

Connected Vehicle Technology Industry Delphi Study



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EXECUTIVE SUMMARY

The automotive industry continues to transform from being predominantly mechanically-based to increasingly electronically-based. This transformation is critical to the State of Michigan as it seeks to maintain its position as a global leader in the automotive sector. The Michigan economy lost more than 460,000 jobs from 2007 to 2010; however, it appears to be headed towards a recovery, gaining more than 140,000 jobs between 2011 and 2012 to-date (Bureau of Labor Statistics, 2012). Connected vehicle technology development offers Michigan a growing high-tech industry where Michigan companies already have a competitive advantage. Michigan is also home to the Michigan Department of Transportation (MDOT) and other public-sector agencies that have demonstrated national leadership in connected vehicles. MDOT is pursuing a strategy for supporting the testing and development of connected vehicle technologies that keep drivers connected, save lives, improve mobility, protect the environment, and employ Michigan residents.

MDOT asked the Center for Automotive Research (CAR) to perform surveys of expert opinion, with panelists from the automotive and public sectors, to help forecast the future of connected vehicle technology research and deployment. In response to this request, CAR conducted a follow-up to its expert panel surveys from 2005 and 2008 to ascertain changes in the strategic direction of the connected vehicle and wireless communication technology industries. This follow-up study also discerns new technical and business trends emerging in this field.

This report summarizes the automotive industry survey results. In particular, it provides a general overview of user services and survey results in several categories:

- Type of Technology
- Embedded Equipment

- Vehicle-to-Vehicle (V2V) vs. Vehicle-to-Infrastructure (V2I) Technology
- Estimated Costs of Connected Vehicle Technology
- National Highway Traffic Safety Administration (NHTSA) 2013 Notice of Regulatory Intent
- Other Government Policy Implications
- Challenges to Broad Adoption of Technology
- Autonomous Vehicles

HIGHLIGHTS OF FINDINGS

Respondents overwhelmingly reaffirmed the consensus that Dedicated Short Range Communication (DSRC) is needed for cooperative, active safety systems, while third generation (3G) and fourth generation (4G) cellular communications tend to be thought of as appropriate for other applications. Also, DSRC was commonly viewed as being standard equipment by 2017. By 2022, respondents indicated that Global Positioning System (GPS) receivers, satellite radios, and Wi-Fi transceivers also will be included as standard equipment. Mobility and Personal Convenience applications were forecasted to be widely available on new vehicles by 2017 through brought-in (as opposed to built-in or original equipment) communication devices, and all applications will be widely available by 2022. The majority think the applications will be built-in by that point.

V2V-only systems are considered valuable, but respondents view a complimentary V2I system as necessary to maximize full public benefits of connected vehicle technology. Respondents also think a V2V system is possible using DSRC technology only, using another communication technology for V2I systems.

The estimated costs to manufacturers for embedding DSRC, the overall added costs to base vehicle price to the consumers, and adding DSRC as aftermarket equipment are

all higher in 2017 and then drop significantly by 2022. However, the forecasted additional costs to the consumer for adding the technology to a vehicle is the highest at \$350 in 2017 and drops to only \$300 in 2022.

Regarding the possible 2013 NHTSA Notice of Regulatory Intent on mandating V2V safety systems for vehicles, most respondents expressed the view that NHTSA will announce that it does intend to mandate V2V safety. Respondents further indicated that, if this proves to be correct, by 2022 all new vehicles sold in the U.S. will be required to have V2V communication equipment as standard equipment. Aftermarket retrofit mandates are less certain, but if there is a mandate, the device will likely be broadcast-only or a device not connected to the vehicle's data bus. If NHTSA does not mandate a safety system (and it has options of calling for a voluntary program, indicating that more

research is needed, or doing nothing at all), respondents are mixed on whether automakers will continue to pursue V2V technology for safety systems.

Most respondents do not think many other connected vehicle applications will be mandated by 2017, but a few, such as intersection control and work-zone alert, may be mandated by 2022. Also, respondents do not foresee additional safety mandates coming by 2022.

One of the biggest challenges respondents see to the broad adoption of connected vehicle technology is funding for roadside infrastructure.

Autonomous vehicles have strength, but respondents believe the most significant public benefit will come from a combination of autonomous and connected vehicles.

I. INTRODUCTION

Road transportation continues to undergo significant technological transformations as wireless communication increasingly enables vehicles to communicate with each other and with the infrastructure. This has multiple benefits, including improved safety, mobility, personal convenience, and economic development. To make the most of this opportunity, public and private entities must collaborate to develop a system that actively engages the automotive, telecommunications, and consumer electronics industries. The challenge lies in building enough confidence on both the public and private sides of the issue to bring them together to cooperate and achieve an integrated outcome.

One of the primary benefits of connected vehicle technology is the potential for vastly improved vehicle safety. Both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication promise significant safety improvements. Assuming a Dedicated Short Range Communications (DSRC)-based safety system, vehicles continuously (ten times per second) broadcast a basic safety message that includes information such as vehicle speed, heading and location. This information is used by other equipped vehicles so that, cooperatively, crashes are avoided. In the V2I realm, safety is enhanced via broadcast of signal phase and timing (SPaT) information at signalized intersections, and this information is used for vehicle speed management to promote green waves and for driver warnings and possibly active crash avoidance in red-light-running scenarios. V2I can also be used for traffic queue detection at controlled intersections.

In addition to safety benefits, connected vehicle technology also helps with traffic mobility. Vehicles already serve as traffic probes based on cellular data and DSRC-based V2I also supports this application. In such applications, vehicles communicate information about travel speed to assist in the detection

of congestion and incidents—information that then can be shared with vehicles that are not yet in the traffic stream, allowing drivers to choose a different route.

The connected vehicle is a central component of the public-private partnership in sustaining technological development in the Michigan automotive sector. Consumers are connected in almost every domain of life, from home to work, or any other location where there is access to cell phones and Wi-Fi communication.

The Michigan Department of Transportation (MDOT) asked the Center for Automotive Research (CAR) to perform Delphi studies to augment previous research done on connected vehicle technology. The two studies focused on the public sector and the automotive sector. This report documents the automotive sector study.

DELPHI SURVEY PROCEDURE

Although several more were asked to and agreed to participate, ultimately twelve respondents participated in the study. Automotive sector panelists come from automakers, Tier 1 suppliers, and wireless communication suppliers. The panelists were told that the process is anonymous, and that their participation and their specific answers tied to their identity would not be shared with anyone outside the research team. Additionally, in lieu of compensation for participating in the study, respondents were given the raw, unanalyzed results for each survey in which they participated. Participants were drawn from the following organizations:

- Connected Vehicle Trade Association
- DENSO
- Johnson Controls
- P3
- Qualcomm
- Siemens
- Sprint

- Toyota
- Vector CANtech
- Visteon
- Volkswagen
- Wilson Consulting

The respondents, or panelists, were given two, iterative surveys to complete, with the second survey arriving several weeks after the first. The questions included in the sur-

veys addressed a broad range of topics, including communication technologies for various applications, possible governmental influence, and the years in which various levels of DSRC deployment will be reached. Other, more technology-specific, topics included when vehicles will have a certain component as standard equipment, how V2V and V2I systems compare, and how applications will be implemented on the vehicle.

II. AUTOMOTIVE SECTOR CONNECTED VEHICLE SURVEY RESULTS

The results of the survey include responses for questions asked in only one of the two survey rounds, as well as responses to questions asked in both rounds, and include a range of technology topics. For questions that were included in both survey rounds, the discussion below tends to focus on the second-round results, though the first-round often is used to extend the discussion.

TYPE OF TECHNOLOGY

One common discussion in the connected vehicle realm concerns which types of technology are most fitting for different types of applications. Respondents reaffirmed the apparent consensus that Dedicated Short Range Communication (DSRC) is needed for cooperative, active safety systems, while third-generation (3G) and fourth generation (4G) cellular communications tend to be thought of as appropriate for other applications.

DSRC AND COOPERATIVE, ACTIVE SAFETY SYSTEMS

More than 80 percent of respondents think DSRC is needed for cooperative, active safe-

ty systems (see Figure 1).

3G AND 4G FOR ALL OTHER APPLICATIONS

Respondents showed less agreement, however, regarding 3G or 4G cellular technologies and other applications. When it comes to whether 3G and 4G cellular technology can handle most other connected vehicle applications, about 58 percent agreed or strongly agreed, and 25 percent disagreed or strongly disagreed (see Figure 2).

EMBEDDED EQUIPMENT

As connected vehicle technology evolves, many wonder whether certain types of equipment will primarily be built into the vehicle (in other words, automakers embed the equipment in vehicles as original equipment) or brought-in via mobile devices such as smartphones. Overall, respondents believe DSRC transceivers are the most likely type of equipment to be embedded in vehicles within the next ten years.

DSRC as Standard Equipment

Most respondents expressed the view that embedded DSRC transceivers will be standard equipment on at least 10 percent of vehi-

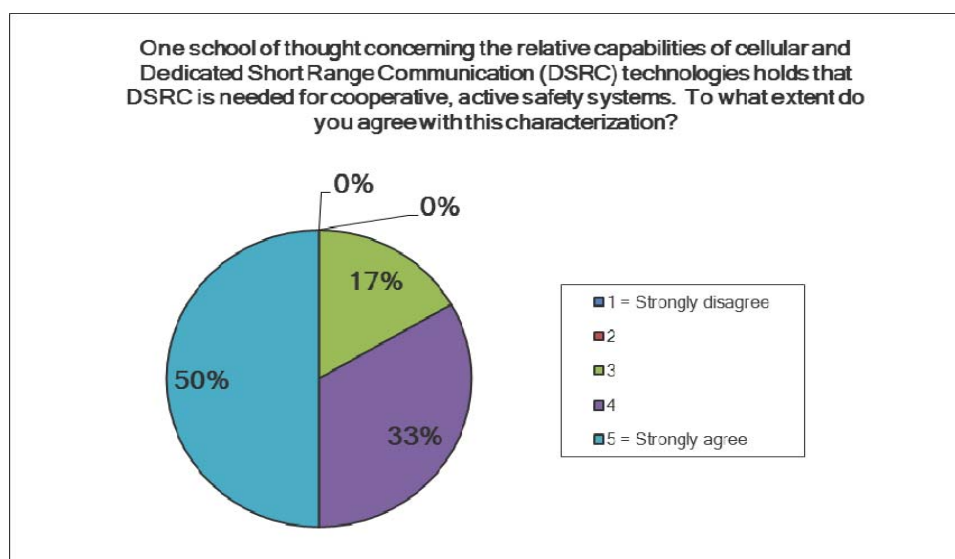


Figure 1: DSRC and Cooperative, Active Safety Systems
Source: CAR 2012

cles sold in the U.S. on or before 2020, and all believe it will be standard equipment by 2025 (see Figure 3).

EMBEDDED (BUILT-IN) VS. BROUGHT-IN

A strong majority of respondents indicated that mobility and personal convenience (through brought-in equipment) connected vehicle applications, as well as vehicle diagnostics (through built-in equipment), would be widely available by 2017, and a slight ma-

jority reported that safety (through built-in equipment) and environmental (through brought-in equipment) applications would be widely available by 2017.

By 2022, strong majorities think all applications will be widely available, and most, aside from mobility and personal convenience applications, will handled through built-in equipment (see Figure 4 and Figure 5).

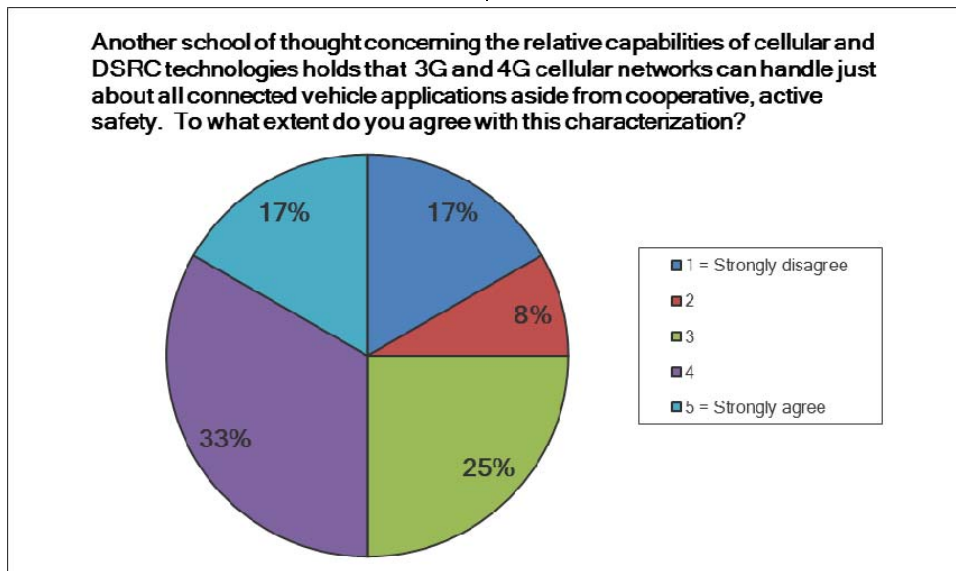


Figure 2: 3G and 4G Cellular Technology and Connected Vehicle Applications

Source: CAR 2012

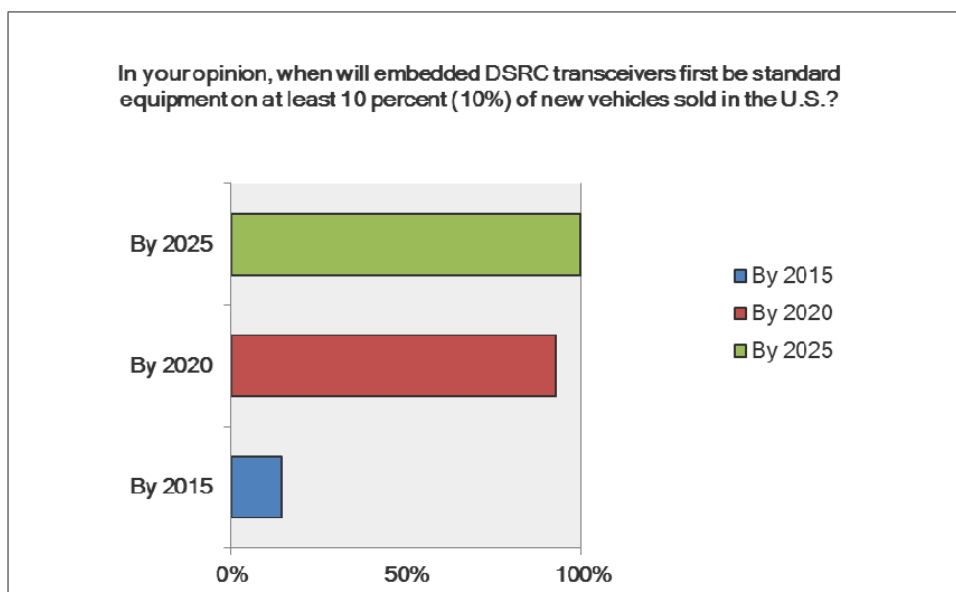


Figure 3: DRSC as Standard Equipment

Source: CAR 2012

BUILT-IN VS. BROUGHT-IN EQUIPMENT

In the first round, respondents indicated they think many connected vehicle applications

such as Personal Convenience, Mobility, and Vehicle Diagnostics, would be built-in by 2022. Given that it is currently so easy to

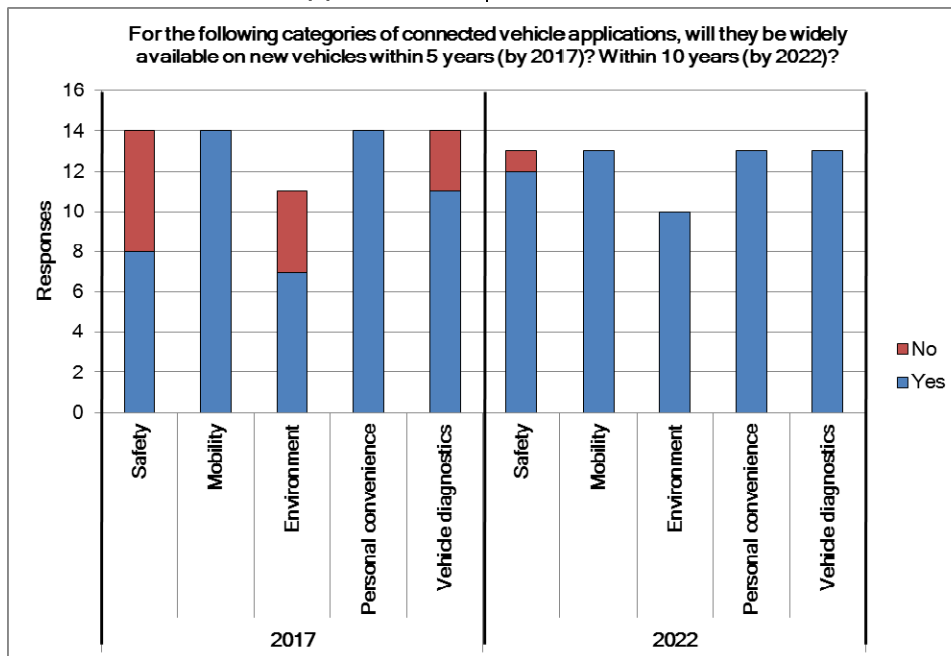


Figure 4: Connected Vehicle Application Forecast
Source: CAR 2012

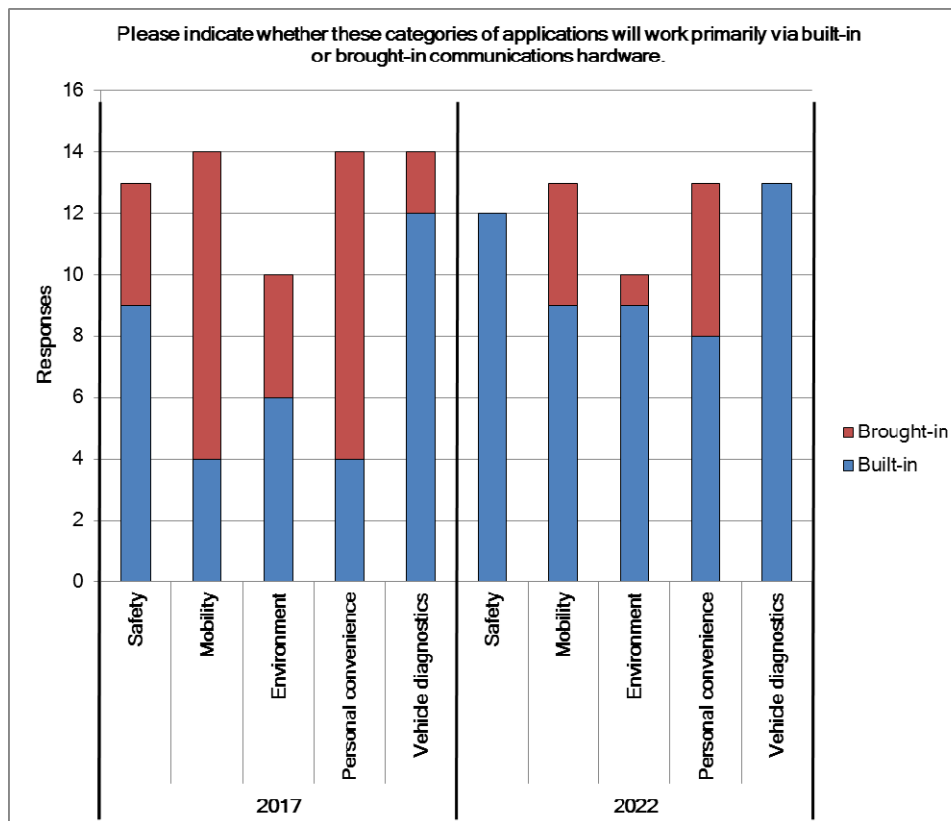


Figure 5: Built-In vs. Brought-in Communication Hardware Forecast
Source: CAR 2012

bring in mobile devices to perform these functions, the second survey asked respondents why they think the trend would reverse. Some of the most common answers were:

- Automakers are in control of the user-experience and data
- Offers automakers customer relationship opportunities
- Product lifecycle, because vehicles must last longer therefore it is better for automakers to have them under control for long-term secure services
- Easier to implement the technology
- Security

COMPONENT TECHNOLOGIES AS STANDARD EQUIPMENT

Respondents felt most strongly that DSRC transceivers, as opposed to other forms of technology, would be standard equipment by 2017 (see Figure 6). In 2022, in addition to DSRC transceivers, more equipment was considered likely to be standard equipment, including GPS receivers, satellite radios, and Wi-Fi transceivers (see Figure 7).

SENSOR AND CONNECTED VEHICLE SYSTEMS INTEGRATION FORECAST

The majority of respondents (85 percent) ex-

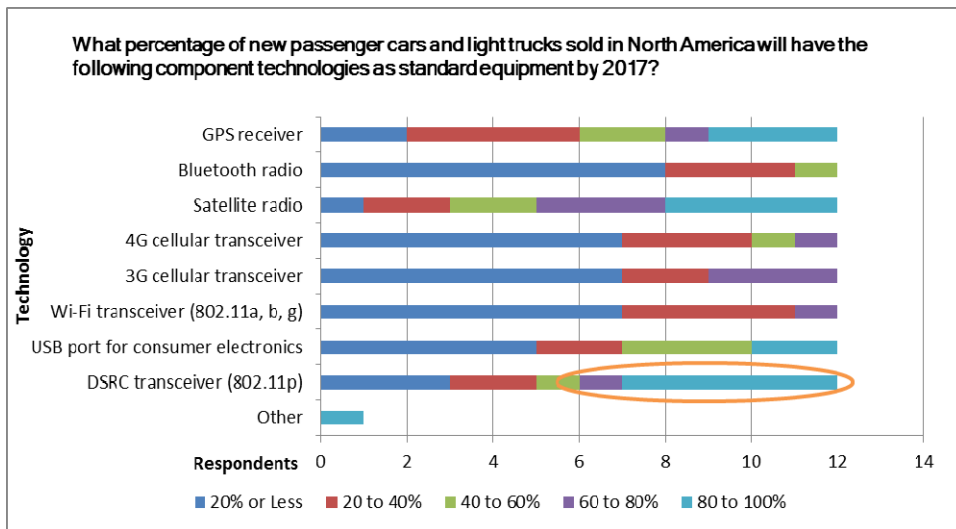


Figure 6: Component Technologies as Standard Equipment by 2017
Source: CAR 2012

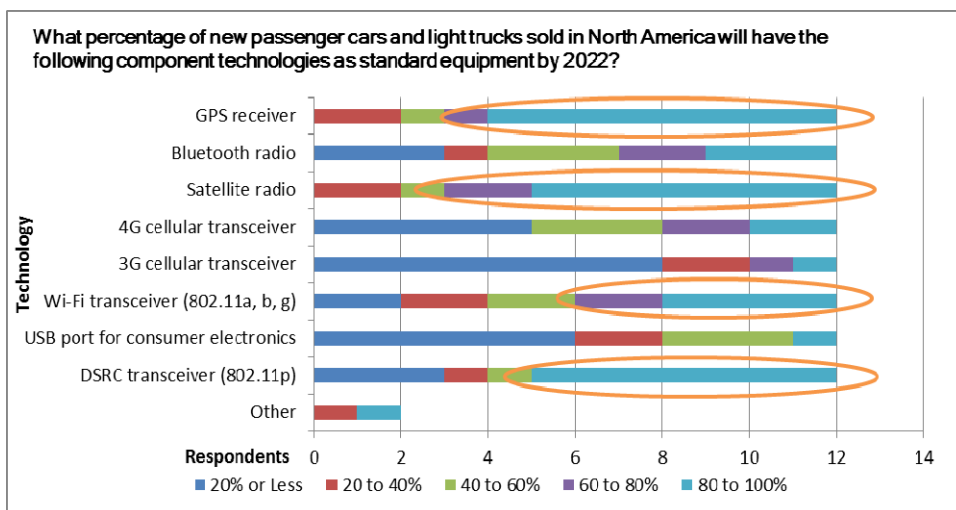


Figure 7: Component Technologies as Standard Equipment by 2022
Source: CAR 2012

pect to see significant integration of sensor systems (e.g., camera, RADAR, LiDAR) and connected vehicle communication systems by 2022 (see Figure 8).

V2V communication, where vehicles communicate directly with each other, or V2I communication, where vehicles communicate with roadside infrastructure. Most respondents think the best system to maximize public good is V2V and V2I working cooperatively.

V2V vs. V2I TECHNOLOGY

Another discussion in the connected vehicle realm is which is most valuable and realistic:

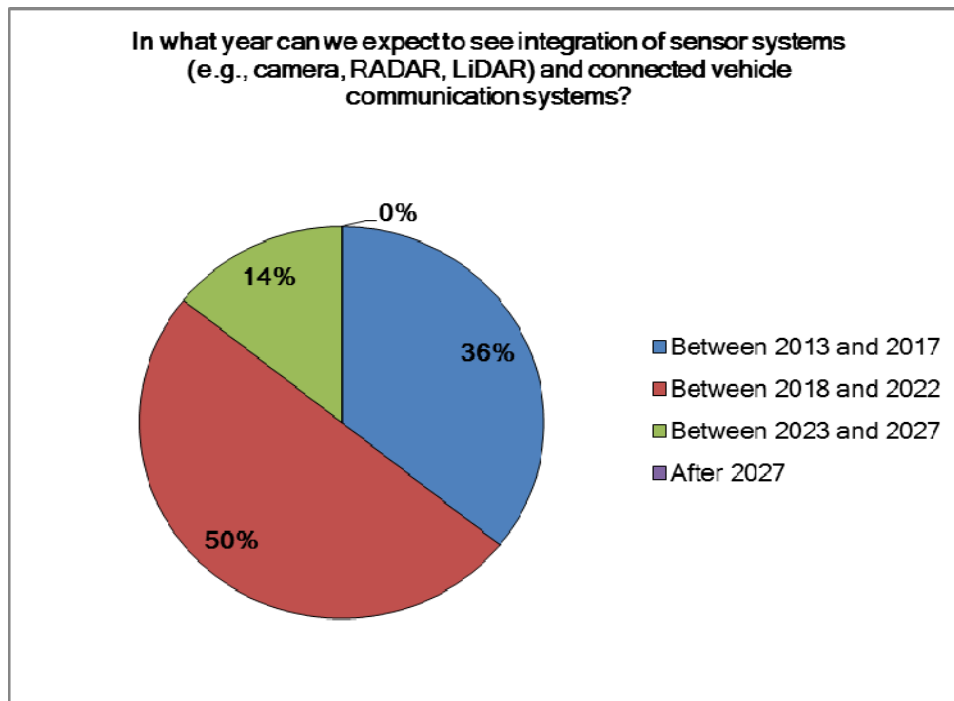


Figure 8: Sensor and Connected Vehicle Systems Integration Forecast
Source: CAR 2012

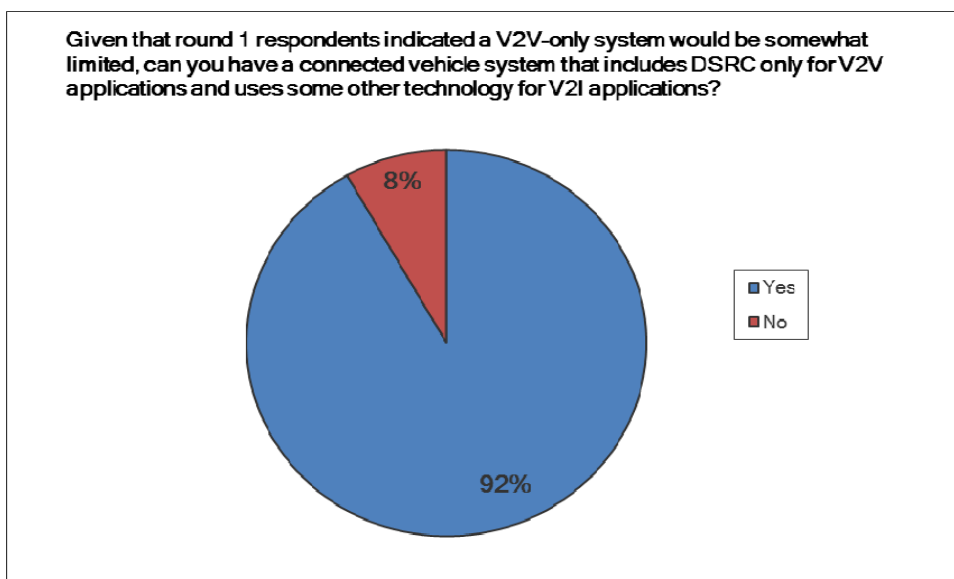


Figure 9: DSRC for V2V versus V2I Applications
Source: CAR 2012

V2V-ONLY SYSTEM

Respondents were asked an open-ended question of whether a V2V-only system is desirable. Many respondents suggested that yes, V2V alone is valuable. Others suggest-

ed that there is only limited value in V2V only, and that V2I is required to achieve full benefits. Early customers may not be willing to pay for a connected vehicle system that does not yet have enough users to be useful, which is a risk especially in a V2V-only sce-

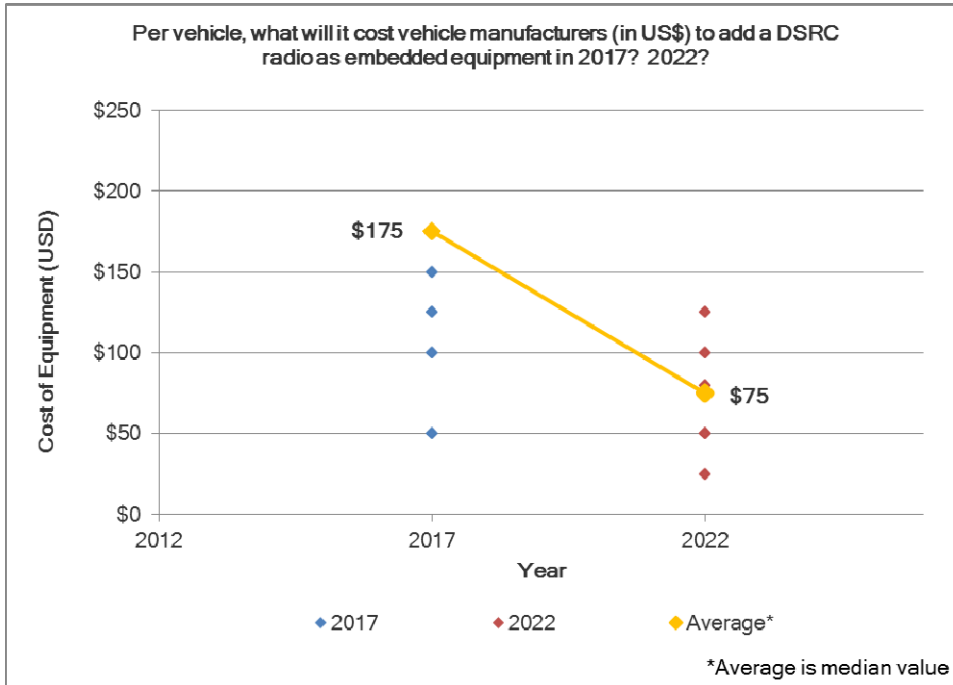


Figure 10: Cost to Vehicle Manufacturers of Embedded DSRC
Source: CAR 2012

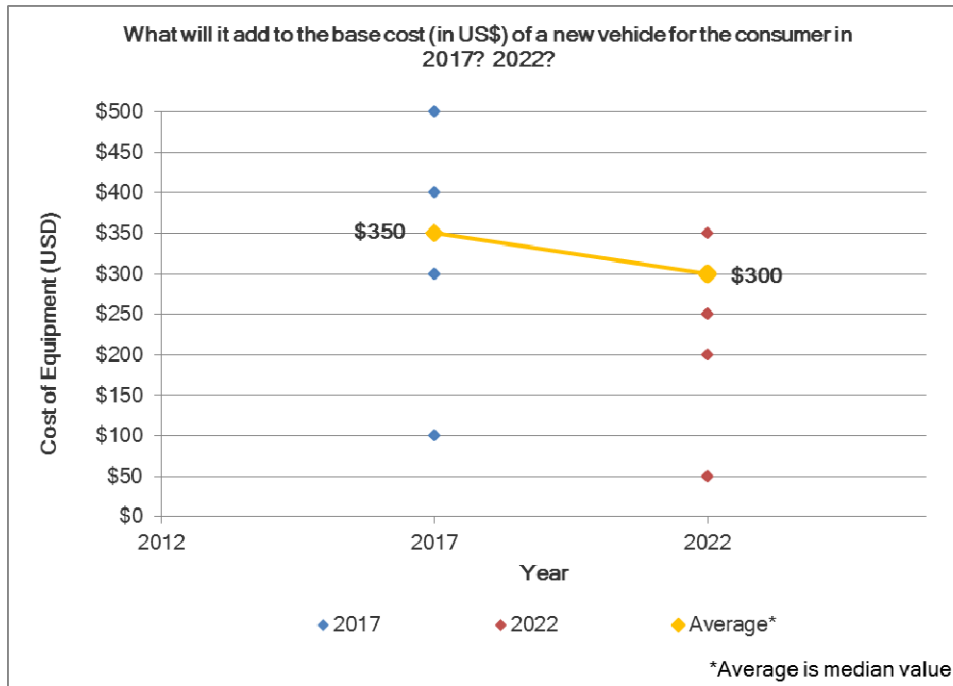


Figure 11: Cost Added to Base Vehicle Price for Connected Vehicle Technology
Source: CAR 2012

nario.

DSRC FOR V2V VERSUS V2I APPLICATIONS

In the first round, slightly more than half agreed that a V2V-only system is possible, but thought it would be somewhat limited and a V2I system in addition to V2V would offer more functionality. Given this, a vast majority of respondents (92%) believe a connected vehicle system is possible using DSRC technology only for V2V applications and another technology for V2I applications (see Figure 9).

ESTIMATED COSTS OF CONNECTED VEHICLE TECHNOLOGY

Adding connected vehicle technology will inevitably add costs to the vehicle. Respondents were asked how much various degrees of implementation would add to the base price of a vehicle, as well as including equipment as aftermarket.

COST TO VEHICLE MANUFACTURERS OF EMBEDDED DSRC

In both rounds, when asked how much it will cost vehicle manufacturers (in US\$) to add a DSRC radio as embedded equipment, respondents gave a median response of \$175 for 2017 and \$75 for 2022. The second round means were \$148 for 2017 and \$73 for 2022. In Figure 10, six respondents selected \$175 as the 2017 cost, but that is not visually reflected in the graph because those points are stacked.

COST ADDED TO BASE VEHICLE PRICE FOR CONNECTED VEHICLE TECHNOLOGY

Regarding what connected vehicle technology will add to the base cost (in US\$) of a new vehicle for the consumer, the median in both rounds was \$350 for 2017 and \$300 for 2022 (see Figure 11). The second round means were \$335 for 2017 and \$260 for 2022.

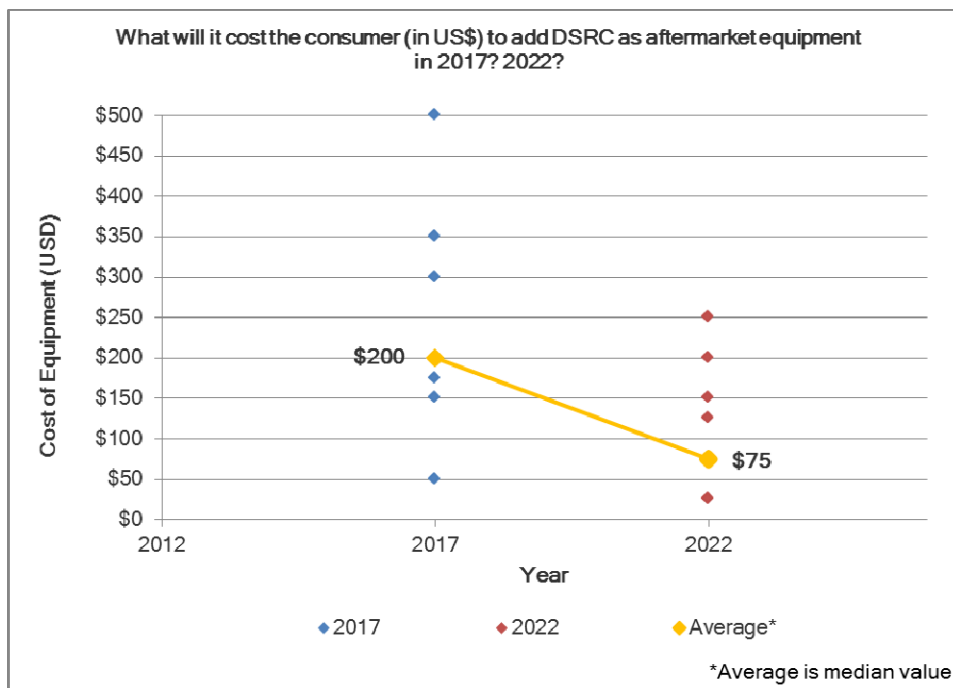


Figure 12: Consumer Cost to Add DSRC as Aftermarket Equipment
Source: CAR 2012

**CONSUMER COST TO ADD DSRC AS
AFTERMARKET EQUIPMENT**

For what it will cost the consumer (in US\$) to add DSRC as aftermarket equipment, the median for both rounds was \$200 for 2017 and \$75 for 2022 (see Figure 12). The second round means were \$233 in 2017 and \$113 in 2022.

NHTSA REGULATORY DECISION

One of the most impactful decisions on the

horizon is whether the National Highway Traffic Safety Administration (NHTSA) will decide to mandate V2V communication systems for safety applications in 2013. It is widely believed that if they do, it will spur deployment of the technology.

NHTSA'S 2013 NOTICE OF REGULATORY INTENT

The majority of respondents (79%) think NHTSA's 2013 notice of regulatory intent will be affirmative (i.e., that it *does* intend to

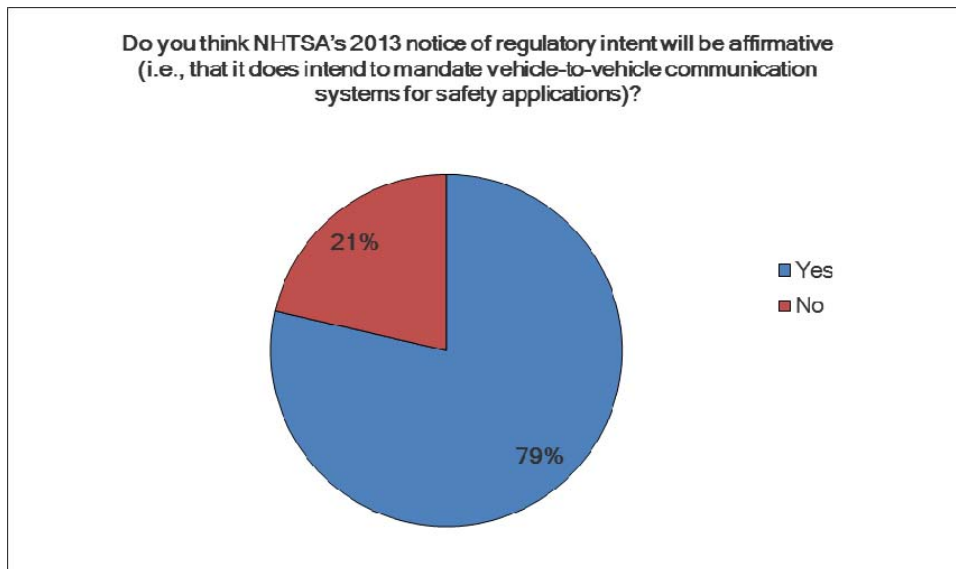


Figure 13: NHTSA's 2013 Notice of Regulatory Intent
Source: CAR 2012

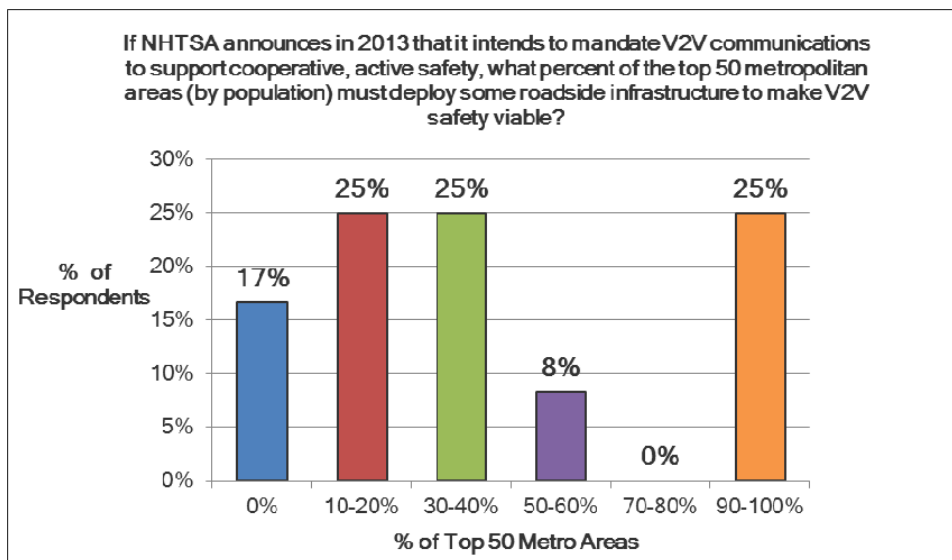


Figure 14: Percentage of Top 50 Metropolitan Areas Deployment Needed for V2V Systems
Source: CAR 2012

mandate V2V communication systems for safety applications), as seen in Figure 13. This bodes well for those in the industry who are working to make the technology more ubiquitous.

PERCENTAGE OF TOP 50 METROPOLITAN AREAS DEPLOYMENT NEEDED FOR V2V SYSTEMS

Answers are very mixed on what percent of the top 50 metropolitan areas would need to deploy V2I roadside equipment to make a V2V system viable. A quarter thought 90 to 100 percent of the areas would need to deploy equipment, but a quarter also thought

only 10 to 20 percent needed to deploy (see Figure 14).

NHTSA MANDATE AND STANDARD EQUIPMENT REQUIREMENTS

The majority of round one responses indicated that if NHTSA announces it does intend to mandate V2V safety technology within five years, all new light vehicles will be required to have this technology as standard equipment. More specifically, more than 80 percent of respondents indicated the belief that *all* new vehicles sold in the U.S. will be required to have this technology as standard equipment (if NHTSA intends to mandate it)

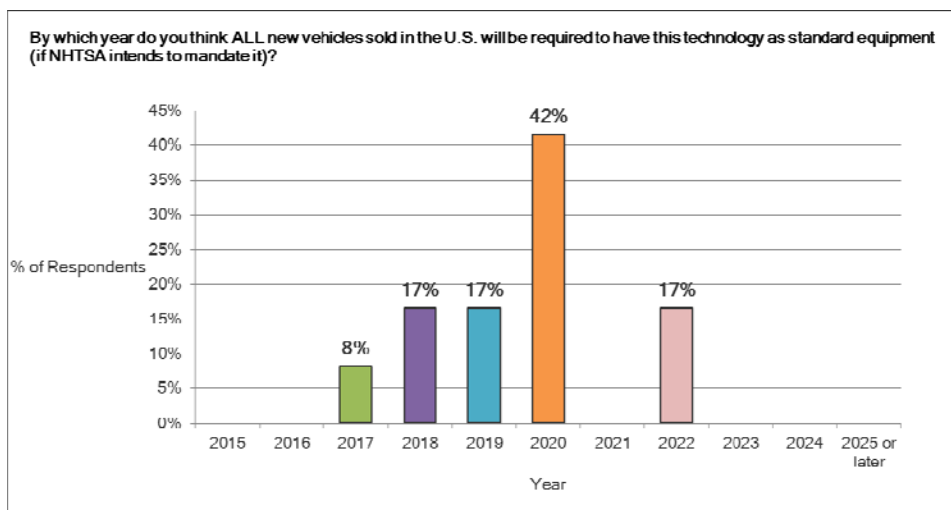


Figure 15: NHTSA Mandate and Standard Equipment Requirements
Source: CAR 2012

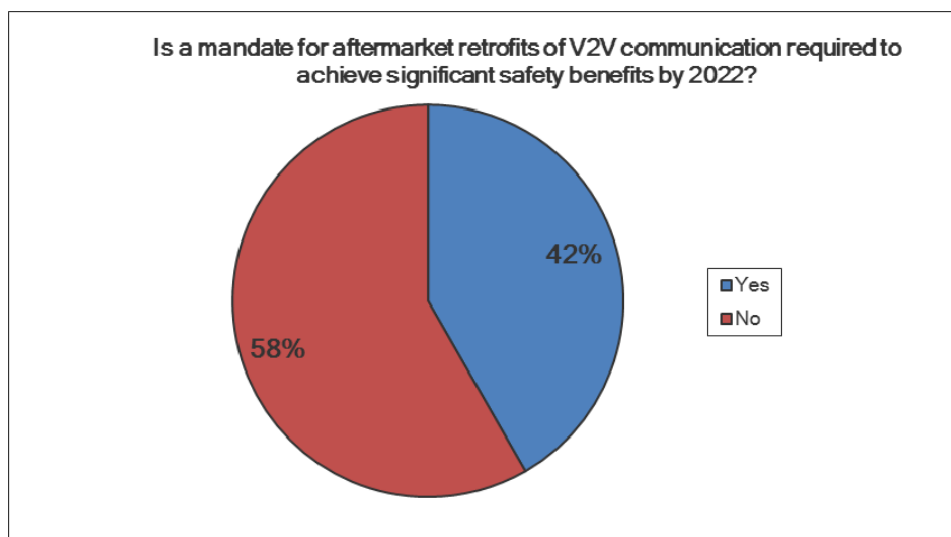


Figure 16: Mandate for Aftermarket V2V Retrofits
Source: CAR 2012

by 2020, and 100 percent think it will happen by 2022 (see Figure 15).

MANDATE FOR AFTERMARKET V2V RETROFITS

Responses are somewhat mixed as to whether a mandate for aftermarket retrofits of V2V communication is necessary for significant safety benefits by 2022, though the majority (58%) think they are not (see Figure 16).

TYPE OF AFTERMARKET DEVICE IF MANDATED

Most first round respondents indicated that if

NHTSA announces it intends to mandate V2V safety technology, it will be very unlikely that NHTSA will also require existing vehicles to be retrofitted with an aftermarket V2V safety device. If, however, NHTSA does introduce an aftermarket mandate, exactly half of respondents believe the vehicle aftermarket device will be for vehicle awareness (broadcast only), and half believe the device will not be connected to the vehicle's data bus (see Figure 17).

NHTSA MANDATE AND AUTOMAKERS PURSUING V2V

If the NHTSA does not intend to mandate

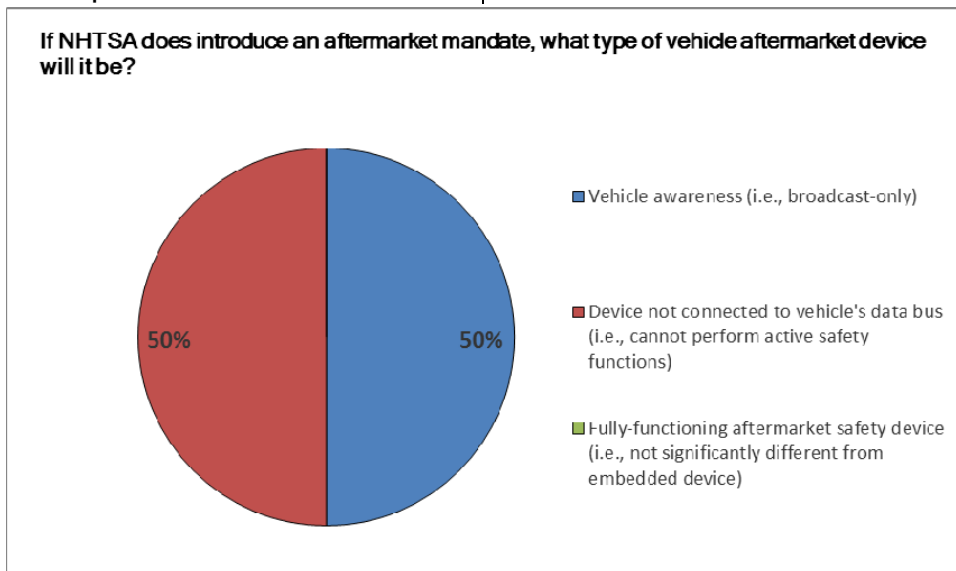


Figure 17: Type of Aftermarket Device if Mandated
Source: CAR 2012

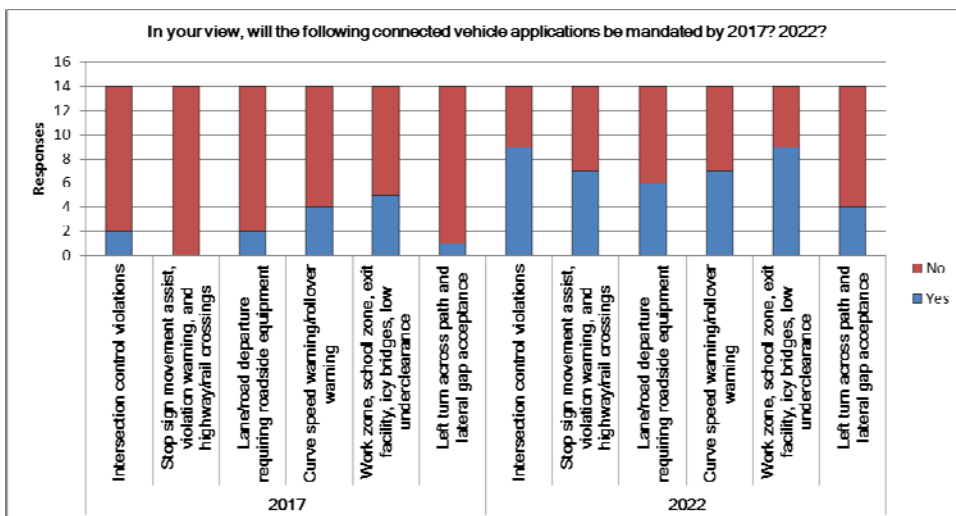


Figure 18: Forecast for Mandated Connected Vehicle Applications
Source: CAR 2012

V2V safety technology, answers remain relatively mixed as to whether automakers will continue to pursue V2V technology for safety systems. For the 33 percent that believe it is very likely automakers will continue, the following reasons were given:

- These technologies offer real safety benefits
- Europe is doing it and we will follow
- Political, marketing and technological benefits for automakers
- Can't sell cars if congestion is too bad
- Can provide functionality for tolling and other connected vehicle apps that will happen

For those who said it was not at all likely (42 percent), several commented that it is only valuable if there is mass adoption of the technology. Without it, automakers do not desire to add costs to vehicles.

OTHER GOVERNMENTAL MANDATES

Another big question for the industry is whether governmental entities will mandate certain types of technology and applications. In general, respondents do not believe many connected vehicle applications will be mandated by 2017, but believe a few, especially relating to intersections and higher-alert

zones, will likely be mandated by 2022.

FORECAST FOR MANDATED CONNECTED VEHICLE APPLICATIONS

The majority of respondents to Round One indicated that the following connected vehicle applications will likely *not* be mandated by 2017 (see Figure 18):

- Intersection control violations
- Stop sign movement assist, violation warning, and highway/rail crossings
- Lane/road departure warning
- Curve speed/rollover warning
- Work-zone, school-zone, exit facility, icy bridges, low clearance warning
- Left-turn across path and lateral gap acceptance

However, respondents did think the following will likely be mandated by 2022:

- Intersection control violations
- Stop sign movement assist, violation warning, and highway/rail crossings
- Curve speed/rollover warning
- Work-zone, school-zone, exit facility, icy bridges, low clearance warning

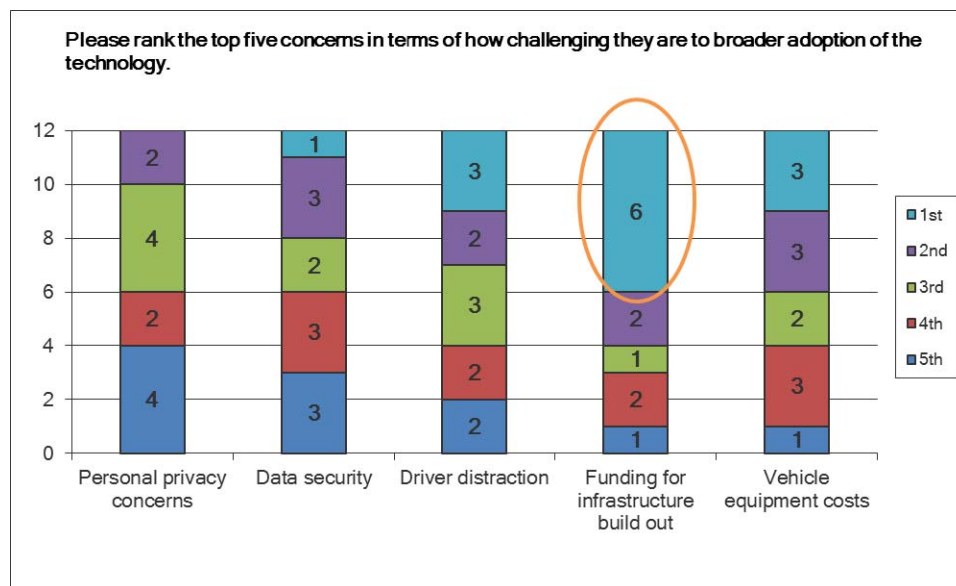


Figure 1: Top Challenges to Broad Adoption

Source: CAR 2012

ADDITIONAL SAFETY APPLICATION MANDATES

Most respondents indicate no additional safety applications will be mandated by 2022, though some thought the following could be mandated:

- Forward collision warning
- Electronic emergency brake lights
- Road conditions ahead
- Emergency vehicle, train, school bus stop warnings

However, one respondent suggested that there is no need for the government to man-

date any applications, just which technology to use.

CHALLENGES TO BROAD ADOPTION

When asked what the biggest challenges to broad adoption of connected vehicle technology are, respondents placed infrastructure funding at the top of the list.

TOP CHALLENGES TO BROAD ADOPTION OF THE TECHNOLOGY

The majority of respondents in Round One indicated that funding infrastructure build-out and driver distraction are the primary challenges to broad adoption of connected vehi-

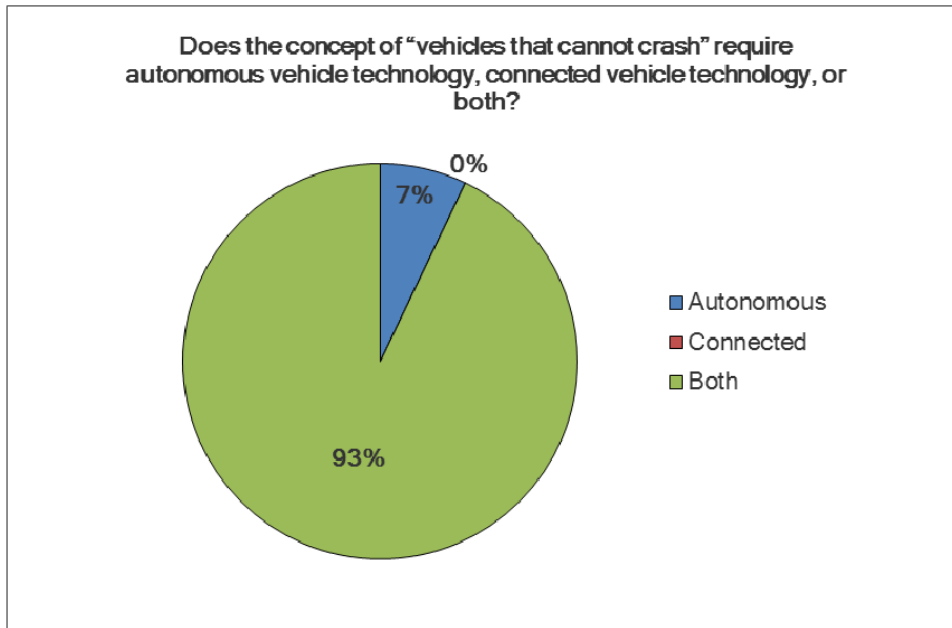


Figure 20: Autonomous vs. Connected Vehicle Technology
Source: CAR 2012

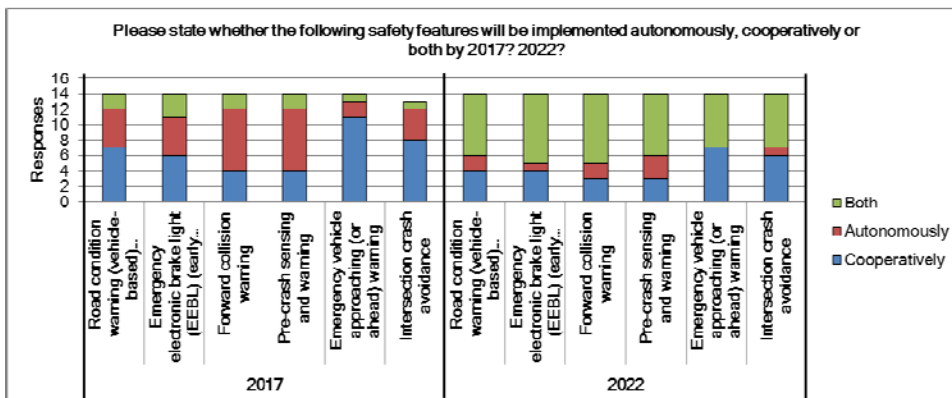


Figure 21: Safety Features and Autonomous vs. Connected Vehicle Technology
Source: CAR 2012

cle technology. In Round Two, infrastructure funding remains the top perceived challenge, followed by vehicle equipment costs and driver distraction (see Figure 19).

AUTONOMOUS TECHNOLOGY

Autonomous technology describes vehicles that operate without drivers and instead use sensors and potentially V2V and V2I applications to navigate their surroundings (Silberg, Wallace et al., 2012). But because this technology does not rely upon other vehicles being equipped with similar communication devices, there is much research happening in this arena. *Google*, for example, has a fully autonomous vehicle that drives on roadways as part of a testing effort, albeit with a human *driver* present in the vehicle in case he or she needs to take control. The survey asked respondents for their thoughts on autonomous vs. connected vehicles, and the majority said that while autonomous vehicles have some benefits, the biggest public benefit would come from autonomous and connected vehicles.

AUTONOMOUS TECHNOLOGY AND SAFETY

Most responses suggest that autonomous vehicle technology can support advanced

safety systems at least partially. A few commented that it would not be able to do all of the things that connected vehicle technology can. Some respondents felt that autonomous vehicle technology is limited in what it can do in that it is too expensive or not advanced enough for real world driving.

AUTONOMOUS VS. CONNECTED VEHICLE TECHNOLOGY

The vast majority of respondents (93%) say the concept of “vehicles that cannot crash” requires both autonomous and connected vehicle technology (see Figure 20).

SAFETY FEATURES AND AUTONOMOUS VS. CONNECTED VEHICLE TECHNOLOGY

The majority of respondents to Round One indicated that the following safety features would likely be implemented through a combination of *both* autonomous *and* connected vehicle technology by 2022 (see Figure 21).

- Road-condition warning
- Emergency electronic brake light
- Forward collision warning
- Pre-crash warning
- Emergency vehicle approaching warning
- Intersection crash avoidance

III. CONCLUSIONS

This report provides an analysis of expert opinions from the automotive and telematics sectors' side of the connected vehicle technology equation. Panelists received two, iterative surveys addressing what they see as the future of connected vehicle technology, including topics such as which technology will be most effective for specific applications, are V2V-only systems desirable, the estimated costs to automakers and consumers of adding connected vehicle technology to vehicles, the role of NHTSA and other governmental mandates, and whether autonomous vehicles offer significant public benefits.

Respondents overwhelmingly agreed that DSRC is needed for cooperative, active safety systems, while 3G and 4G cellular technologies tend to be thought of as appropriate for other applications. Panelists also had a good deal of agreement that DSRC will become standard vehicle equipment by 2017. In 2022, GPS receivers, satellite radios, and Wi-Fi transceivers also are likely to be included as standard equipment, according to the panelists. Mobility and personal convenience applications as brought-in equipment are forecasted to be widely available on new vehicles by 2017, and all applications will be widely available by 2022. The majority think the applications will be built-in by that point.

V2V-only systems are considered valuable, but respondents view a complimentary V2I system as necessary to maximize full public benefits of connected vehicle technology. Respondents also think a V2V system is possible using DSRC technology only, and using another communication technology for V2I systems.

The estimated costs to manufacturers for embedding DSRC, the overall added costs to

base vehicle price to the consumers, and adding DSRC as aftermarket equipment are all higher in 2017 and then drop significantly by 2022. However, the forecasted additional costs to the consumer for adding the technology to a vehicle is the highest at \$350 in 2017 and drops to only \$300 in 2022.

Regarding the NHTSA 2013 Notice of Regulatory Intent on V2V safety systems for vehicles, most respondents expressed the opinion that NHTSA will announce that it does intend to mandate V2V safety. If this proves to be correct, all respondents believe that by 2022 all new vehicles sold in the U.S. will be required to have V2V communication equipment as standard equipment. Respondents are less confident about aftermarket, retrofit mandates, but indicated that, if there is a mandate, the device will likely be broadcast-only or a device not connected to the vehicle's data bus. If NHTSA elects not to mandate a V2V safety system, then respondents hold mixed views on whether automakers will continue to pursue V2V technology for safety systems.

Most respondents do not think many other connected vehicle applications will be mandated by 2017, but a few, such as intersections and higher-alert zones, may be mandated by 2022. Also, respondents do not foresee additional safety mandates coming by 2022.

One of the biggest challenges respondents see to the broad adoption of connected vehicle technology is funding for infrastructure.

Autonomous vehicles have strength, but respondents believe the most significant public benefit will come from a combination of autonomous and connected vehicles.

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APPENDIX A: FIRST- AND SECOND-ROUND INDUSTRY DELPHI SURVEY QUESTIONS

The following pages in this appendix are the survey questions panelists in this study received. The appendix begins with the first round survey, followed by the second round survey.

2012 Connected Vehicle Technology Forecast

Vehicle Communication

1. What percentage of new passenger cars and light trucks sold in North America will have the following component technologies as standard equipment in the years 2017 and 2022?

	Percentage
Global Positioning System (GPS) receiver	<input type="text"/>
Dedicated Short Range Communication (DSRC) transceiver (802.11p)	<input type="text"/>
USB port for connecting consumer electronic products	<input type="text"/>
Wi-Fi transceiver (802.11a, b, g)	<input type="text"/>
3G cellular transceiver	<input type="text"/>
4G cellular transceiver	<input type="text"/>
Satellite radio	<input type="text"/>
Bluetooth radio	<input type="text"/>
Other	<input type="text"/>
Other (please specify)	<input type="text"/>

2. One school of thought concerning the relative capabilities of cellular and DSRC technologies holds that DSRC is needed for cooperative, active safety systems, while 3G and 4G cellular networks can handle just about all other connected vehicle applications. To what extent do you agree with this characterization?

- 1 = Strongly disagree
- 2
- 3
- 4
- 5 = Strongly agree

3. In your opinion, when will embedded DSRC transceivers first be standard equipment on at least 10 percent (10%) of new vehicles sold in the U.S.?

2012 Connected Vehicle Technology Forecast

Connected Vehicle Applications

4. For the following categories of connected vehicle applications, will they be widely available on new vehicles within 5 years (by 2017)? Within 10 years (by 2022)? Also, please indicate whether these categories of applications will work primarily via built-in or brought-in communications hardware.

	2017	Built-in / Brought-in (2017)	2022	Built-in / Brought-in (2022)
Safety	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Mobility	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Environment	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Personal convenience	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Vehicle diagnostics	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Other	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Other (please specify)

5. For the following categories of connected vehicle applications, will vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communication be more important in 2017? In 2022?

	2017	2022
Safety	<input type="text"/>	<input type="text"/>
Mobility	<input type="text"/>	<input type="text"/>
Environment	<input type="text"/>	<input type="text"/>
Personal convenience	<input type="text"/>	<input type="text"/>
Vehicle diagnostics	<input type="text"/>	<input type="text"/>
Other	<input type="text"/>	<input type="text"/>

Other (please specify)

Infrastructure Challenges

6. Please describe the characteristics (e.g., extent, location, etc.) of the DSRC infrastructure that you think are necessary to make in-vehicle installation worthwhile?

7. In your view, is a V2V-only system possible?

8. Whether or not you think it is possible, is a V2V-only system desirable?

2012 Connected Vehicle Technology Forecast

Key Challenges

9. How challenging are each of the following issues to broader adoption of connected vehicle technology?

	Very Challenging	Somewhat Challenging	Neutral	Somewhat unchallenging	Very unchallenging
Personal privacy concerns	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Data security	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Driver distraction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Funding for infrastructure build out	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Vehicle equipment costs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Standards	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

2012 Connected Vehicle Technology Forecast

Technology Costs

10. Per vehicle, what will it cost vehicle manufacturers (in US\$) to add a DSRC radio as embedded equipment in 2017? 2022?

2017

2022

11. What will it add to the base cost (in US\$) of a new vehicle for the consumer in 2017? 2022?

2017

2022

12. What will it cost the consumer (in US\$) to add DSRC as aftermarket equipment in 2017? 2022?

2017

2022

2012 Connected Vehicle Technology Forecast

Connected vs. Autonomous Vehicles

We are interested in your views about how connected vehicle technology (i.e., V2V and V2I communication) will evolve with autonomous vehicle technology (i.e., each vehicle uses only its own sensors).

13. In your view, is autonomous vehicle technology sufficient to support advanced safety applications?

14. Does the concept of “vehicles that cannot crash” require autonomous vehicle technology, connected vehicle technology, or both?

- Autonomous
- Connected
- Both

15. In what year can we expect to see integration of sensor systems (e.g., camera, RADAR, LiDAR) and connected vehicle communication systems?

16. Please state whether the following safety features will be implemented autonomously, cooperatively or both by 2017? 2022?

	2017	2022
Road condition warning (vehicle-based) environmental sensing	<input type="text"/>	<input type="text"/>
Emergency electronic brake light (EEBL) (early notification of lead vehicle braking hard)	<input type="text"/>	<input type="text"/>
Forward collision warning	<input type="text"/>	<input type="text"/>
Pre-crash sensing and warning	<input type="text"/>	<input type="text"/>
Emergency vehicle approaching (or ahead) warning	<input type="text"/>	<input type="text"/>
Intersection crash avoidance	<input type="text"/>	<input type="text"/>

Government Mandates

17. Do you think NHTSA's 2013 notice of regulatory intent will be affirmative (i.e., that it does intend to mandate vehicle-to-vehicle communication systems for safety applications)?

- Yes
- No

18. If NHTSA announces that it does intend to mandate V2V safety technology, how many years will it take for all new light vehicles to be required to have this technology as standard equipment?

- 1 year
- 2
- 3
- 4
- 5 years
- More than 5 years

19. Again, if NHTSA announces that it intends to mandate V2V safety technology, how likely is it that NHTSA will also require existing vehicles to be retrofitted with an aftermarket V2V safety device?

- 1 = Not at all likely
- 2
- 3
- 4
- 5 = Very likely

2012 Connected Vehicle Technology Forecast

20. If NHTSA indicates it does not intend to mandate V2V safety technology, how likely is it that automotive manufacturers will continue to pursue V2V communications for safety systems?

- 1 = Not at all likely
- 2
- 3
- 4
- 5 = Very likely

21. In your view, will the following connected vehicle applications be mandated by 2017? 2022?

	2017	2022
Intersection control violations (i.e., stop sign & signal) (in-vehicle & external)	<input type="text"/>	<input type="text"/>
Stop sign movement assist, violation warning, and highway/rail crossings	<input type="text"/>	<input type="text"/>
Lane/road departure (e.g., electronic speed bumps) requiring roadside equipment	<input type="text"/>	<input type="text"/>
Curve speed warning/rollover warning (infrastructure-based)	<input type="text"/>	<input type="text"/>
Work zone, school zone, exit facility, icy bridges, low underclearance (bridge, parking garage, storage), wrong way warning, road features warning)	<input type="text"/>	<input type="text"/>
Left turn across path and lateral gap acceptance	<input type="text"/>	<input type="text"/>

22. Are there any other noteworthy safety applications that you believe will be mandated by 2017? 2022? Please list them.

2017

2022

Second Round: 2012 Connected Vehicle Technology Forecast

Vehicle Communication

1. In the first round survey, few respondents expressed the opinion that any of the technologies that enable V2X will be standard equipment by 2022. Please review round the 1 results and respond again to the following question.

What percentage of new passenger cars and light trucks sold in North America will have the following component technologies as standard equipment in the years 2017 and 2022?

	2017	2022
Global Positioning System (GPS) receiver	<input type="text"/>	<input type="text"/>
Dedicated Short Range Communication (DSRC) transceiver (802.11p)	<input type="text"/>	<input type="text"/>
USB port for connecting consumer electronic products	<input type="text"/>	<input type="text"/>
Wi-Fi transceiver (802.11a, b, g)	<input type="text"/>	<input type="text"/>
3G cellular transceiver	<input type="text"/>	<input type="text"/>
4G cellular transceiver	<input type="text"/>	<input type="text"/>
Satellite radio	<input type="text"/>	<input type="text"/>
Bluetooth radio	<input type="text"/>	<input type="text"/>
Other	<input type="text"/>	<input type="text"/>

Other (please specify)

2. One school of thought concerning the relative capabilities of cellular and Dedicated Short Range Communication (DSRC) technologies holds that DSRC is needed for cooperative, active safety systems.

To what extent do you agree with this characterization?

- 1 = Strongly disagree
- 2
- 3
- 4
- 5 = Strongly agree

Second Round: 2012 Connected Vehicle Technology Forecast

3. Another school of thought concerning the relative capabilities of cellular and DSRC technologies holds that 3G and 4G cellular networks can handle just about all connected vehicle applications aside from cooperative, active safety. To what extent do you agree with this characterization?

- 1 = Strongly disagree
- 2
- 3
- 4
- 5 = Strongly agree

Connected Vehicle Applications

4. In the 1st round, respondents indicated they think many connected vehicle applications such as Personal Convenience, Mobility, and Vehicle Diagnostics, would be BUILT-IN by 2022. Given that it is currently so easy to bring in mobile devices to perform these functions, why will this trend reverse?

Infrastructure Challenges

5. If NHTSA announces in 2013 that it intends to mandate V2V communications to support cooperative, active safety, what percent of the top 50 metropolitan areas (by population) must deploy some roadside infrastructure to make V2V safety viable?

- | | |
|---------------------------|----------------------------|
| <input type="radio"/> 0% | <input type="radio"/> 60% |
| <input type="radio"/> 10% | <input type="radio"/> 70% |
| <input type="radio"/> 20% | <input type="radio"/> 80% |
| <input type="radio"/> 30% | <input type="radio"/> 90% |
| <input type="radio"/> 40% | <input type="radio"/> 100% |
| <input type="radio"/> 50% | |

6. Is a mandate for aftermarket retrofits of V2V communication required to achieve significant safety benefits by 2022?

- Yes
 No

7. In the 1st round, slightly more than half agreed that a V2V-only system is possible, but that it would be somewhat limited and a V2I system in addition to V2V would offer more functionality.

Given this, can you have a connected vehicle system that includes DSRC only for V2V applications and uses some other technology for V2I applications?

- Yes
 No

Please explain.

Second Round: 2012 Connected Vehicle Technology Forecast

Key Challenges

8. The majority of respondents in Round 1 indicated that funding infrastructure build-out and driver distraction are the primary challenges to broad adoption of connected vehicle technology.

Please rank the top five concerns in terms of how challenging they are to broader adoption of the technology.

	1st	2nd	3rd	4th	5th
Personal privacy concerns	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Data security	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Driver distraction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Funding for infrastructure build out	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Vehicle equipment costs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Second Round: 2012 Connected Vehicle Technology Forecast

Technology Costs

9. In round 1, when asked how much it will cost vehicle manufacturers (in US\$) to add a DSRC radio as embedded equipment, respondents gave a median response of \$175 for 2017 and \$75 for 2022.

Given these medians, please provide your current estimate of how much it will cost vehicle manufacturers (in US\$) to add a DSRC radio as embedded equipment in 2017 and 2022.

2017

2022

10. Regarding what connected vehicle will add to the base cost (in US\$) of a new vehicle for the consumer, the median was \$350 for 2017 and \$300 for 2022.

Given these medians, please provide your current estimate of what connected vehicle technology will add to the base cost (in US\$) of a new vehicle for the consumer in 2017 and 2022.

2017

2022

11. For what connected vehicle will cost the consumer (in US\$) to add DSRC as aftermarket equipment, the median was \$200 for 2017 and \$75 for 2022.

Given these medians, please provide your current estimate of what it will cost the consumer (in US\$) to add DSRC as aftermarket equipment in 2017? 2022?

2017

2022

Second Round: 2012 Connected Vehicle Technology Forecast

Government Mandates

12. The majority of round 1 responses indicated that if NHTSA announces it does intend to mandate V2V safety technology within 5 years, all new light vehicles to be required to have this technology as standard equipment.

More specifically, by which year do you think ALL new vehicles sold in the U.S. will be required to have this technology as standard equipment (if NHTSA intends to mandate it)?

- 2015
- 2016
- 2017
- 2018
- 2019
- 2020
- 2021
- 2022
- 2023
- 2024
- 2025 or later

13. Most 1st round respondents indicated that if NHTSA announces it intends to mandate V2V safety technology, it will be very unlikely that NHTSA will also require existing vehicles to be retrofitted with an aftermarket V2V safety device.

If, however, NHTSA does introduce an aftermarket mandate, what type of vehicle aftermarket device will it be?

- Vehicle awareness (i.e., broadcast-only)
- Device not connected to vehicle's data bus (i.e., cannot perform active safety functions)
- Fully-functioning aftermarket safety device (i.e., not significantly different from embedded device)

Second Round: 2012 Connected Vehicle Technology Forecast

14. For the following question, 1st round responses were mixed. Therefore, please answer again, and explain why you answered as you did.

If NHTSA indicates it does not intend to mandate V2V safety technology, how likely is it that automotive manufacturers will continue to pursue V2V communications for safety systems?

- 1 = Not at all likely
- 2
- 3
- 4
- 5 = Very likely

Please explain.