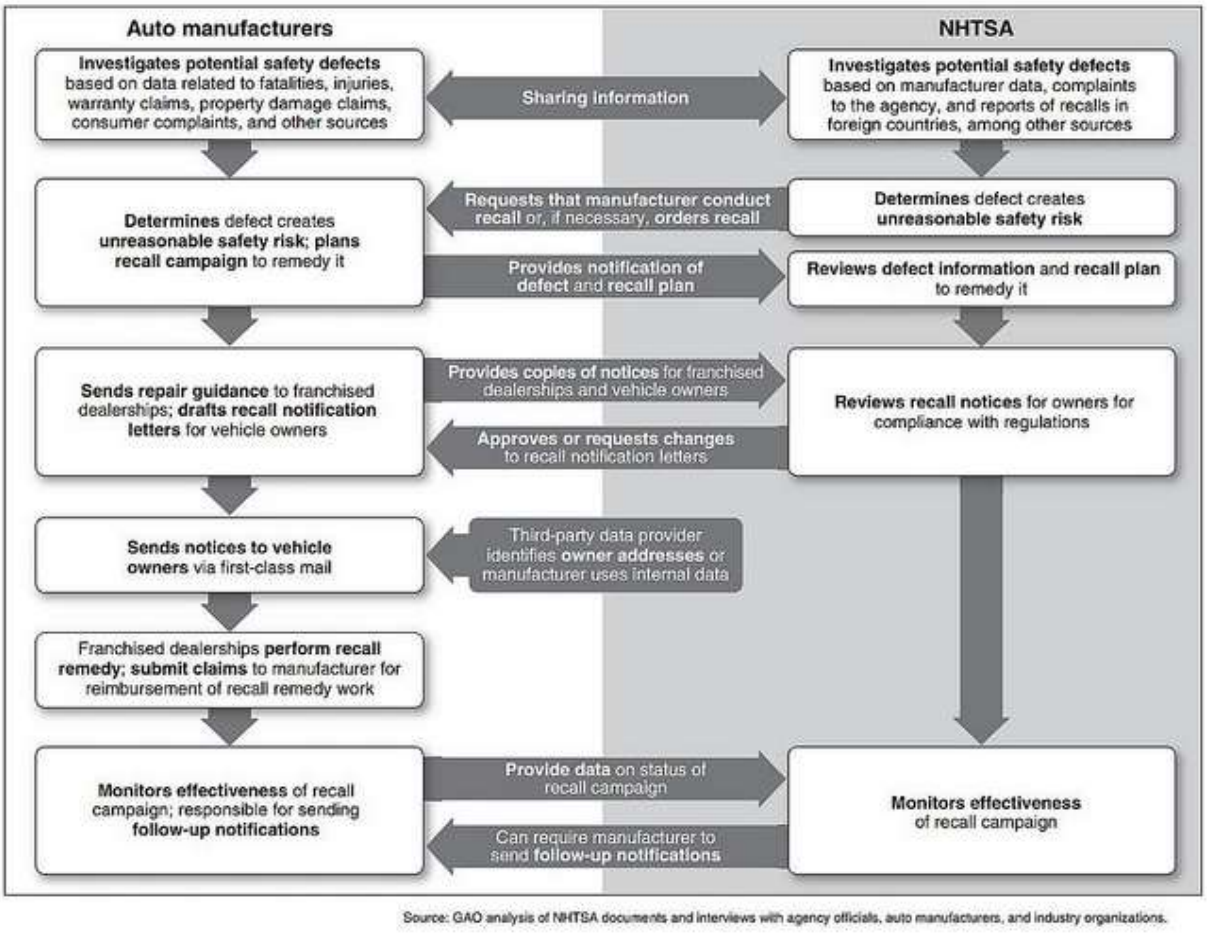



**Figure 1.** Overview of the Recall Process

### 1.1.1. Vehicle Recall Notifications

Recall notification is addressed by 49 CFR part 577, Defect and Noncompliance Notification. Section 577.5 specifies the required content and structure of owner notifications where a manufacturer has decided a defect or noncompliance exists. The following requirements for notification letters are included in this section:

- The words “SAFETY RECALL NOTICE” all in capital letters on the outside of each envelope—larger than the type used in the address section, and in a type that is larger and distinguishable from the other type in a manner other than size.

- Where a vehicle is the subject of the recall, the owner's vehicle identification number (VIN) placed at the top of the letter or, if not possible, in another conspicuous location in the notification.
- The opening statement, "This notice is sent to you in accordance with the requirements of the National Traffic and Motor Vehicle Safety Act.''
- A statement indicating that the manufacturer has decided that a defect which relates to the motor vehicle safety exists, or that an item of replacement equipment has failed to conform to a Federal Motor Vehicle Safety Standard.
- If applicable, an additional statement that the defect or non-compliance may not exist in each vehicle or item of replacement equipment.
- A clear description of the defect or noncompliance.
- An evaluation of the risk to motor vehicle safety reasonably related to the defect or noncompliance.
- A statement of measures to be taken to remedy the defect or noncompliance.
- That any lessor who receives a notification of a determination of a safety-related defect or noncompliance pertaining to any leased motor vehicle shall send a copy of such notice to the lessee, unless the manufacturer has directly notified a lessor's lessees.

### 1.1.2. Recall Completion Rates

The FAST Act required that the Secretary of Transportation conduct an analysis of vehicle recall completion rates and submit the findings of that report to the Committee on Commerce, Science, and Transportation of the Senate and the Committee of Energy and Commerce of the House of Representatives.[9] NHTSA submitted a report to Congress in response to this requirement; its most significant findings:

- 67% of vehicles recalled by major, light-vehicle manufacturers between 2010 and 2014 were remedied. The average recall completion rate during this period was 81% (unweighted) for recalls issued by those same manufacturers (Appendix B – Figure 12).
- The annual recall completion rate varies significantly, even among major manufacturers of light vehicles.
- The recalled component is the second-most determining factor when assessing recall-completion rates. Controlling for other relevant factors, a recall for fuel systems would perform 16 percentage points higher (on average) than the same recall if it instead involved seats (Appendix B – Figure 13).
- The age of the recalled vehicle also plays a significant role in recall completion. Recalls for newer vehicles tend to have higher completion rates than recalls for older vehicles. Controlling for other relevant factors, reducing the age of the oldest vehicle in the recall by 5 years would increase the completion rate by 13 percentage points on average (Appendix B – Figure 14).

[9] National Highway Traffic Safety Administration, REPORT TO CONGRESS: "VEHICLE SAFETY RECALL COMPLETIONS REPORT" (May 2017), *available at* https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13376-recall_completion_rates_rtc-tag_final.pdf

- NHTSA's model predicts approximately 65% of recall completion rates accurately within a 10-percentage point margin of error. This suggests that other factors relevant to recall completion rates are present but not identifiable with the available data (Appendix B – Figure 15).

NHTSA's efforts to improve the recall process and the recall completion rates include, but may not be limited to, the following actions:

- On August 20, 2013, NHTSA published a final rule **78 FR 51382** revising certain provisions of the early warning reporting rule and the regulations governing motor vehicle and equipment safety recalls.[10] Under the revised regulation, NHTSA is requiring the following:
  - Vehicle manufacturers must issue notification letters to owners within 60 days of notifying NHTSA of a safety recall.
  - The inclusion of the owner's VIN in the notification letter.
  - A specific label printed on every recall notification envelope (label shown in Figure 2).
  - The secure electronic transfer of manufacturer recall data to NHTSA through the agency's web site.
- NHTSA launched its VIN Look-up Tool on https://www.nhtsa.gov/recalls, which allows owners to search for their vehicle by VIN to learn of open safety recalls.
- In November 2018, NHTSA met with federal and industry leaders to discuss boosting recall repair rates. Discussion focused on four main topics: Data and dealers, communicating and connecting with consumers, recall outreach, and unique recalls.
- NHTSA kicked off its first Vehicle Safety Recalls Week on March 2, 2020 to raise awareness about recalls, including how to check, and receive a repair, for an open recall .


**Figure 2**. New Recall Label

## 1.2. Current Challenges of the Recall Process and Completion Rates

Closing a recall process and getting vehicles remedied is a challenge for automakers and regulators. In 2019, automakers initiated 881 separate recall campaigns affecting approximately 38.6 million vehicles, up from approximately 29.5 million vehicles the previous year. As of April 2019, more than 52 million vehicles are operating with unresolved safety recalls.[11]

There are several factors affecting the recall completion rate according to NHTSA and industry studies. The age of the vehicle, for example, can affect recall completion rates, with older models seeing lower completion rates. A plausible reason for this is that vehicles can easily change hands multiple times over

[10] *Available at* https://www.gpo.gov/fdsys/pkg/FR-2013-08-20/pdf/2013-19785.pdf.
[11] Joe Overby, *52 Million Vehicles with Open Recalls on US Roads, Carfax finds* (Apr. 8, 2018), https://www.autoremarketing.com/trends/52-million-vehicles-open-recalls-us-roads-carfax-finds.

their lifetime. When a recall occurs, it then becomes increasingly difficult for manufacturers and dealerships to notify the current owners.

The size of the recall is another factor affecting recall completion rates. Completion rates for larger recalls (more than 100,000 units) are often approximately five percent to ten percent lower than those for smaller-sized recalls.[12] This may happen because smaller recalls typically involve newer vehicles covered under warranty, and their owners are more likely to visit a dealer.

Traditionally, automakers notify owners about a safety recall through first-class mail. Doing so requires merging vehicle purchase records with state registration information (since there is no federal vehicle registration), and second and third owners do not appear in sale records. Adding to this, some states do not supply the most current registration information to third-party database and analytics firms used by automakers to obtain updated VINs.[13]

In addition to first-class mail, automakers use a multitude of communication methods to reach owners including: emails, phone calls, and social media. Automakers engage owners not just once, but many times to get repairs completed. Some manufacturers have even offered incentives, like gift cards, to get customers to complete needed recall-related repairs.[14] However, roughly 30% of all consumers still ignore an automotive recall notice.[15] The principal reason for consumers not acting on recall notices continues to be that they do not remember receiving the notice, do not perceive the recall as important, or it has not been convenient to get the repairs completed. Others note consumer fatigue due to significant increases in recall volumes.[16]

The perceived severity of the defective or noncompliant component is also a factor affecting recall completion rates. Vehicle owners are more likely to get their vehicle repaired when they perceive the risk to be severe component failures (e.g., seat belts, windshield wipers, etc.).[17] NHTSA's Recall Completion Rates report to Congress speaks to this issue (see footnote 9, above).

Considering that today's vehicles are increasingly technologically advanced, one possible way to close the recall completion gap is through vehicle connectivity. Recall reminders could be sent to the vehicle or a smartphone, much like a dashboard light warns when it is time to get an oil change.[18]

This report explores state-of-the-art technology capable of sending recall messages to vehicles. The main objective is to assess the feasibility to determine the functional capability of a messaging system

---

[12] Neil Steinkamp and Jack Reed, *A Study of Recall Completion Rates* (July 6, 2015), https://www.foley.com/a-study-of-recall-completion-rates-07-06-2015/

[13] Kulisch, *Recall Process Still Waiting for Repair*, http://www.autonews.com/article/20171204/OEM11/171209989/recall-process-still-waiting-for-repair.

[14] Wayne Mitchell, *Increasing Recall Completion Rates During an Auto Recall* (Apr. 17, 2015), https://www.stericycleexpertsolutions.com/increasing-auto-recall-completion-rates/.

[15] Quentin Fottrell, *Why 30% of Car Owners Ignore Recalls* (June 5, 2014), https://www.marketwatch.com/story/why-honda-and-gm-drivers-will-ignore-recalls-2014-03-18.

[16] Mitchell, *Increasing Recall Completion Rates During an Auto Recall,* https://www.stericycleexpertsolutions.com/increasing-auto-recall-completion-rates/.

[17] Andrew Malec, *Automotive Recall Completion Rates* (Mar. 21, 2017), https://www.okeefellc.com/news/automotive-recall-completion-rates/.

[18] Kulisch, *Recall Process Still Waiting for Repair,* http://www.autonews.com/article/20171204/OEM11/171209989/recall-process-still-waiting-for-repair

and potential cost of vehicle-based concept systems that would operate in new light motor vehicles to indicate when the vehicle is subject to an open recall.

## 2. Review of Existing Telematics Systems

Volpe reviewed the technology architecture, connectivity options, security considerations, and privacy implications of the existing OEM and aftermarket telematics systems.

Telematics systems allow OEMs to have constant access to vehicle data and typically have a human-machine interface (HMI) where drivers have access to a variety of services. The visual display of an HMI makes it an ideal screen to show a recall message. Telematics technology connects vehicles to the outside world (OEMs, off-site computers, call centers, operation centers, etc.) using wireless connectivity.

Wireless transmission of vehicle data makes it readily and constantly available to the automaker. OEMs continue to treat much, if not most, of the vehicle data as proprietary. Non-proprietary vehicle data can be accessed over the air via aftermarket telematics devices (dongles) attached to the OBD-II port.

### 2.1. OEM Telematics System Architecture

Telematics uses wireless connectivity to exchange data over the air between the vehicle's internal network to off-site computers where it can be stored, processed, and converted into usable information.[19] This data is sent via the TCU, a special electronic control unit that provides the platform for the delivery of telematics services. Telematics data can then be used for all kinds of purposes including safety enhancement, remote monitoring, customer relationship management, entertainment, and other applications.

Figure 3 illustrates a typical OEM telematics system that includes the following key components:[20]

- TCU located in the vehicle and connected to the vehicle data bus.
- Global Positioning System (GPS) receiver that is attached to, or forms part of, the TCU.
- Network operations hub ("Telematics Operations Center"), located outside the vehicle, where data from the TCU is processed, other data is gathered, and telematics services are delivered.
- Wireless communications system over which data and voice communications are exchanged between the TCU and the network operations center.
- Call center where customer service representatives can communicate with vehicle occupants.
- Service and content providers who provide information, entertainment, and other services (e.g., traffic feeds, music, video, on-demand streaming of data) to the network operations hub for use in various telematics and infotainment applications.

Telematics uses a variety of wireless communications technologies depending on the application. Short-range wireless communications within the vehicle, such as those connecting user smartphones to the car's dashboard display or to the aftermarket dongle, are typically handled by personal area network systems such as Bluetooth or Wireless Universal Serial Bus (USB).

[19] Craig Michael, *What Is Telematics?* (Jan. 8, 2018), https://www.geotab.com/blog/what-is-telematics/.
[20] British Columbia Freedom of Information and Privacy Association, *The Connected Car: Who Is in the Driver's Seat? A Study on Privacy and Onboard Vehicle Telematics Technology* (May 2015), *available at* https://fipa.bc.ca/wordpress/wp-content/uploads/2015/05/CC_report_lite-1v2.pdf.

Communication of data between the TCU and the operations center is typically handled by cellular communications. Wireless Local Area Network technology, known as Wi-Fi, is also used together with high-speed cellular communications to create “hotspots” with the capacity to link several devices within the car to the internet.

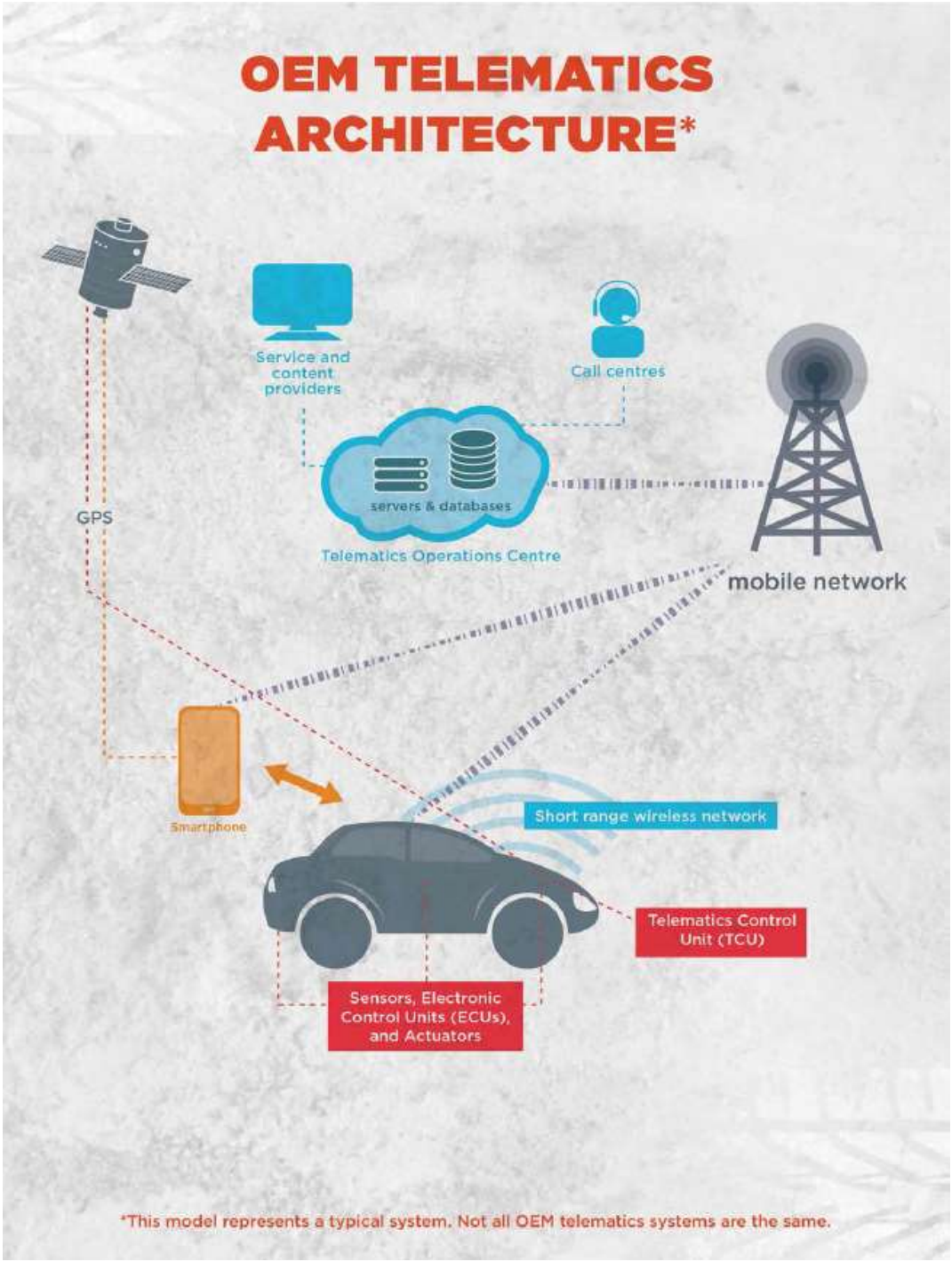


**Figure 3**. Telematics System Architecture (Source: *British Columbia Freedom of Information and Privacy Association,* The Connected Car: Who Is in the Driver's Seat? A Study on Privacy and Onboard Vehicle Telematics Technology (May 2015))

## 2.2. Aftermarket Telematics Systems

In addition to OEM telematics systems, aftermarket telematics applications are also available to vehicle owners. OEM telematics systems are internal to the car and the HMI for infotainment systems is typically a screen or other unit built into the vehicle dashboard. Aftermarket telematics systems use a device ("dongle") that connects to the OBD-II port and provides access to vehicle data. The device typically includes a built-in modem allowing it to communicate with both the customer and the service provider. It may also include a GPS unit, or may instead rely upon the customer's mobile device for location information.[21]

Aftermarket system manufacturers do not have access to the in-vehicle HMI, and either rely upon the user's mobile device or provide their own separate interface device that can be mounted on the car dashboard.

Aftermarket telematics service providers have their own back-end systems, including in some cases call centers and networks of repair technicians for roadside assistance, as well as third-party application providers for such services as remote home appliance control. Table 5 in Appendix A shows a list of aftermarket telematics applications or devices in the market.

## 2.3. Connectivity Options

According to the Global System for Mobile Communications Association (GSMA), there are three different options to connect vehicles to the mobile communication network:[22,23]

1. Embedded Connectivity: Mobile devices may be used to monitor or control the vehicle environment remotely. In embedded connectivity, both the connectivity (subscriber identity module (SIM) card and modem) and intelligence are built directly into the vehicle without the need of other devices. All data are transmitted via the OEM. Security- and safety-related services may be particularly appropriate for embedded connectivity, as these services need to be highly reliable, always on, and seamless for the end user.
2. Tethered Connectivity: In tethered connectivity, external modems and/or SIM cards provide the connectivity while the intelligence remains embedded in the vehicle. Tethered connectivity typically focuses on connected navigation and internet-based infotainment features. The tethered connectivity approach is less costly in terms of vehicle hardware and has the advantage that the external modem is more likely to be up-to-date.

[21] *Id.*
[22] GSMA, *Connecting Cars: The Technology Roadmap* (Feb. 2015), https://www.gsma.com/iot/wp-content/uploads/2013/02/GSMA_mAutomotive_TechnologyRoadmap_v2.pdf
[23] BC Freedom of Information and Privacy Association, *The Connected Car: Who Is in the Driver's Seat?*, https://fipa.bc.ca/connected-car-download/.

3. Integrated Connectivity: Integrated connectivity is based upon integration between the vehicle and the owner's mobile device, in which all communication modules and intelligence remain strictly on the smartphone. This approach to connectivity is not connected to the vehicle Controller Area Network (CAN) bus. All that the vehicle provides is the port into which the phone or device is plugged and, in some cases, an interface screen that mirrors the owner's smart phone interface. Integrated connectivity is typically used for high-bandwidth and personalized applications such as voice and on-demand music, video, and social networking.

These three connectivity approaches are not mutually exclusive and can be used in tandem as appropriate for the proposed applications. A tandem approach might be used, for example, when the technology employed for the embedded system is likely to be inappropriate for newer generation or higher bandwidth services.

Table 6 and Table 8 of Appendix A tabulate existing OEM telematics systems by the connectivity technology they use to communicate with vehicle owners.

## 2.4. Security Considerations of Telematics Systems

Telematics system components may present security vulnerabilities. The significance of each component to the security of the systems is based on the role of the component and/or other systems reliance on that component.[24]

### 2.4.1. Significance of Components on the Security Telematics Systems

Figure 4 illustrates the components of a generic telematics system. The roles of the components and system reliance on that component are briefly described below:

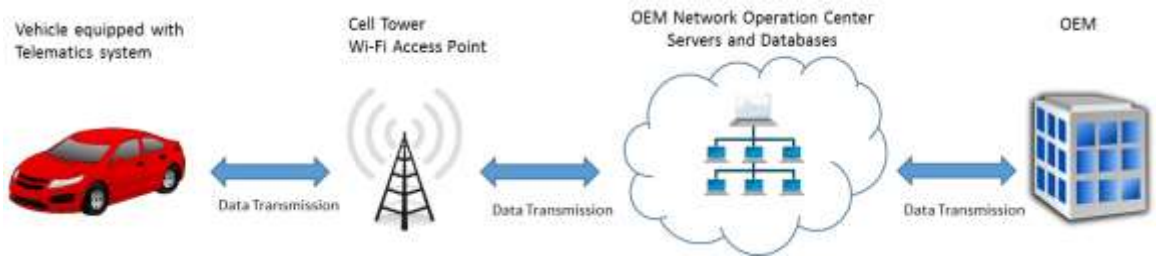



**Figure 4.** Telematics System Components

Vehicle

The vehicle is an especially challenging component regarding cybersecurity. The following present challenges to cybersecurity in a vehicle:

- The communication of data via a network inherent to the vehicle.
- When the vehicle network is proprietary to the vehicle manufacturer.
- When vehicle networks are designed for performance at the cost of security.

[24] Section 2.4 draws most of its information from a report prepared by the Volpe Center for the Department of Homeland Security: J. Clark and D. Chin, *Telematics Cybersecurity Primer for Agencies* (June 27, 2017).

- Many vehicles allow vehicle performance and safety systems to reside on the same network.

Telematics

The security of the telematics device is essential to the security of the vehicle. The telematics device acts as a gateway between the vehicle and the communications infrastructure, which is required for exchanging data between the vehicle and a back-end system.

Communications

The communications component encompasses wireless (i.e., Wi-Fi, Bluetooth), directly connected, and Internet Protocol communications. These communications vary, from serial cable connectivity for device diagnostics to mobile communications such as Global System for Mobile communication, Code Division Multiple Access, etc. Regardless of the communication method, each extends and essentially provides access to the telematics device that, in turn, provides access to the vehicle network.

Management System

The management system component is comprised of a user interface, processing devices, and methods required for presenting the vehicle data in a useable format. These components commonly include publicly-connected Internet web servers and vendor controlled and managed back-end servers. The management system is essentially the gateway to the vehicle data.

Databases

The database component of the concept systems is another significant area for security control review and implementation, possibly more specific on the policy and legal side for third-party controlled data stores. Focus on this area is extremely important; this area of the systems is where all the logistical data are correlated and stored.

### 2.4.2. Vulnerabilities in Aftermarket OBD II Devices

Aftermarket telematics devices also may present security vulnerabilities. When vehicle owners decide to plug one of these devices into their car, they are unintentionally moving the security boundary from the vehicle itself to the device manufacturer's network, associated services, and any other connected device. Vulnerabilities may include:

- Insecure firmware updates and downloads
- Hardcoded or non-existent Bluetooth Personal Identification Numbers
- Weak Wi-Fi Protected Access 2 passwords
- Hardcoded credentials
- An Internet-enabled administrative interface

In summary, several aspects of telematics systems are periodically subjected to security control and implementation. The telematics devices, embedded in the vehicle or aftermarket devices, may present cybersecurity vulnerabilities that need to be addressed. For instance, OEMs need to protect the vehicle network, secure recall databases, and make sure that third-party providers follow the same security

control when using the vehicle network. In addition, smartphones connected to the vehicle network need to follow cybersecurity measures to protect the vehicle and the network.[25]

## 2.5. Privacy Implications of Systems

This section reviews data collection and existing privacy practices relevant to telematics-based systems and how the data collection could be utilized in a recall notification system.

### 2.5.1. Types of Data Collected in Telematics–Based Systems

Telematics-based systems collect different types of data that could be associated with the vehicle owner and present a privacy risk. Different types of data collected by system components can be found below:[26]

- Identification data: Information to identify a particular individual or a device that can be linked to a particular individual. For example, the VIN links a registered owner with his or her vehicle through state-required vehicle registration (thus, in state-level databases). Automakers are also developing biometric sensors that can identify individuals who enter the vehicles.[27]
- Customer account data: Information about customers kept by the manufacturers and franchised dealers. Data may include names, address, telephone numbers, date of purchase or lease, selling dealer, make and model of vehicle, VIN, license plate number, details of any trade-ins, and details of service and repair. It may also include financial and credit information.
- Vehicle health data: Information generated by the vehicle's internal system about the performance of all the various components of the vehicle: engine, transmission, brakes, climate control, safety restraints, tire pressure, etc. It is used for vehicle diagnostics and most telematics applications.
- Vehicle status data: Information about how and when the vehicle is operating. This includes data generated by the vehicle internal system—e.g., vehicle speed, acceleration, direction, braking, cornering, ignition, and door locking.
- Location data: Information about the precise vehicle location at any given time. It is generated by GPS modules that typically form part of both the vehicle telematics and infotainment systems.
- Personal communications (voice, text, email, social networking) data: Information generated by individuals in the vehicle and sent or received via systems that rely on the user's smartphone for connectivity and intelligence. These systems receive and transmit data via the vehicle's HMI, and are therefore capable of gathering and storing information about a person's communications to and from the vehicle.

---

[25] Dan Klinedinst and Christopher King, *Onboard Diagnostics: Risks and Vulnerabilities of the Connected Vehicle* (Mar. 2016), *available at* https://resources.sei.cmu.edu/asset_files/WhitePaper/2016_019_001_453877.pdf

[26] British Columbia Freedom of Information and Privacy Association, *The Connected Car: Who Is in the Driver's Seat? A Study on Privacy and Onboard Vehicle Telematics Technology* (May 2015), *available at* https://fipa.bc.ca/wordpress/wp-content/uploads/2015/05/CC_report_lite-1v2.pdf.

[27] Danny Thakkar, *Global Automobile Industry Inclined Towards Adopting Automotive Biometrics*, https://www.bayometric.com/automobile-industry-adopting-automotive-biometrics/ (last accessed Nov. 7, 2019).

### 2.5.2. Current Privacy Practices

The Government Accountability Office (GAO) in a recent report identified a set of six leading practices that apply to the privacy of data collected by connected vehicles.[28] These privacy practices are based on the privacy frameworks developed by the Organization for Economic Co-operation and Development and several federal agencies. As indicated in Figure 5, these leading practices include: transparency, focused data use, data security, data accuracy and access, individual control, and accountability.

**Leading Privacy Practices Identified as Relevant to Connected Vehicle Data**

| Leading practice | Description |
|---|---|
| Transparency | Provide consumers with understandable and accessible information about privacy practices, including information that specifies the types of personal data collected; why such data are needed; how data will be used; and whether and for what purpose(s) data will be shared with third parties. |
| Focused data use | Provide reasonable limits on personal data collected and retained, including collecting only as much personal data as needed to accomplish specific purposes; using de-identified data to the extent possible; and securely disposing of data once no longer needed. Consumers also have a right to understand the limits that the respective company sets as part of its privacy policy. |
| Data security | Maintain reasonable safeguards to control risks related to data—such as loss, unauthorized access, use, destruction or modification, and improper disclosure—and take associated steps including conducting risk assessments. |
| Data accuracy and access | Allow consumers to access and correct their personal data, and use reasonable measures to ensure personal data is accurate. |
| Individual control | Allow consumers to control what personal data companies collect from them and how these data are used. Further, companies should offer clear and simple choices, presented in ways that enable consumers to make meaningful decisions about data collection, use, and sharing. |
| Accountability | Handle data with appropriate measures, including holding company employees responsible for adhering to the company's privacy principles and requiring third-party recipients of data to adhere to those same principles. |

Source: GAO analysis of privacy frameworks. | GAO-17-656

**Figure 5**. Leading Privacy Practices

Telematics systems transmit and collect personal data through the vehicle network, thus raising privacy concerns. Vehicle owners who have active OEM customer accounts may have their personal information linked to the VIN. OEMs identify vehicles that need to be recalled by their VIN and the network operation center managing the recall databases has this information to send a recall message. Several parties to the systems also have access to the VIN and owner's personal information through their customer accounts: dealers, dongle manufacturers, mobile device system providers, mobile network operators, and third-party application providers. Typically, owners have privacy agreements with OEMs and dongle manufacturers that describe the terms and conditions of the transfer of data.

[28] United States Government Accountability Office, Report to the Subcommittee on Research and Technology, Committee on Science, Space, and Technology, House of Representatives, VEHICLE DATA PRIVACY (July 2017), *available at* https://www.gao.gov/assets/690/686284.pdf.

# 3. Concept In-Vehicle Recall Notification Systems

This section describes three concept in-vehicle recall notification systems according to the type of wireless connectivity the system uses to send recall messages to the vehicle:

- Concept System 1 (Embedded)
- Concept System 2 (Tethered)
- Concept System 3 (Integrated)

These three connectivity approaches are not mutually exclusive and can be used in tandem, as appropriate. Each concept system includes the following components to connect the vehicles with the OEMs: telematics system, HMI, communication technology, and OEM network operation center (Figure 6).

This chapter summarizes the operational and technical implementation strategies of the concept systems, including system characteristics, owner roles, and OEM roles for each concept.

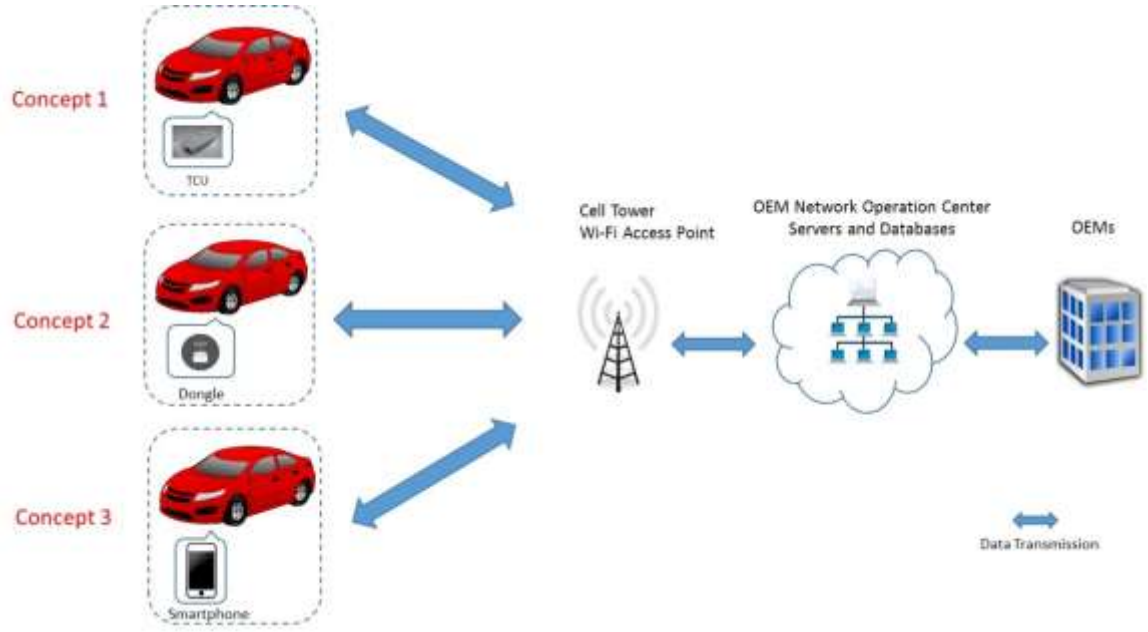



**Figure 6**. Concept In-Vehicle Recall Notification Systems

## 3.1. Technical and Operational Characteristics of Concept Systems

Tables 1-3 summarize and compare general characteristics, vehicle owner roles, and OEM roles for the three concept systems. Each table is divided into three columns for each of these three concept systems. Each row describes a single technical or operational aspect of the system. Shaded rows represent common aspects among the systems.

**Table 1.** Concept System Characteristics

<table>
<tr><th>Concept System 1 (Embedded)</th><th>Concept System 2 (Tethered)</th><th>Concept System 3 (Integrated)</th></tr>
<tr><td>Data transmission and wireless communication in the vehicle are done via a TCU (Figure 6).</td><td>Data transmission and wireless communication in the vehicle are done via an aftermarket device or dongle that plugs into the OBD-II port (Figure 6). Connectivity is provided through an external modem:<ul><li>Dongles can come equipped with a cellular communication chip that sends data directly to the cloud.</li><li>Dongles can be Bluetooth-enabled, which connect to an owner's smartphone to transmit the data to the cloud.</li></ul></td><td>The smartphone and the vehicle form an integrated communication system (Figure 6). The system relies on the owner’s mobile device for wireless connectivity and sometimes for HMI - if not included in the vehicle:<ul><li>This system requires a Bluetooth-enabled TCU in the vehicle.</li><li>This system does not have access to the vehicle on-board diagnostics system.</li></ul></td></tr>
<tr><td colspan="3">The vehicle can connect with an OEM network operation center that has access to recall databases (e.g., OEM databases with open safety recalls).</td></tr>
<tr><td colspan="3">The system is capable of exchanging messages over the air, via a cellular network or Wi-Fi, between the vehicle and the OEM network operation center (i.e., servers and databases).</td></tr>
<tr><td>The system includes an HMI to display the recall messages to the driver. If the system can pair with a smartphone, messages can also be displayed on the smartphone screen.</td><td colspan="2">The system includes an HMI unit or uses a smartphone to display the recall messages to the driver. If the system uses a smartphone display, the vehicle owner would use an OEM phone application that will work with the system.</td></tr>
<tr><td colspan="3">The system’s display can show required recall message content.</td></tr>
<tr><td colspan="3">Owners/drivers will be able to view recall messages on the system’s display until recalled equipment is remedied or replaced.</td></tr>
<tr><td colspan="3">The system could be programmed to allow owners/drivers to adjust how frequently the recall message will be displayed.</td></tr>
<tr><td colspan="3">The system could be programmed so that the recall message will not be displayed in the system’s display when the vehicle is in motion.</td></tr>
</table>

**Table 2.** Potential Vehicle Owner Roles for Concept Systems

| Concept System 1 (Embedded) | Concept System 2 (Tethered) | Concept System 3 (Integrated) |
|---|---|---|
| • Take the vehicle to an authorized dealer to start remedy work, once the recall message is received.<br>• Provide OEM network operation center with the vehicle's VIN to identify vehicle receiving the recall messages. This can be done via HMI input.<br>• Sign a privacy agreement with the OEM to protect personal information. | | |
| N/A | Sign a privacy agreement with aftermarket device manufacturer to protect personal information. | N/A |
| Download an OEM phone application if required for system's subscription. | Download an OEM phone application that will work with the recall system in case smartphone integration is required to display messages. | Download OEM phone application and input the vehicle's VIN information. The phone application will show recall messages. |

**Table 3.** Potential OEM Roles for Concept Systems

| Concept System 1 (Embedded) | Concept System 2 (Tethered) | Concept System 3 (Integrated) |
|---|---|---|
| Have a privacy agreement with the vehicle owner. | Have a privacy agreement with the vehicle owner and aftermarket device manufacturer to protect personal information. | Have a privacy agreement with the vehicle owner. |
| • Have a network operation center to manage messages sent to the in-vehicle recall system.<br>• Indicate to the network operation center when a recall message must be sent to the vehicle.<br>• Stop recall message when vehicle has been remedied.<br>• Keep up-to-date its own database of outstanding safety recalls. | | |
| N/A | Provide aftermarket device manufacturers access to OEM vehicle operation center recall databases via a secure gateway. | N/A |
| N/A | Have an OEM recall phone application, if message is displayed in the smartphone. | Have an OEM recall phone application. |

## 3.2. Recall Process Steps with Concept In-Vehicle Recall Notification System

OEMs are required by 49 CFR part 577 to send recall notifications to vehicle owners and franchised dealers. The concept in-vehicle recall notification system may involve four simple steps when the OEMs initiate the recall process, as illustrated in Figure 7.

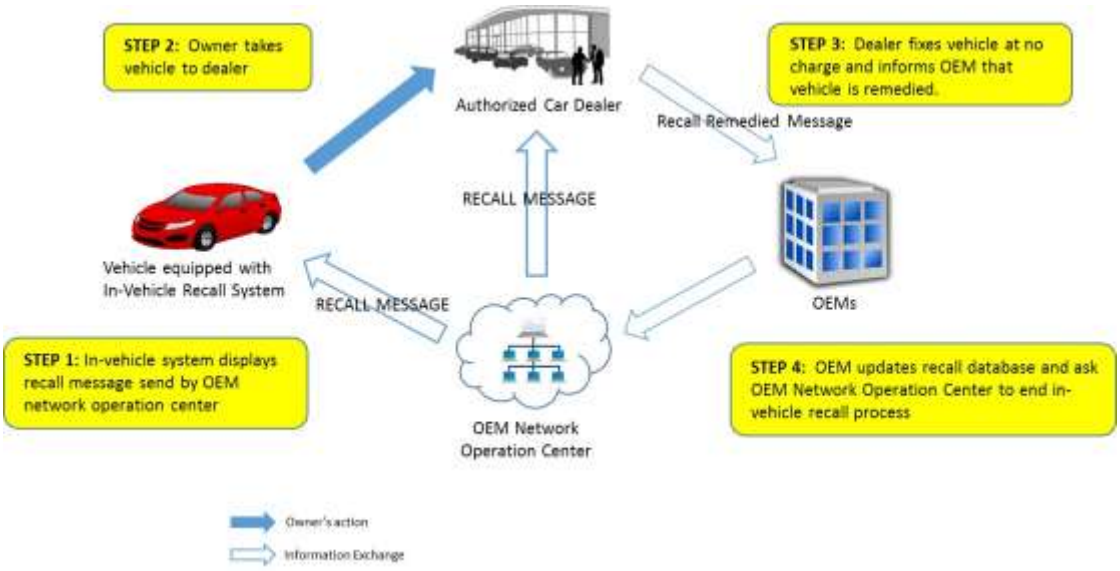



**Figure 7.** Recall Process Steps with Concept System

STEP 1: The OEM indicates to its network operation center to send a recall message to the vehicle. The network operation center oversees managing the in-vehicle recall notification system and determines which vehicles have a recall by their VIN. The message is sent wirelessly to the vehicle and displayed on the system's HMI.

STEP 2: The vehicle owner takes the vehicle to an authorized dealer for repair.

STEP 3: Authorized dealers repair vehicle at no charge and notify OEM that the vehicle has been remedied.

STEP 4: The OEM updates its recall database after receiving the remedy message from the authorized dealer, and asks the network operation center to end the in-vehicle recall process. The concept system stops displaying the recall message on the HMI.

## 3.3. System Modifications and Future Upgrades

Some OEMs are making their telematics systems compatible with smartphone applications like Android Auto[29] and Apple CarPlay.[30] These applications allow the smartphone display to be shown in the vehicle's built-in screen. These applications are also compatible with aftermarket in-car media receivers and include their proprietary voice assistants (e.g., Siri and Google Assistant) for voice commands.

The concept in-vehicle recall notification systems have the capability of pairing with smartphones. Since OEMs are already making their systems compatible with smartphone applications,[31] [32] they could also include their own application that can send recall messages to the Android Auto and Apple CarPlay lineup of applications.

Some of the telematics systems reviewed during this effort offer updating capabilities (e.g., ConnectedDrive (BMW), mbrace (Mercedes-Benz) and uConnect (Chrysler, Dodge, Jeep, Ram, Fiat)), but having Android Auto and Apple Carplay in the vehicle means that vehicle may have the latest smartphone technology and the ability to receive faster upgrades than with a built-in vehicle system, depending on the type of smartphone the drivers connect to the vehicle and the extent to which the driver updates their smartphones operating system.

[29] androidauto, https://www.android.com/auto/ (last accessed Nov. 7, 2019).
[30] CarPlay, https://www.apple.com/ios/carplay/ (last accessed Nov. 7, 2019).
[31] Cherise Threewitt, *Which 2017 Cars have Android Auto?* (Jan. 30, 2017), https://cars.usnews.com/cars-trucks/which-2017-cars-have-android-auto.
[32] Cherise Threewitt, *Which 2017 Cars have Apple CarPlay?* (Jan. 30, 2017), https://cars.usnews.com/cars-trucks/which-2017-cars-have-apple-carplay.

# 4. Analysis of Costs

Because of data availability, cost-description for vehicle owners was the only evaluation studied at this point. Cost-description is a type of evaluation where only the costs of the service program are estimated or compiled. No comparison of any alternative is covered in this evaluation.

In addition to data availability and based on the complexity and evolving capabilities of these concept systems, only a qualitative discussion of OEM costs is provided in this chapter.

The concept in-vehicle recall notification process as presented in chapter 4:

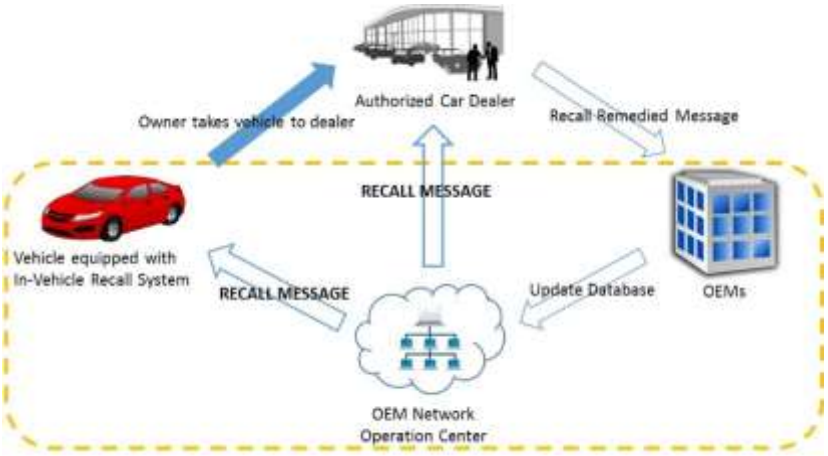



**Figure 8.** Recall Process Steps with Concept System

As Figure 8 shows, the concept in-vehicle recall notification system involves several parties and/or entities. The differences in costs for each entity depend on their level of involvement or interaction with the system—that is, the mechanism for conveying the message to the owners (telematics unit screen, phone app, etc.) and how the vehicle owner acknowledges them. These differences in costs lie in the orange box overlaid on Figure 8. Table 4 summarizes the differences in costs for different concept systems by entity.

**Table 4.** Summary of Potential Cost Differences by Concept System and Entity

| Entity | Potential Elements | Concept 1: Embedded | Concept 2: Tethered | Concept 3: Integrated |
|---|---|---|---|---|
| OEM | OEM | Manufacturer | Dongle Company | Software Company |
| | Hardware | Telematics Unit | Dongle Unit | Bluetooth Unit |
| | Operations Cost | • Technology Development (including software for continuous updates; can be third party or in-house)<br>• Back-end server or cloud for data management and transmission (can be third party or in-house) | | |
| | Administrative Costs | Administrative Costs such as staffing, etc. with bulk on legal costs to ensure privacy of vehicle owners[32] | | |
| | Agreement Costs | • Telecom Companies for Wi-Fi connections<br>• Back-end service | • Car manufacturers<br>• Telecom Companies for Wi-Fi connections<br>• Back-end service | • Car manufacturers<br>• Telecom Companies for Wi-Fi connections<br>• Back-end service |
| Vehicle Owners | Capital Cost | Cost of telematics unit, usually built into price of vehicle | Cost of Dongle Unit | • Cost of Bluetooth installation, unless already installed<br>• Cost of the app |
| | Recurring Cost[33] | Subscription + cost of upgrades (most car manufacturers offer free trial after purchase of new vehicle. Reports however still show huge dropout rates)[34] | Subscription + cost of upgrades | Subscription + cost of upgrades |
| | Other unquantifiable costs | N/A | Cost in terms of time entering the VIN for tethered systems | • Cost in terms of time of downloading the app on the phone and entering the VIN on the app<br>• Cost in terms of cellphone use; i.e., data plan |
| Dealers | Cost of transmitting information/communicating with the OEM that the repair has been completed | | | |

## 4.1. Vehicle Owner Costs

Appendix C presents a preliminary assessment of vehicle owner cost for the different concept systems discussed in this report. Figure 9 summarizes the average costs with standard deviations for car owners of the different concept systems. The solid colors represent subscription costs and the pattern filled bars

[32] Fred Blumer, *Telematics Nightmare Scenario: Litigation* (June 6, 2014), http://www.insurancetech.com/telematics-nightmare-scenario-litigation/a/d-id/1315288d41d.html.

[33]

[34] IMS, *IMS Insurance Telematics*, https://www.intellimec.com/automotive-oem (last accessed Nov. 7, 2017).

represent the initial one-time cost for the device. The standard deviations are represented by the vertical whiskers.

As Figure 9 shows, OEM-embedded units are typically built in the price of the vehicle; hence, the additional cost of hardware for a recall system is minimal. The average costs of OEM dongle/device and Bluetooth device are $60 and $100, respectively. In terms of subscription costs, embedded systems and integrated systems are closely similar, while tethered connectivity subscription has the lowest cost. Note, however, that subscription costs for embedded systems may include other type of services (e.g., navigation, entertainment radios etc.) other than in-vehicle recall notification so the actual costs for individual service is harder to disentangle. In addition, the integrated system requires additional payments to mobile carriers because it uses the mobile data plan.

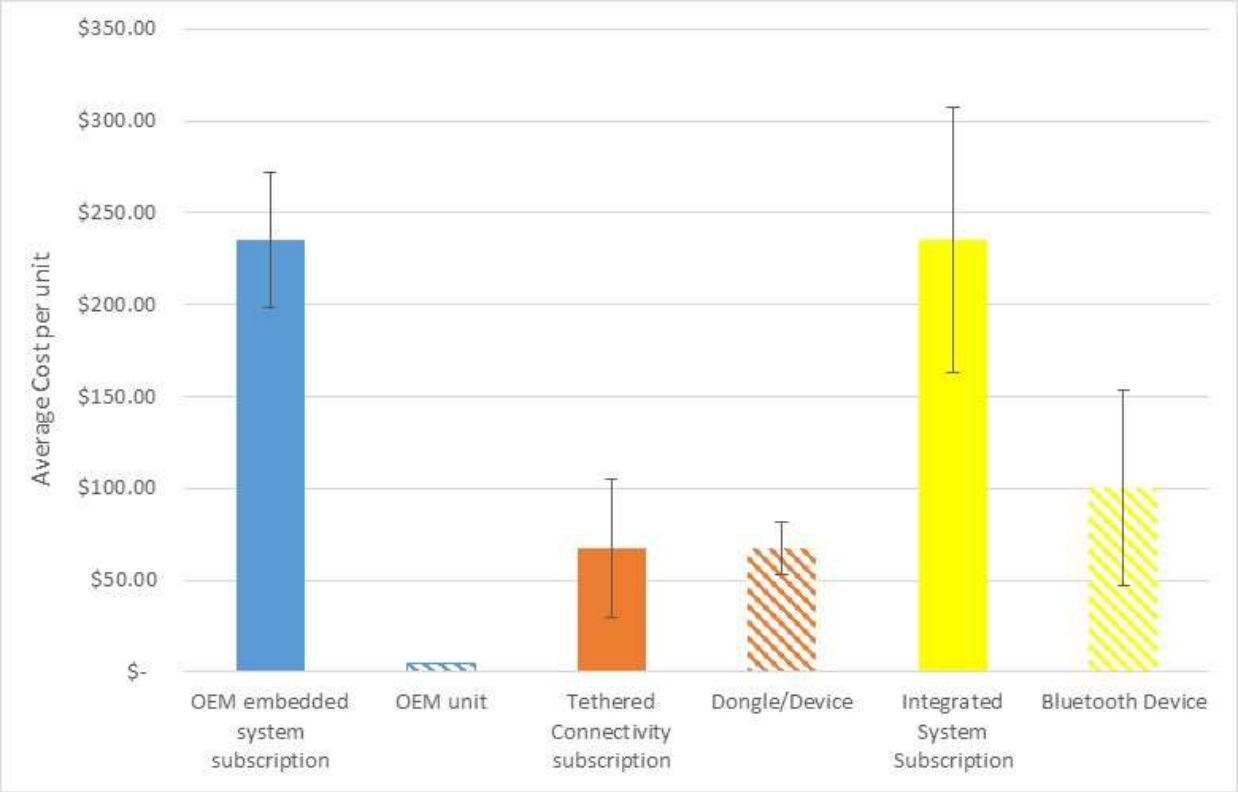



**Figure 9.** Car Owner Average Costs for Different In-Vehicle Recall Notification Concept Systems

## 4.2. OEM Costs

As previously mentioned, OEM costs are much more difficult to estimate and such information is not publicly available. Moreover, the telematics value chain is dynamic, and mirrors the overall wireless industry with the vehicle serving as the service delivery platform. Figure 10 shows the current existing value chain for telematics.

The content providers and telematics service providers (Figure 10) provide the cloud and back-end service. Back-end service is usually a third-party service for mobile applications, which handles the business logic, data storage, and security. The front-end is the users' web browser or mobile device, and

the back-end is the server or servers where data are stored and shared. Third-party back-end servers may be costly. Applications may expense as much as $500,000 to build front-end and back-end services.[35]

In addition to back-end data storage and management, wireless network access is also an important component of the value chain. An InCode Telecom[36] report notes that the primary operating costs are related to wireless network access and the call centers. Network carrier and call center contracts must be negotiated such that these costs are less than the subscription fees for which consumers are willing to pay.

Separate from third-party contracts, costs are simply transferred within the value chain. Figure 11 summarizes the possible telematics revenues and cost for the OEMs. A report by Frost and Sullivan[37] points out that the cost burden for telematics systems is on OEMs rather than vehicle owners. Hence, the subscription-based model offers the OEMs a potential relief from cost burdens.

[35] *How Much Does It Cost to Make an App in 2018?* (last updated June 6, 2019), https://www.codementor.io/blog/how-much-does-it-cost-to-make-an-app-in-2017-1nqj6ehste.
[36] InCode Telecom Report, *Telematics: How Economic and Technological Forces Will Shape the Industry in the U.S.* (May 2001), *available at*https://confluence.engin.umich.edu/download/attachments/1605717/Telematics_Position_Paper_v11.pdf.
[37] Frost & Sullivan, *eCall Mandate - A Cost Burden for Car Manufacturers Rather than a Driver for the European Connected Car Market* (May 12, 2015), https://ww2.frost.com/files/8614/6719/4903/TomTom_Telematics_Award_Write_Up.pdf (last accessed Jan. 26, 2018).

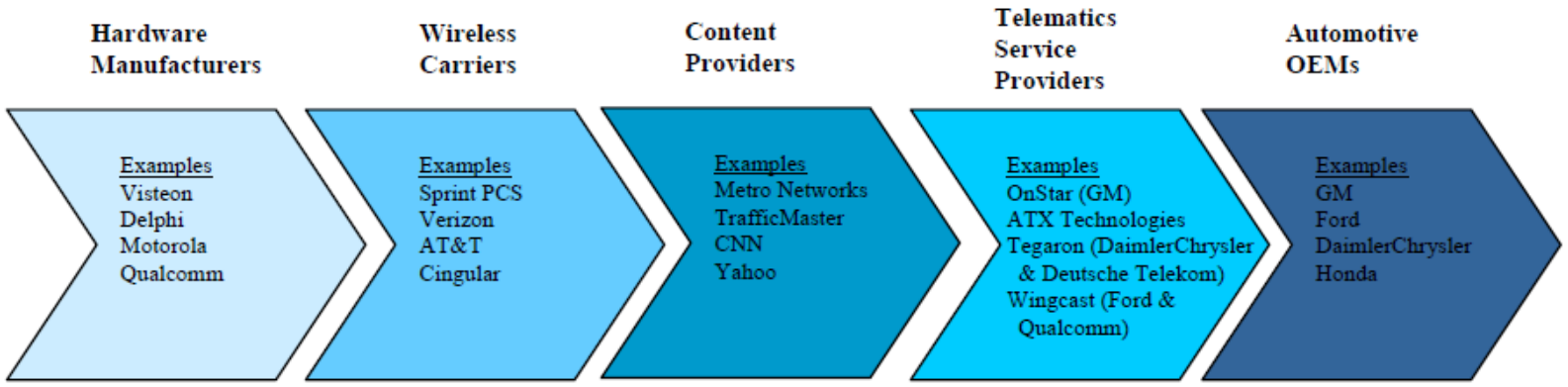



**Figure 10**. Telematics Value Chain[38]

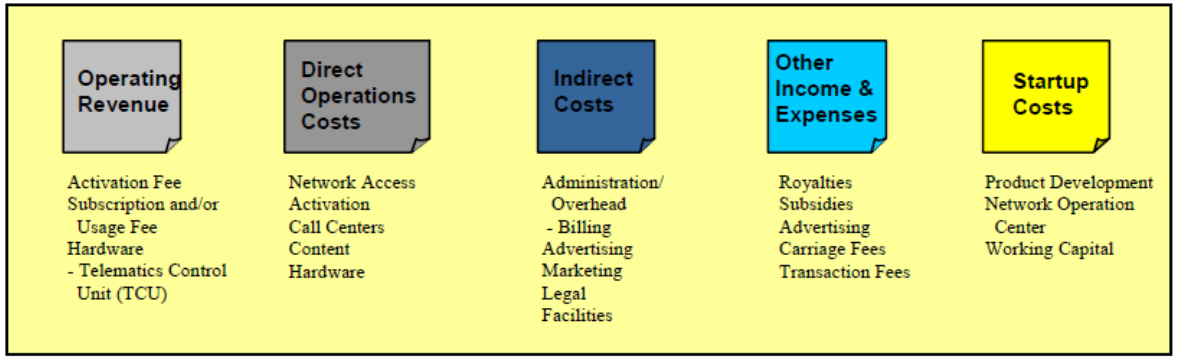



**Figure 11**. Possible Telematics Revenues and Costs for Automotive OEMs

[38] InCode Telecom Report, *Telematics: How Economic and Technological Forces Will Shape the Industry in the U.S.* (May 2001), *available at* https://confluence.engin.umich.edu/download/attachments/1605717/Telematics_Position_Paper_v11.pdf.

# 5. Feedback from Subject Matter Experts

Volpe conducted a series of interviews via web teleconference with SMEs from the automotive, telecommunications, and insurance industry to solicit their feedback on Volpe's concepts, technical considerations, and feasibility assessment. Volpe presented the SMEs with a document that included a list of topics and subtopics to discuss during the interviews. (See Appendix D for a copy of this document).

## 5.1. Technology Assessment of the Concept Systems

SMEs agreed that the wireless technology of the concept systems currently exist and is functionally capable of sending recall messages to owners. The caveat is vehicles need to be connected to the mobile communication network to receive recall messages, raising concerns in areas with no cellular coverage. Some SMEs from the automotive industry mentioned that they are prepared to deploy the technology soon (in less than a year).

SMEs agreed that if a government mandate is released, the automotive industry is technologically ready. Some concerns remain about how the technology should be implemented, including the following:

- Frequency of recall messages: How frequent and for how long a recall message should be visible or audible in the vehicle without annoying or distracting the driver.
- False recall messages due to data latency: Time lags in the recall process loop with in-vehicle recall systems issuing recall messages to drivers even after the issue has been remedied.
- Life cycle of communication technology much faster than life cycle of the vehicle: Wireless technology chipsets need to be upgraded with changing standards.
- Issue with concept system 2: Dongle could be plugged in or removed by owners, thus presenting the potential for limited efficacy.

## 5.2. Partnership

All SMEs from the automotive industry were reluctant to have third parties managing their recall database unless it is done by NHTSA. SMEs from insurance companies stated there is no incentive for insurance companies to play an active role in the in-vehicle recall process. For them, it will be more of a gesture of goodwill to notify customers of the recall.

SMEs believe the in-vehicle message should be handled by the OEM. Franchise dealers may not process the completion report fast enough to turn off the recall notification, creating false messages and annoyance to the driver.

## 5.3. Privacy and Security

SMEs mentioned they do not have any privacy and security concerns as their industry has protocols already in place. An SME stated that its current free applications to track recalls have a high download rate (over one million) and over 90 percent of the users accept their privacy agreement.

## 5.4. Cost Description

Initial capital cost for producing in-vehicle recall systems is minimal for the OEMs given the current telematics system. Most have the capability already if they deploy telematics systems on their vehicle.

As mentioned in the previous section, the cost burden for telematics systems is on OEMs rather than vehicle owners and the subscription-based model offers the OEMs a potential relief from cost burdens.

For vehicle owners, subscription for in-vehicle telematics systems is usually free for the first year, but SMEs say that dropout rate after the free period is high. Mobile applications are normally free and as previously mentioned, one SME stated that over 90 percent of owners accept the agreement but another SME also mentioned that owners tend to forget about it and not log in.

## 5.5. System Effectiveness

All SMEs agreed that the concept systems would be able to reach all new vehicle owners if the vehicles were connected to a network operation center. It is still yet to be determined how such systems could improve the recall process and completion rates.

Generally, system effectiveness depends highly on owner risk assessment of a recall and how important it is to their safety to take their vehicles to the dealer for repair.

# 6. Conclusions

The technology capable of sending recall messages to vehicles currently exists in the market in the form of telematics systems. Telematics in-vehicle systems allow OEMs to communicate with vehicle owners connected to the mobile communication network. These systems are functionally capable of reaching out to new owners of vehicles that are subject to an open recall. They include an HMI that makes it possible to display a recall message and use communication technologies (i.e., cellular and wireless) to connect the vehicle to the mobile communication network. Therefore, vehicles need to be connected to receive recall messages.

This report covers three vehicle-based concept systems that may be utilized to send recall messages to vehicle owners. The concept in-vehicle recall notification systems were defined according to the type of wireless connectivity the system uses: embedded, tethered, and integrated connectivity. These systems are not mutually exclusive and can also be combined.

The recall process with the concept systems may involve four simple steps:

1. The system displays recall message sent by OEM network operation center.
2. The owner takes vehicle to dealer for repair.
3. The authorized dealer remedies vehicle at no charge.
4. The OEM updates the recall database after receiving remedy message from authorized dealer and asks the OEM network operation center to end in-vehicle recall process.

The following are potentially-significant considerations for concept in-vehicle recall systems within the recall process:

- All concept systems are periodically subject to security control and implementation. They are protected from unauthorized access. OEMs protect the vehicle network and secure recall databases.
- Owners are responsible for taking the vehicle to an authorized dealer for repair.
- Dealers inform the OEM that the vehicle has been remedied.
- OEMs stop the recall message when the vehicle has been repaired.
- OEM network operation center keeps an up-to-date recall database.

Results from the analysis of the concept systems show that the differences in costs across the three concept systems depend on level of involvement or interaction by each agent—that is, the mechanism for conveying the message to the owners (telematics unit screen, phone application, etc.) and how the vehicle owner acknowledges them. In general, OEM-embedded units are typically built in to the price of the vehicle; hence, the cost for the consumer is minimal. The average consumer costs of OEM dongle/device and Bluetooth device currently range between $60 and $100. In terms of consumer subscription costs, embedded systems and integrated systems are closely similar and range between $200 and $250 annually.[39] Tethered connectivity has the least subscription cost but also depends on cellphone's data plan. OEM costs are much more difficult to estimate for two reasons: (1) such information is not publicly available and (2) they are highly dependent on telematics value chain which is dynamic and differs across the three concept systems.

SMEs interviewed for this study agreed that the wireless technology of the concept systems currently exist and is functionally capable of sending recall messages to owners. The caveat is that vehicles need to be connected to the mobile communication network to receive recall messages, raising concerns in areas with no cellular coverage. The SMEs also expressed concerns about the implementation of a recall process using in-vehicle recall systems, including the following:

- Recall message frequency
- Driver distraction
- Time lags in the recall process loop

All SMEs agreed that the concept systems would be able to reach owners of new vehicles (and subsequent owners thereof) if the vehicles were connected to the mobile communication network. It is still yet to be determined as to how such systems could improve the recall process and completion rates. Generally, system effectiveness highly depends on owner risk assessment of a recall and how important it is to their safety to take their vehicles to the dealer for repair.

**Although this study did not assess costs, benefits, or effectiveness to inform a regulatory outcome, it concludes that in-vehicle recall concept systems may be functionally capable of notifying owners of an open recall. More research would be needed to understand how these systems could improve the recall process and completion rates.**

## Appendix A: Technology Review

**Table 5.** List of Aftermarket Telematics Applications[40]

| Aftermarket System | Web Address |
|---|---|
| CAARMO | www.caarmo.com |
| RepairLync | http://www.repairlync.com/ |
| Zubie | http://zubie.co |
| Mojio | https://www.moj.io/how-it-works |
| Voyo | http://voyomotive.com/ |
| Golo | http://business.golocarcare.com/ |
| Hum | https://www.hum.com/ |
| Mobley | https://www.att.com/devices/zte/mobley.html#sku=sku7700323 |
| Automatic | https://www.automatic.com/ |
| Vinli | https://www.vin.li/ |
| Red Tail | http://www.redtailgps.com/ |
| Mechanicadvisor.net | http://www.mechanicadvisor.net |
| Openbay connect | http://www.openbayconnect.com/ |
| Carista | http://www.caristaapp.com/ |
| Dash | https://dash.by/ |

[40] Christopher Cloutier, *Telematics (Connected Car) Vendors* (Nov. 20, 2015), https://www.linkedin.com/pulse/telematics-connected-car-vendors-list-from-me-you-happy-cloutier/.

**Table 6.** OEM Embedded Systems - Technology Review[41]

| OEM | Platform | Implemented Concept System 1 Components | Sources |
|---|---|---|---|
| BMW | ConnectedDrive | • TCU for data transmission and wireless communication<br>• Capable of exchanging messages over the air to a cloud (Open Mobility Cloud built on Microsoft Azure to process data and information from all sorts of different sources)<br>• Media display (BMW Connected Drive screen)<br>• Costumers open an account and add vehicle by entering the VIN<br>• Text messages can be shown on the screen<br><br>Other capabilities:<br>• BMW Connected North America Application<br>• Bluetooth® interface integrates your smartphone into BMW Connected Drive display<br>• Remote access to your BMW through your mobile phone<br>• System has updating capabilities | https://www.bmw-connecteddrive.my/app/my/index.html#/portal<br><br>http://www.bimmerfile.com/2016/07/29/bmw-debuts-completely-updated-bmw-connected-app/<br><br>https://www.youtube.com/watch?v=hMmlqAXEUL0 |

[41] This is not an exhaustive list of OEMs with embedded systems. There are other OEMs who may offer such systems.

| | | | |
|---|---|---|---|
| GM | OnStar | • GM TCU unit for data transmission and wireless communication. The console is connected to a Vehicle Communication and Interface Module (VCIM), which uses a cellular antenna on top of the car to transmit signals to OnStar's cellular network.<br>• Capable of exchanging messages over the air to a cloud (e.g. Service Cloud to manage cases with merchants. Marketing Cloud to drive email communications, personalized customer journeys, and relevant offers to each consumer)<br>• Display media (OnStar's cellular service is voice-activated and hands-free)<br>• Uses AT&T Inc to provide high-speed wireless service (4G LTE connection)<br><br>Other capabilities:<br>• Wi-Fi hotspot<br>• AtYourService application on their mobile devices<br>• Remote access with mobile application | https://www.onstar.com/us/en/home.html<br><br>https://auto.howstuffworks.com/onstar2.htm<br><br>https://www.salesforce.com/products/platform/customer-stories/gm-onstar/ |
| **OEM** | **Platform** | **Implemented Concept System 1 Components** | **Sources** |
| Volvo | Sensus Connect | • Volvo TCU unit for data transmission and wireless communication<br>• Capable of exchanging messages over the air to a cloud (e.g. Volvo cloud- and application-based services)<br>• 3G connectivity service powered by AT&T<br>• Media display (e.g. the digital dashboard and center stack displays)<br>• Internet, phone, and text message access (with text-to-speech)<br>• Costumers open an account and add vehicle by entering the VIN.<br>• Text messages can be shown on the screen.<br><br>Other capabilities:<br>• Volvo On Call smartphone application with remote access<br>• Wi-Fi hotspot and tethering capabilities | https://www.volvocars.com/intl/own/explore/sensus-connect<br><br>https://www.media.volvocars.com/us/en-us/media/pressreleases/150089/volvo-leading-the-industry-with-car-connectivity-and-telematics-as-standard-on-every-model-introduci |
| Mercedes-Benz | mbrace | • Bluetooth®-enabled TCU unit for data transmission and wireless communication.<br>• Connectivity provided by Verizon.<br>• It uses a cloud connection over 3G to provide new services, most notably Mercedes-Benz Applications. | https://www.mbusa.com/mercedes/mbrace<br><br>https://www.autoblog.com/2013/04/30/hands-on-with-mbrace2-and- |

| | | | |
|---|---|---|---|
| | | • Vehicle VIN submitted at registration.<br>• Allows over-the-air (OTA) updates of the system<br><br>Other capabilities:<br>• Remote access<br>• Mercedes me smartphone application<br>• Wi-Fi hotspot | mercedes-benz-smartphone-apps-video/ |
| Chrysler, Dodge, Jeep, Ram, Fiat | uConnect | • Bluetooth®-enabled TCU unit for data transmission and wireless communication<br>• Capable of exchanging messages over the air to a cloud<br>• Media display (e.g. 8.4-inch touchscreen display, smartphone display)<br>• Voice commands<br>• Over-the-air- software updates<br><br>Other capabilities:<br>• Remote access<br>• Uconnect access application<br>• Wi-Fi hotspot | https://www.driveuconnect.com/uconnectaccess.html<br><br>https://www.cnet.com/roadshow/pictures/ten-telematics-systems-connect-your-car-to-the-cloud/5/<br><br>https://www.att.com/shop/wireless/connected-car/uconnect/dodge.html |
| **OEM** | **Platform** | **Implemented Concept System 1 Components** | **Sources** |
| Hyundai | Blue Link | • Hyundai TCU for data transmission and wireless communication<br>• Cloud based platform<br>• Media display (e.g. screen display, smartphone display)<br>• Offers smartphone and smartwatch integration<br>• Vehicle VIN submitted at registration<br><br>Other capabilities:<br>• Remote access with service alerts<br>• Blue Link application<br>• Wi-Fi hotspot | https://www.hyundaiusa.com/bluelink/index.aspx<br><br>http://www.autoconnectedcar.com/2016/06/why-youll-want-hyundai-blue-link-connected-car-remote-services-with-alerts/ |
| Nissan | NissanConnect | • Nissan TCU that transmits and receives data<br>• Smartphone and smartwatch integration<br>• Vehicle VIN submitted at registration<br>• Media display (e.g. 8-inch touchscreen display, smartphone display)<br>• Bluetooth® technology<br>• Voice recognition technology | https://www.nissanusa.com/connect<br><br>http://nissannews.com/en-US/nissan/usa/releases/2017-nissan-pathfinder-offers-expanded-nissanconnect-services-availability-and-next-gen-infotainment-system |

| | | | |
|---|---|---|---|
| | | Other capabilities:<br>• Remote access<br>• Customizable alerts via email, text message or automated phone call<br>• NissanConnect application<br>• Wi-Fi hotspot | |

**Table 7.** Aftermarket Device Manufacturer Tethered Systems - Technology Review

| Device Manufacturer | Implemented Concept System 2 Components | Sources |
|---|---|---|
| Zubie | • Data transmission and wireless communication in the vehicle are done by plugging the Zubie dongle into the On-Board Diagnostics (OBD)-II port.<br>• Connectivity is provided through an external modem. The Zubie dongle comes equipped with a cellular communication chip that sends data directly to the cloud.<br>• Zubie application that allows to create a Zubie account where VIN is input to identify the vehicle.<br>• Media display is the mobile phone screen.<br>• Partnered with Verizon to allow Wi-Fi connection<br>• Sends automatic alerts about vehicle events via application | http://zubie.co<br><br>https://www.digitaltrends.com/car-accessory-reviews/zubie-gps-plus-in-car-wi-fi-review/#/7 |
| Voyomotive | • Data transmission and wireless communication in the vehicle are done by plugging the Voyomotive dongle into the On-Board Diagnostics (OBD)-II port.<br>• VOYO uses Bluetooth® 4.0 Low Energy to connect to your cell phone and link to the Voyomotive Cloud.<br>• VOYO application that allows to create a Voyo account.<br>• Media display is the mobile phone screen. | http://voyomotive.com/<br><br>https://www.digitaltrends.com/cars/voyomotive-gives-old-cars-new-tech/#/2 |
| Carista | • Data transmission and wireless communication in the vehicle are done by plugging the Carista dongle into the On-Board Diagnostics (OBD)-II port.<br>• Carista uses a Bluetooth-enabled dongle to connect to your Smartphone and Carista Servers<br>• Carista application that allows you to subscribe and check faults.<br>• Media display is the mobile phone screen. | https://caristaapp.com/<br><br>https://carwitter.com/2017/05/19/carista-bluetooth-obd2-review/ |
| Dash | • Data transmission and wireless communication in the vehicle are done by plugging the dongle into the On-Board Diagnostics (OBD)-II port.<br>• Dash uses a Bluetooth-enabled dongle to connect to your Smartphone to the cloud.<br>• Dash application that allows you to create an account and monitor your vehicle.<br>• Media display is the mobile phone screen. | https://dash.by/<br><br>https://www.cnet.com/products/dash-android/review/ |
| Golo CarCare | • Data transmission and wireless communication in the vehicle are done by plugging the Golo CarCare dongle into the On-Board Diagnostics (OBD)-II port.<br>• Dongle is Bluetooth-enabled.<br>• Golo CarCare application that allows to create an account where VIN is input to identify the vehicle. Application reports vehicle's faults.<br>• Compatible with Launch Android tablet (Repair shops' professional scanners)<br>• Media display (e.g. smartphone phone screen, Launch tablet screen)<br>• Voice and text communication<br>• Emails diagnostic reports | http://business.golocarcare.com/<br><br>https://www.youtube.com/watch?v=75l_s4P2s2g |

| Device Manufacturer | Implemented Concept System 2 Components | Sources |
|---|---|---|
| Hum | • Data transmission and wireless communication in the vehicle are done by plugging the Hum dongle into the On-Board Diagnostics (OBD)-II port.<br>• Connects to 4G LTE network. Powered by Verizon.<br>• In-car Wi-Fi<br>• Bluetooth-enabled speaker<br>• Media display (e.g. mobile phone screen, speaker)<br>• Hum application that allows to create an account where VIN is input to identify the vehicle. | https://www.hum.com/<br><br>https://www.digitaltrends.com/car-accessory-reviews/verizon-hum-x-review/ |

**Table 8.** OEM Integrated Systems - Technology Review[42]

| OEM | Platform | Implemented Concept System 3 Components | Sources |
|---|---|---|---|
| Ford | SYNC 3 | • Bluetooth-enabled TCU (Uses Bluetooth® wireless technology to pass information between your vehicle and your phone)<br>• Smartphone integration<br>• Media display (e.g. voice activated technology and 8-inch touchscreen, smartphone display)<br>Other capabilities:<br>• Mobile application to remotely access vehicle features<br>• Wi-Fi hotspot | https://www.ford.com/technology/sync/?searchid=742988121%7c39203551632%7c124565918453%7c&s_kwcid=AL!2519!3!174540115135!e!!g!!ford%2520sync%25203&ef_id=VrUkCgAABU2C4SQ1:20171108195227:s |
| Toyota | Entune | • Bluetooth-enabled TCU (Wirelessly connect your compatible phone for hands-free calling and audio streaming)<br>• Smartphone integration<br>• Media display (e.g. advanced voice recognition, touchscreen, smartphone display)<br>Other capabilities:<br>• Mobile application (Entune application channels phone data to applications)<br>• Wi-Fi hotspot | https://www.toyota.com/entune/<br><br>https://www.digitaltrends.com/infotainment-system-reviews/toyota-entune-review/<br><br>https://www.cnet.com/pictures/toyota-entune-telematics-system-photos/ |

[42] This is not an exhaustive list of OEMs with embedded systems. There are other OEMs who may offer such systems.

| | | | |
|---|---|---|---|
| Audi | Audi Connect | • Bluetooth-enabled TCU (Uses Bluetooth® wireless technology to pass information between your vehicle and your phone)<br>• Two options to connect:<br>  ○ Pairing mobile phone with SIM card via Bluetooth connection<br>  ○ Using Vehicle's SIM card<br>• AT&T 4G LTE or 3G coverage<br>• Receives data from various cloud sources - ranging from traffic control centers and satellites, to cell towers and traffic signals -.<br>• Media display (e.g. voice activated technology, touchscreen, smartphone display)<br>• Costumers setup myAudi account and add vehicle by entering the VIN.<br><br>Other capabilities:<br>• MMI® connect Application<br>• Wi-Fi hotspot<br>• Google Voice Search™ | https://www.audiusa.com/technology/intelligence/audi-connect<br><br>https://www.edmunds.com/car-news/audi-turns-to-att-to-connect-its-2016-lineup.html<br><br>https://www.youtube.com/watch?v=DxD4xxvMdB8 |
| **OEM** | **Platform** | **Implemented Concept System 3 Components** | **Sources** |
| Jaguar / Land Rover | InControl | • Jaguar/Land Rover TCU is fitted with an AT&T SIM card and connects to the internet.<br>• Costumers create an account in the InControl Admin website where VIN is required.<br>• Media display (e.g. touchscreen, voice control, smartphone display)<br><br>Other capabilities:<br>• InControl Remote application. Uses USB port to connect smartphone applications.<br>• Built-in Wi-Fi hotspot. Driver needs to insert SIM card for a 4G connection to be routed through the car's antenna. | https://www.jaguarusa.com/owners/index.html<br><br>https://www.pocket-lint.com/cars/news/jaguar/141468-jaguar-incontrol-explored-a-deep-dive-into-jaguar-s-infotainment-system<br><br>https://www.motoring.com.au/infotainment-review-land-rover-incontrol-connected-features-107781/ |
| Mazda | Mazda Connect | • Bluetooth integration with smartphones<br>• Uses phone provider data plan<br>• Voice control commands<br>• 7" Touchscreen<br>• The in-vehicle software can be updated to support additional functions and evolving smartphone operating systems so that it will never go out-of-date. | http://infotainment.mazdahandsfree.com/home?language=en-CA<br><br>https://www.digitaltrends.com/infotainment-system-reviews/mazda-connect-review/ |

| | | | |
|---|---|---|---|
| | | Other capabilities:<br>• Mazda Toolbox Application<br>• Wi-Fi hotspot | |

## Appendix B. Recall Completion Rate Information

Figure 12 - Figure 15 illustrate data on recall completion rates from NHTSA's report to Congress[43].

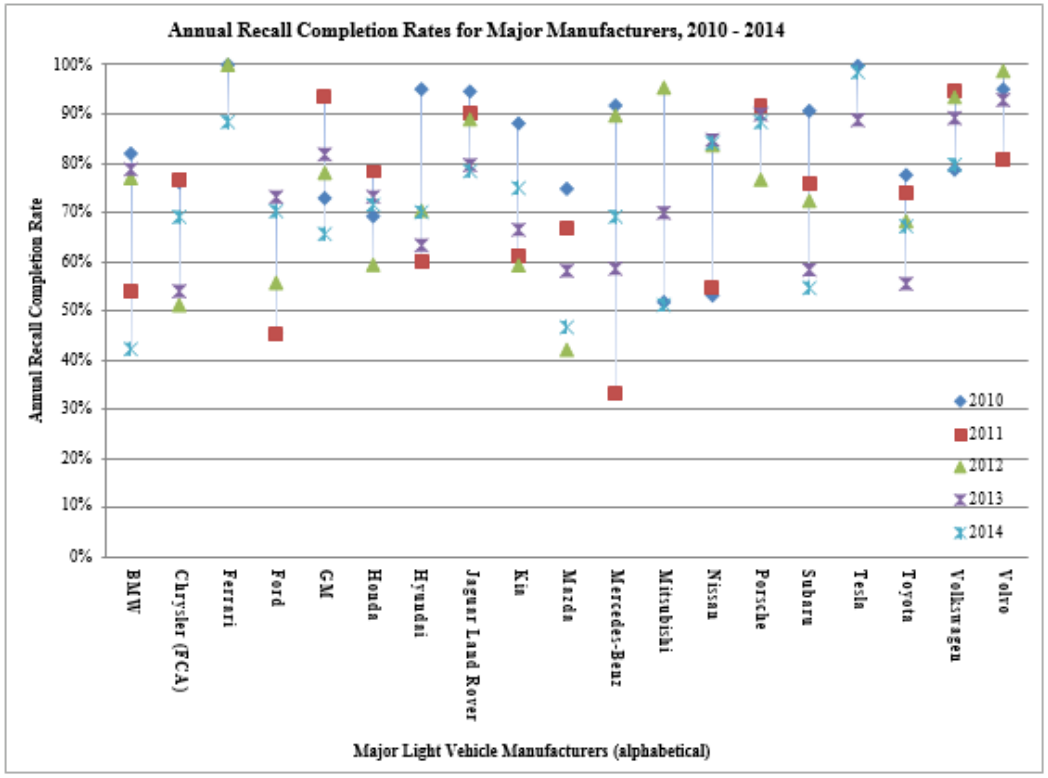



**Figure 12.** Annual Recall Completion Rate Statistics by OEM

[43] National Highway Traffic Safety Administration, REPORT TO CONGRESS: "VEHICLE SAFETY RECALL COMPLETIONS REPORT" (May 2017), *available at* https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13376-recall_completion_rates_rtc-tag_final.pdf.

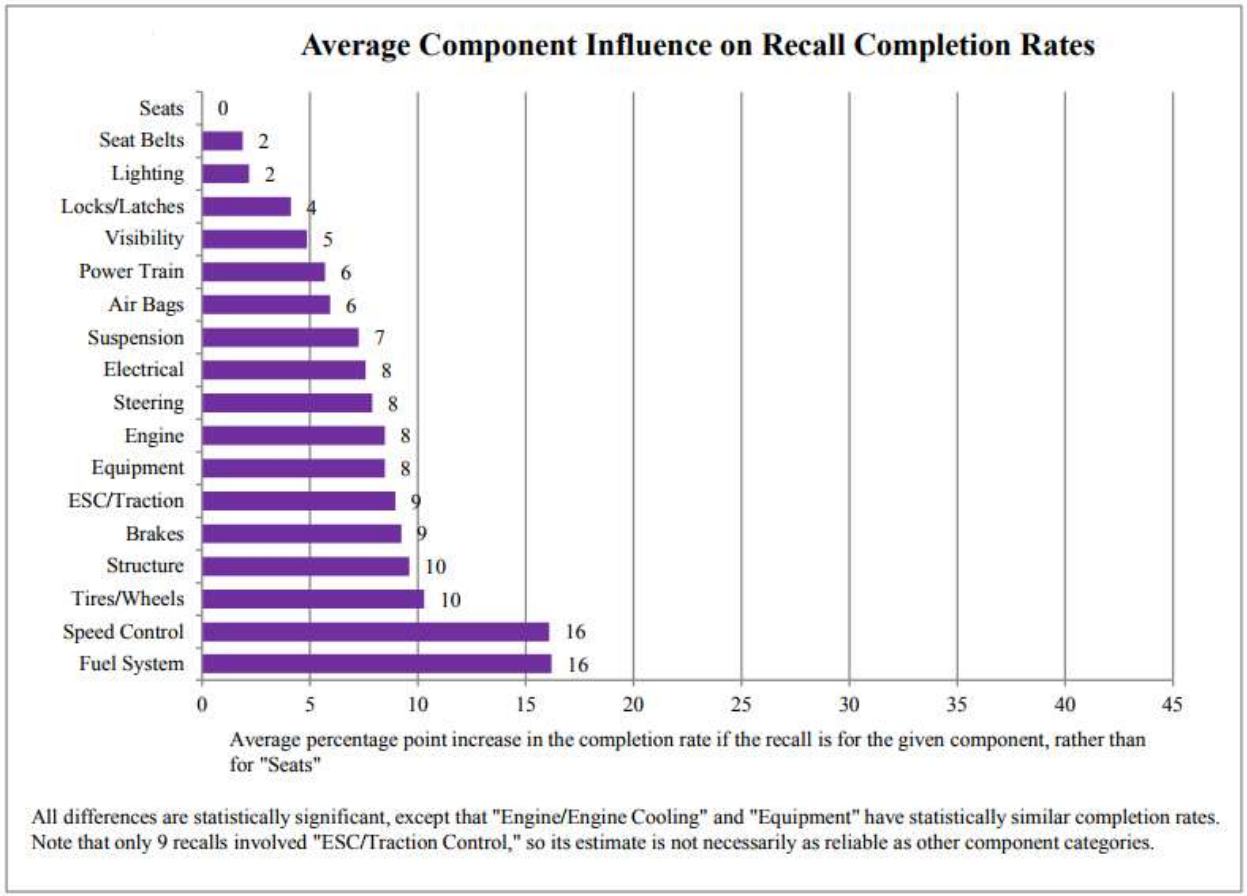



**Figure 13.** Component Influence on Recall Completion Rate

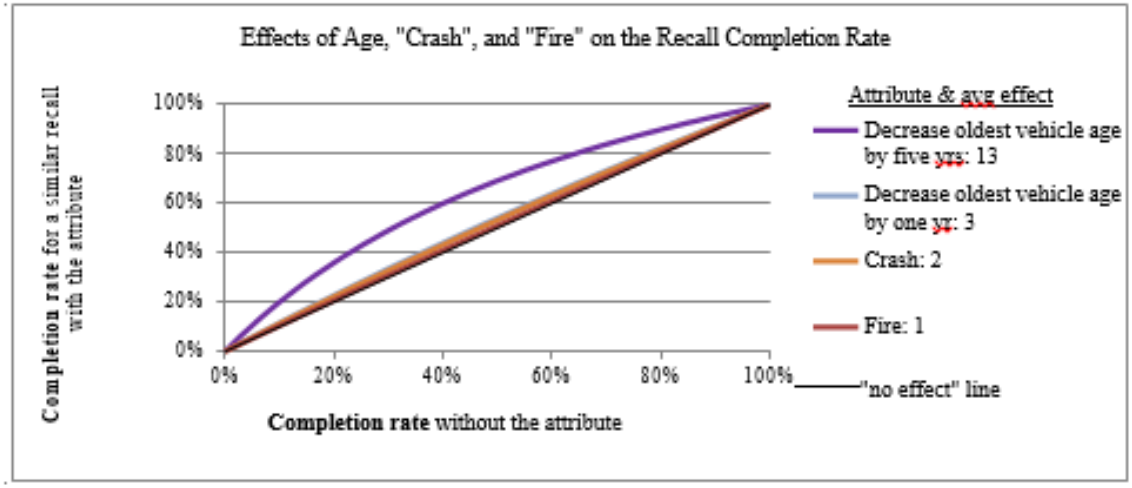



**Figure 14.** Effects of Vehicle Age on Recall Completion Rates

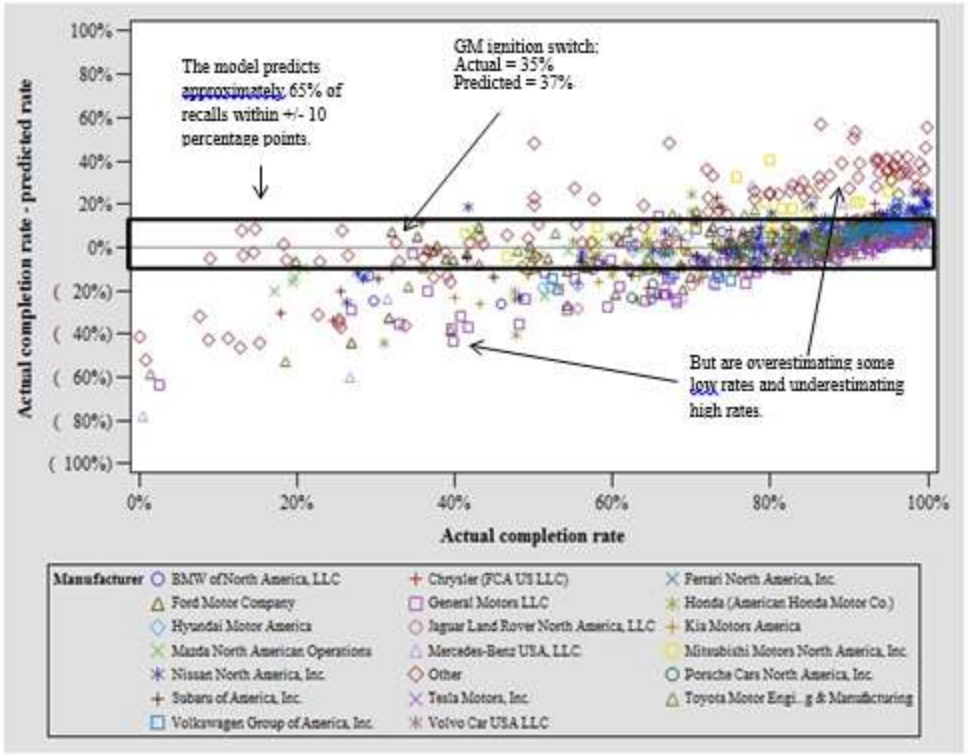



**Figure 15.** NHTSA's Model fit at Predicting Recall Completion

## Appendix C: Cost Assessment

**Table 9.** OEM Embedded Systems - Cost Assessment

| OEM | Cost | Unit | Cost for Application | Sources for Cost |
|---|---|---|---|---|
| BMW | Safety Plan: $199<br>Safety and Convenience Plan: $398 | Annual Subscription | Free | https://www.bmwusa.com/secured/content/forms/assistrenewal.aspx?from=/Standard/Content/Owner/BMWAssist/assistrenewal.aspx&return=/Standard/Content/Owner/BMWAssist/assistrenewal.aspx |
| GM | Base Price: $299<br>PLUS<br>Protection Plan: $19.99<br>Security Plan: $24.99<br>Guidance Plan: $34.99 | Base Price plus Monthly Subscription | N/A | https://www.onstar.com/us/en/what_you_get/plans_and_pricing/<br><br>https://www.cnet.com/roadshow/news/onstar-fmv-drops-to-99-including-installation/ |
| Volvo | 12 Months = $200<br>18 Months = $250<br>30 Months = $390<br>42 Months = $500<br>54 Months = $600 | Monthly Subscription | N/A | http://volvo.custhelp.com/app/answers/detail/a_id/9082/~/volvo-on-call-overview |
| Mercedes-Benz | Safety and Security: $199<br>Travel and Assistance: $240<br>Entertainment: $216 | Annual Subscription | N/A | https://www.mbusa.com/mercedes/mbrace |

| OEM | Cost | Unit | Cost for Application | Sources for Cost |
|---|---|---|---|---|
| Chrysler, Dodge, Jeep, Ram, Fiat | $149.99 | Annual Subscription | N/A | https://www.driveuconnect.com/uconnectaccess.html |
| Hyundai | Connected Care: $99<br>Remote: $99<br>Guidance: $99 | Annual Subscription | N/A | https://www.hyundaiusa.com/myhyundai/manuals-and-how-tos/Getfaq?faqId=9&category=blue_link |
| Nissan | Services Select: $11.99<br>Premium: $19.99<br>Premium Plus: $24.99 | Monthly Subscription | N/A | https://www.nissanusa.com/connect/features-app/system-requirements/nissan-connect-payment-options |

**Table 10.** Aftermarket Device Manufacturer Tethered Systems - Cost Assessment

| Device Manufacturer | Hardware | Subscription Cost | Unit | Application Cost | Sources for Cost |
|---|---|---|---|---|---|
| Zubie | $99.99 | $179.95 | Annual Subscription | 0 | http://zubie.co<br><br>https://www.amazon.com/Zubie-GL500C12M-Consumer-Connected-Tracking/dp/B01LXRUD7D/ref=pd_sim_263_3/137-7130389-4372213?_encoding=UTF8&pd_rd_i=B01LXRUD7D&pd_rd_r=S78E3PB3H34V6F7QE061&pd_rd_w=WBbMe&pd_rd_wg=qr8LV&psc=1&refRID=S78E3PB3H34V6F7QE061 |
| Voyomotive | VOYO Controller: $100<br>Voyomotive Relay: $50 | 1-year subscription: $30<br>3-year subscription: $60<br>Lifetime Premium Pack Unlock: $100 | Varies | 0 | https://www.voyomotive.com/what-is-voyo/ |
| Carista | $39.99 | $39.99/year<br>$9.99/1-week pass | Varies | 0 | https://caristaapp.com/pricing |
| Dash | $39 | uses mobile plan | None | 0 | https://dash.by/buy-now.html |

| Device Manufacturer | Hardware | Subscription Cost | Unit | Application Cost | Sources for Cost |
|---|---|---|---|---|---|
| Golo | $74 | uses mobile plan | None | 0 | http://business.golocarcare.com/<br><br>https://www.napaonline.com/en/p/BK_7002592 |
| Hum | $49.99 | uses mobile plan | None | 0 | https://www.hum.com/ |

**Table 11.** Automaker Integrated Systems - Cost Assessment

| OEM | Platform | Cost | Unit | Cost for Application | Sources for Cost |
|---|---|---|---|---|---|
| Ford | SYNC 3 | Base Price: $295<br>Plus<br>Subscription: $60 | Annual Subscription | N/A | http://autoweek.com/article/car-news/ford-lowers-sync-price<br><br>https://owner.ford.com/how-tos/sync-technology/sync/sync-services/sync-services-overview.html |
| Toyota | Entune | Base Price: $895-1295<br>Plus<br>Subscription: $10 | Monthly Subscription | N/A | https://www.toyota.com/entune/#!/about/entune30<br>https://www.verizonwireless.com/support/connected-car-faqs/#eligible-plans |
| Audi | Audi Connect | Connect PRIME Plans<br>Connect PRIME - 6 Months - $199<br>Connect PRIME - 18 Months - $499<br><br>Connect PLUS Plans<br>AT&T Existing Monthly Postpaid Plan ($10)<br>Connect PLUS - 1GB Monthly - Auto Renew - $10<br>Connect PLUS - 4GB Monthly - Auto Renew - $20<br>Connect PLUS - 10GB Monthly - Auto Renew - $40<br>Connect PLUS - 10GB - 6 Months - $99 | Varies | N/A | https://www.audiworld.com/forums/q7-mkii-discussion-211/connect-plans-price-increased-2918179/ |

| | | | | | |
|---|---|---|---|---|---|
| | | Connect PLUS - 30GB - 18 Months - $270<br>Connect PLUS - Unlimited - Auto Renew - $20 | | | |
| Jaguar / Land Rover | InControl | $995 for hardware<br>$15 subscription | Monthly Subscription | N/A | https://www.jaguarusa.com/disclaimer.html<br><br>https://myconnectedcar.att.com/webclient/#/backseat/learn |
| Mazda | Mazda Connect | 1 Year subscription: $119<br>3 Years subscription: $184.9 | Varies | N/A | http://infotainment.mazdahandsfree.com/howto-windows-connectedservices?language=en-EU |

# Appendix D: Subject Matter Experts Interview Topics[44]

## In-Vehicle Recall Notification System – Interview Topics

### Assessing Telematics Systems for an In-Vehicle Recall Notification System

#### Background

The Volpe National Transportation Systems Center, in conjunction with the National Highway Traffic Safety Administration, is currently performing an analysis on the feasibility and potential cost of vehicle-based concept systems that would operate in each new light motor vehicle to indicate when the vehicle is subject to an open recall.

#### Objective

We would like your input on the feasibility of vehicle-based concepts and on the challenges and limitations of implementing them.

#### Interview Topics

1. Concepts:

We thought of the following concepts and we would like your feedback on whether there are better or additional system options to send an open recall message. Figure 1 shows three concepts systems that can notify vehicle owners/drivers of a recall.

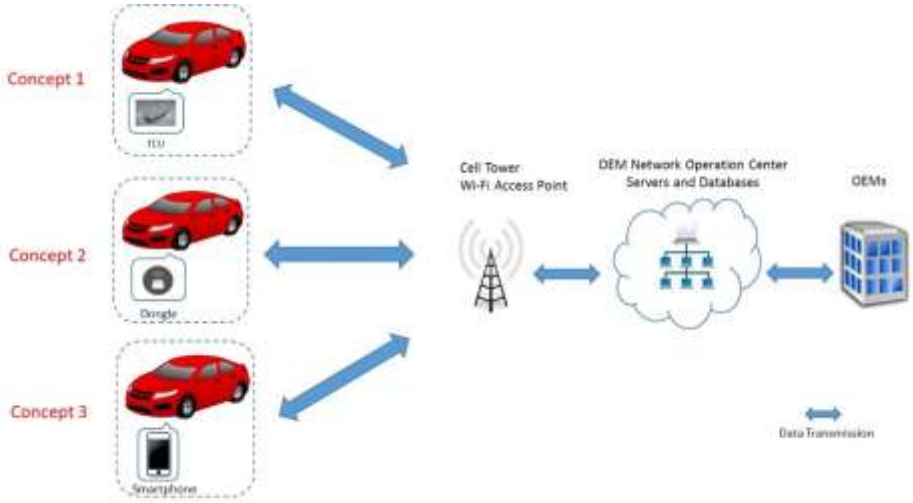



**Figure 1**. Concept In-Vehicle Recall Notification Systems

Concept system 1 - Embedded Connectivity: The connectivity (subscriber identity module card and modem) and intelligence are built directly into the vehicle without the need of other devices. All data are transmitted via the original equipment manufacturer using a telematics control unit (TCU).
Concept system 2 - Tethered Connectivity: In tethered connectivity, external modems and/or SIM card provide the connectivity using a dongle while the intelligence remains embedded in the vehicle.
Concept system 3 - Integrated Connectivity: Integrated connectivity is based upon integration between the vehicle and the owner's mobile device (i.e., smartphone), in which all communication modules and intelligence remain strictly on the phone. This approach to connectivity is not connected to the vehicle

Controller Area Network (CAN) bus. All that the vehicle provides is the port into which the phone or device is plugged into and, in some cases, an interface screen that mirrors the owner's smartphone interface.

1. Technology Assessment:
   - 2.1 Type of wireless connectivity necessary for a concept in-vehicle recall notification system
     a. Embedded
     b. Tethered
     c. Integrated
     d. Combination of them
     e. Other
   - 2.2 Challenges that a recall system would add to the telematics system you already have
   - 2.3 Software and hardware updates needs for a recall notification system
   - 2.4 Display of recall messages to drivers through the in-vehicle recall system
     a. Screen display
     b. Smartphone display
     c. Voice message
     d. Minimizing owner annoyance
   - 2.5 Recall message smartphone application
     a. Using your own OEM phone application
     b. Creating a new phone application for recall messages
   - 2.6 Type of wireless communication to connect an aftermarket device with the vehicle, smartphone and cloud
     a. Modem
     b. Bluetooth

2. Partnerships:
   - 3.1 Partnering with aftermarket device manufacturers or/and service providers
     a. Access to vehicle data
     b. Access to your recall databases
     c. OEM-Dongle phone application
     d. Types of agreements
   - 3.2 Recall database management using third party providers
     a. Data security
     b. Service provider agreement
     c. Aftermarket device manufacturer agreement

3. Franchised dealers' involvement:

Figure 2 shows how the concept in-vehicle recall system is integrated in the recall process.

[44] This form was provided from Volpe to the SMEs to gather their responses for this NHTSA report.

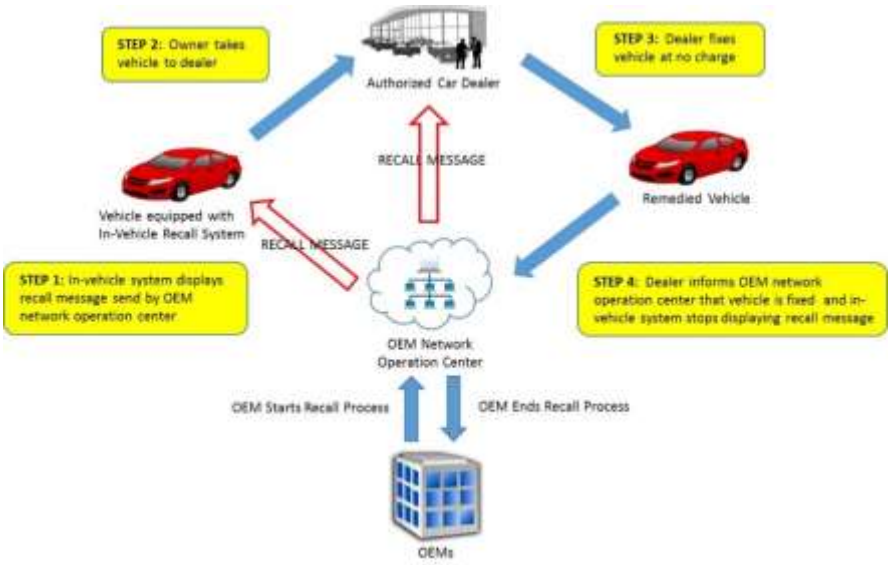



**Figure 1 .** Recall Process Steps with Concept System

4.1 Your thoughts on the process shown above. Are we missing any key links in the process?

4.2 Communication with your franchised dealers

a. Communication means to reach owners and dealers
b. Dealers responsibility to inform when a vehicle has been fixed
c. Updating recall databases
d. Recall completion rates

4.3 Dealers input to the in-vehicle recall notification system

a. Using the in-vehicle recall system to communicate with the network operation center
b. Recall database update

## 1. Privacy and Security:

5.1 In-vehicle recall notification system security concerns

a. Cybersecurity issues
b. Current security measures

5.2 Privacy concerns

a. Current privacy principles
b. Protecting vehicle owners data

## 2. Economic/Effectiveness Analysis:

6.1 Your safety recall notification practices in addition to using the mail (i.e., e-mail, electronic messages, automated phone call, live-person phone call, etc.)

a. Distribution of safety recall notification techniques (e.g., 100% mail, 20% automated phone calls, etc.)
b. Reasons for your choice of notification practices (i.e., cost, effectiveness, etc.)

6.2 Effectiveness of the different mediums of safety recall notification in terms of recall completion rates or consumer responses (e.g., 10% consumer responses in 1st contact, 15% in 2nd contact, and so on.)

6.3 Any studies or reports assessing the effectiveness of different notification practices