Connected Vehicle Technology
Local Government Delphi Study

September, 2012

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Table of Contents

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 public needs emerging in this field.

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

- Type of Technology
- Vehicle-to-Vehicle (V2V) vs. Vehicle-to-Infrastructure (V2I) Technology
- Public Sector and Connected Vehicles
- Roadside Infrastructure Needs
- National Highway Transportation Safety Administration (NHTSA) 2013 Notice of Regulatory Intent
- Other Government Policy Implications
- Challenges to Broad Adoption of Technology

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 viewed as appropriate for many other applications. Respondents also indicated that 3G and 4G cellular technology will be the primary communication pipeline for probe data collection, fleet management, commercial and private applications, and asset management, while DSRC will be used for in-vehicle warnings. Respondents also indicated that DRSC is capable of providing traffic incident information.

Most respondents answered that, while a V2V-only system is possible, it is undesirable, because V2V must be combined with V2I systems to maximize public benefit. Nonetheless, V2V systems are seen as easier to implement; therefore, concerted effort will likely have to be made to ensure appropriate V2I systems are also in place. This finding stands out in that the respondents for this survey largely represent public agencies.

According to respondents, the highest priority use of connected vehicle technology for the public sector is crash avoidance. Given that one of the public sectors' main charges is to enhance safety, this is not surprising. Respondents are unsure whether automakers will share sensor data with agencies, but they indicated that a public/private partner-

ship would be the best way to encourage this sharing.

Respondents indicated that DSRC is the likely transmission mode for infrastructure used in urban intersections, and correspondingly, intersection safety is seen as the highest necessity to make in-vehicle installation of DSRC worthwhile. Cellular technology is the more likely transmission mode for urban highways. For a successful national deployment, both Traffic Management Centers and Networked Traffic Signal Systems are viewed as essential by the respondents.

Public sector respondents overwhelmingly think that the potential NHTSA Notice of Regulatory Intent in 2013 will be in the affirmative, and if it is, that it will take five or more years for all vehicles to be required to have the safety technology installed as standard equipment. While they do not believe existing vehicles will be required to have aftermarket retrofits, they concur that not requiring retrofits will significantly degrade overall system performance, because lacking a mandate for retrofits, until there is significant fleet turnover, most vehicles on the road will not have the safety technology for some years after a new vehicle mandate goes into effect. Offering some type of consumer incentive is seen as the best way to encourage drivers to retrofit their own vehicles with the technology. Respondents do not expect federal or state mandates of V2I applications. This, too, may be viewed as limiting overall system performance.

According to the respondents, the biggest challenge to broad adoption of the technology is procuring enough funding to deploy infrastructure along roadways.

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 Communication (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 cooperatively used by other equipped vehicles so that 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 can be used to warn drivers about vehicle about to run a red light, to actively prevent red-light running, and to recommend travel speeds so as to create green waves, among other possible intersection applications.

In addition to safety benefits, connected vehicle technology also helps with traffic operations. Equipped vehicles will serve as traffic probes, communicating information about travel speed to assist in the detection of congestion and incidents. This information can then 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.

To inform the department's connected vehicle activities, the Michigan Department of Transportation (MDOT) asked the Center for Automotive Research (CAR) to perform two Delphi studies to augment previous research done on connected vehicle technology and to provide insights into private- and public-sector views on the future of the technologies. This report focuses on the public sector study and presents both methods used in the study and the findings resulting from it, along with conclusions.

DELPHI SURVEY METHODS

Although several more were asked to and agreed to participate, ultimately seventeen respondents participated in the first round and fifteen participated in the second round of the study. Public sector panelists came from state Departments of Transportation (DOTs), local DOTS, and engineering and other firms that provide services to public-sector agencies. The panelists (respondents) were informed 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:

- American Association of State Highway and Transportation Offices (AASHTO)

- Booz Allen Hamilton
- CalTrans
- HNTB
- Michigan Department of Transportation
- Minnesota Department of Transportation
- National Highway Transportation Safety Administration
- New York Department of Transportation
- Ohio Department of Transportation
- Parsons Brinkerhoff
- Road Commission for Oakland County
- SAIC
- Southeast Michigan Council of Governments
- Texas Department of Transportation
- Transport Canada

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 surveys addressed a broad range of topics, including communication technologies for various applications, possible governmental influence, and roadside infrastructure needed for a successful deployment. Other, more technology-specific topics included appropriate transmission modes at roadside locations, how V2V and V2I systems compare, and which communication pipelines will best serve various applications.

II. PUBLIC SECTOR CONNECTED VEHICLE SURVEY RESULTS

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

TYPE OF TECHNOLOGY

One discussion in the connected vehicle realm is which types of technology best fit which types of applications. Respondents 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 technology tend to be thought of as appropriate for other applications.

DSRC AND COOPERATIVE, ACTIVE SAFETY SYSTEMS

More than 90 percent of respondents expressed the view that DSRC is needed for cooperative, active safety systems, as shown in Figure 1.

3G AND 4G FOR ALL OTHER APPLICATIONS

As Figure 2 shows, while the consensus is not as firm as with DSRC and safety systems, 63 percent of respondents agree or strongly agree that 3G and 4G cellular technology can handle other connected vehicle applications, while only 19% disagree.

DSRC AND TRAFFIC INCIDENT INFORMATION

Responses from the first round were split regarding whether DSRC-based connected vehicle systems will support the required two-way communication systems to deliver traffic incident information and similar public warnings to the vehicle. When asked again in the second round, however, respondents were more definitive that they think DSRC will at least be capable of providing traffic incident information. (See Figure 3.)

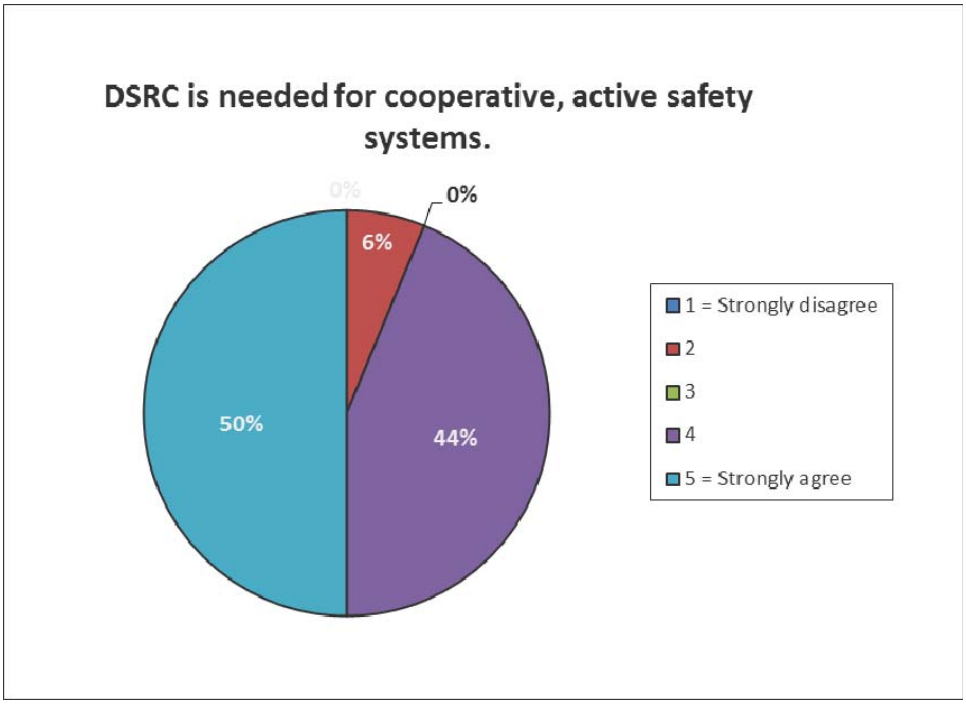

Figure 1: DSRC Needed for Cooperative, Active Safety Systems
Source: CAR 2012

COMMUNICATION TECHNOLOGY AND PRIMARY COMMUNICATION PIPELINE BETWEEN VEHICLES AND INFRASTRUCTURE

Respondents see 3G and 4G cellular technology as the primary communication pipeline for probe data collection, fleet management, commercial and private applications, and asset management (see Figure 4). DSRC is primarily thought of for in-vehicle warnings, and radio frequency identification (RFID) technology is thought best for tolls and electronic payments.

As Figure 5 shows, in 2022, the major difference that respondents see is that DSRC and cellular technology will have an increased

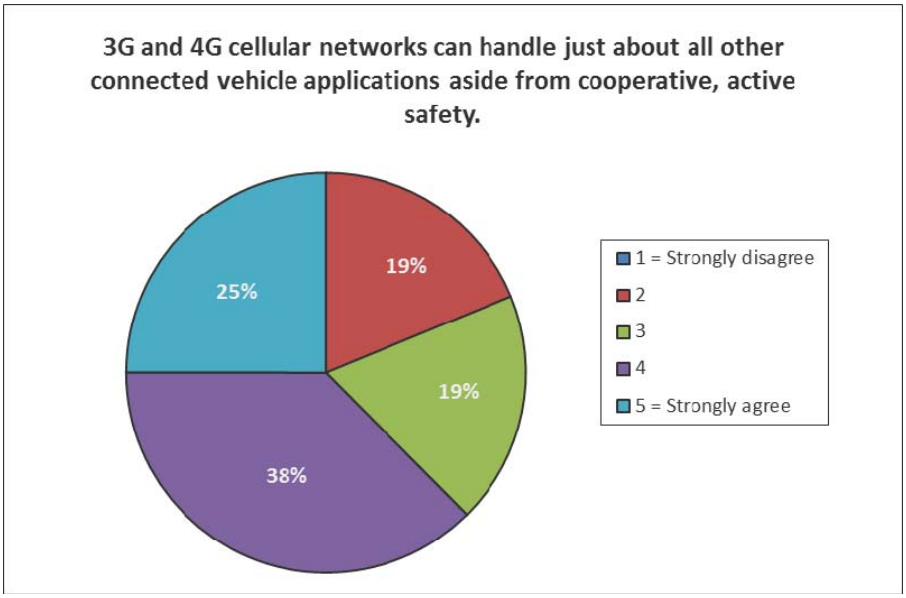

Figure 2: 3G and 4G for All Other Applications
Source: CAR 2012

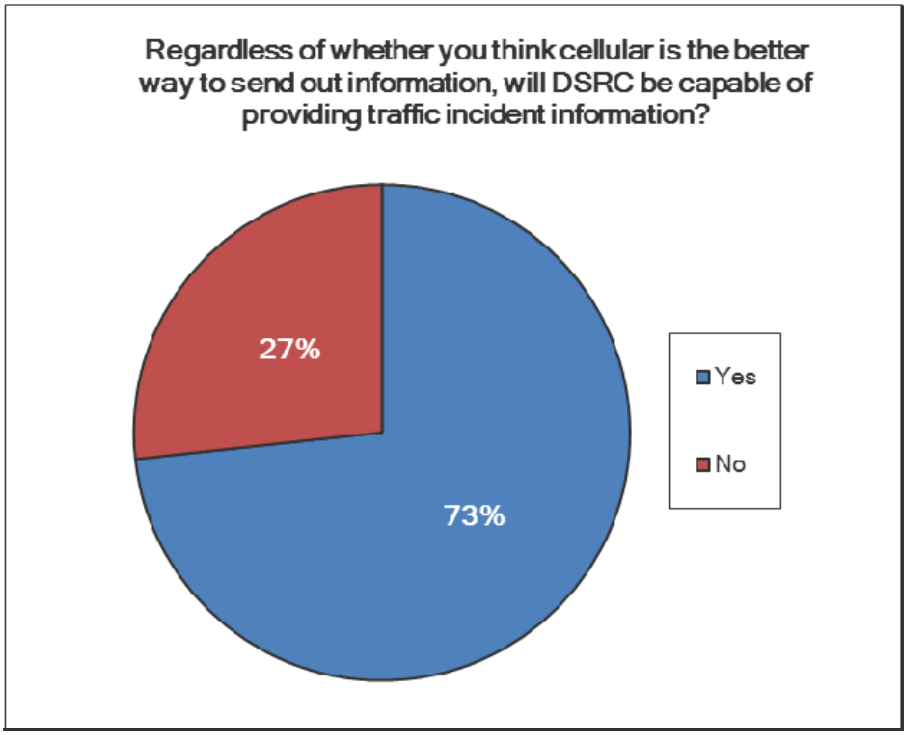

Figure 3: DSRC and Traffic Incident Information
Source: CAR 2012

role in tolls and electronic payments.

CONNECTED VEHICLE TECHNOLOGY AND BACKHAUL OPTIONS

The majority of respondents agree or strongly agree that connected vehicle technology will be sufficiently flexible to allow a variety of communication backhaul options (e.g., fiber optic, cellular, other wireless etc.), as shown in Figure 6.)

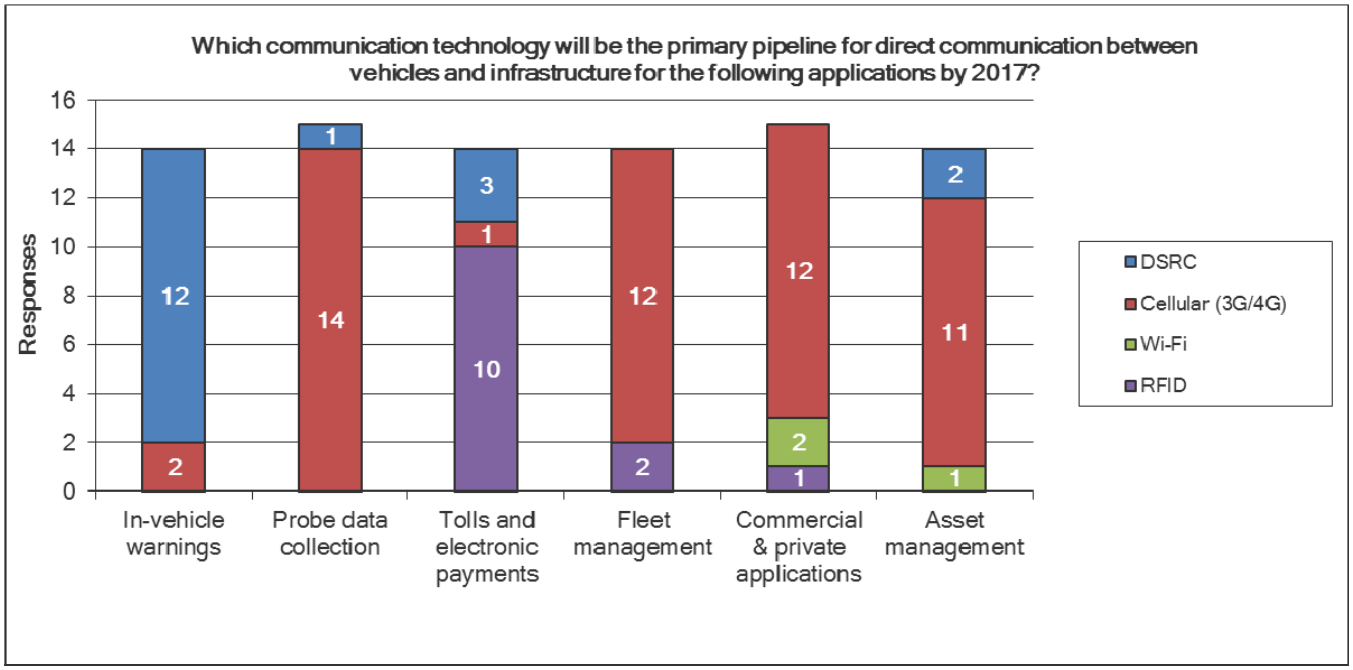

Figure 4: Communication Technology and Primary Communication Pipeline in 2017
Source: CAR 2012

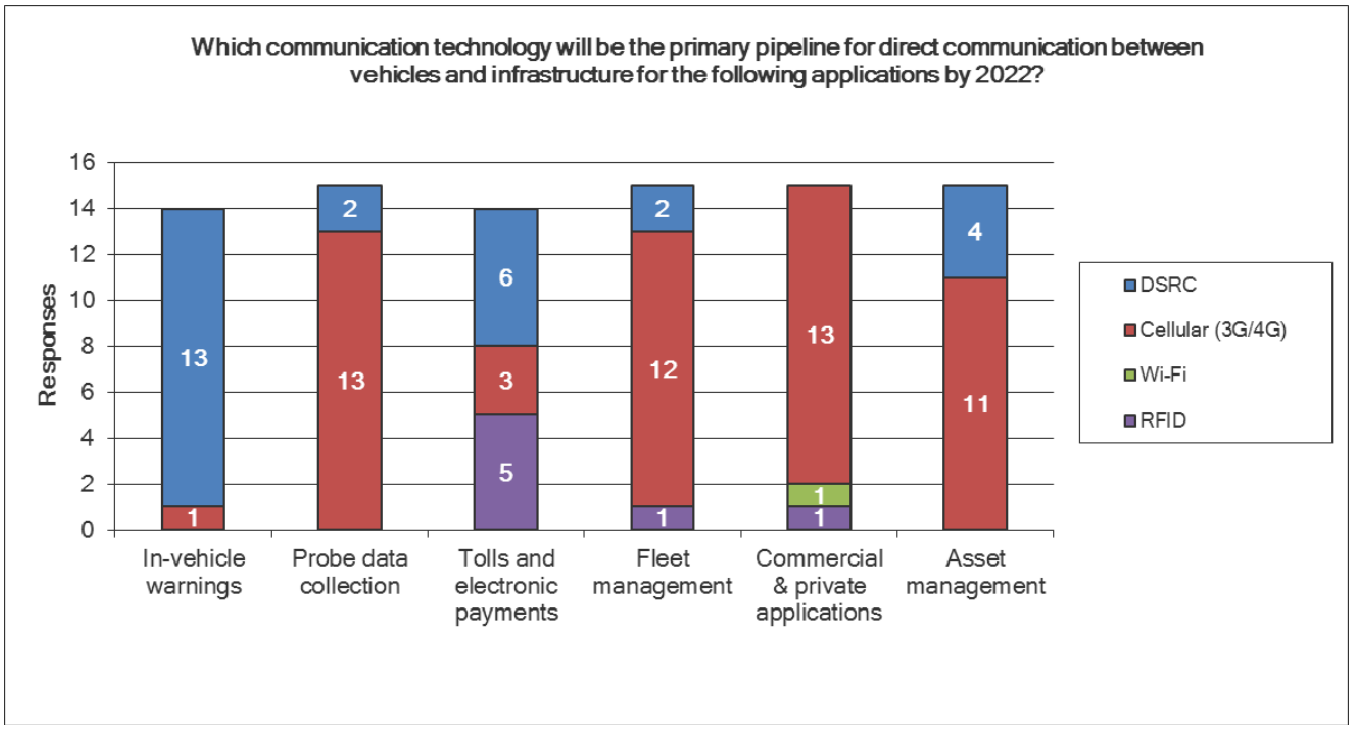

Figure 5: Communication Technology and Primary Communication Pipeline in 2022
Source: CAR 2012

V2V VS. V2I TECHNOLOGY

Another discussion in the connected vehicle realm is which is most valuable and realistic: vehicle-to-vehicle (V2V) communication, whereby vehicles communicate directly with each other, or vehicle-to-infrastructure (V2I) communication, whereby vehicles communicate with roadside infrastructure. Most respondents indicated that V2V and V2I working cooperatively is the best system to maximize public good.

V2V-ONLY SYSTEM

Respondents were asked whether a V2V-only system is possible, and 63 percent replied that yes, it is, but 88 percent indicated that such a system is not desirable. (See Figures 7 and 8.)

V2V-only is undesirable, because it cannot extend the same benefits as a combined V2V/V2I system. Some respondents state that if V2I is not taken up by public sector, V2V-only will be deployed by automakers, and V2I will be difficult since no one agency controls all the infrastructure and a NHTSA mandate will not require V2I applications on the vehicle.

In addition, with the current funding constraints, unknown infrastructure performance, and operational requirements, deployment of V2V-only seems to be the simplest approach, even if it is not the most beneficial. Some respondents believe that some infrastructure is needed for the security component of the V2V system, but others suggest that this could be done using another system such as cell phone networks or secure Wi-Fi connections.

V2V AND V2I AND APPLICATIONS

In the first-round survey, respondents were asked whether V2V or V2I communication will be more important for a variety of applications in 2017 and 2022. Open-ended responses indicated we should address two more applications; therefore, in the second round, we asked about those two specifically. The combined responses are shown in Figure 9. The public sector respondents clearly think V2I is more important for most applications, both in 2017 and 2022. The one exception to this is for safety applications; for these, for both years, V2V is viewed as more

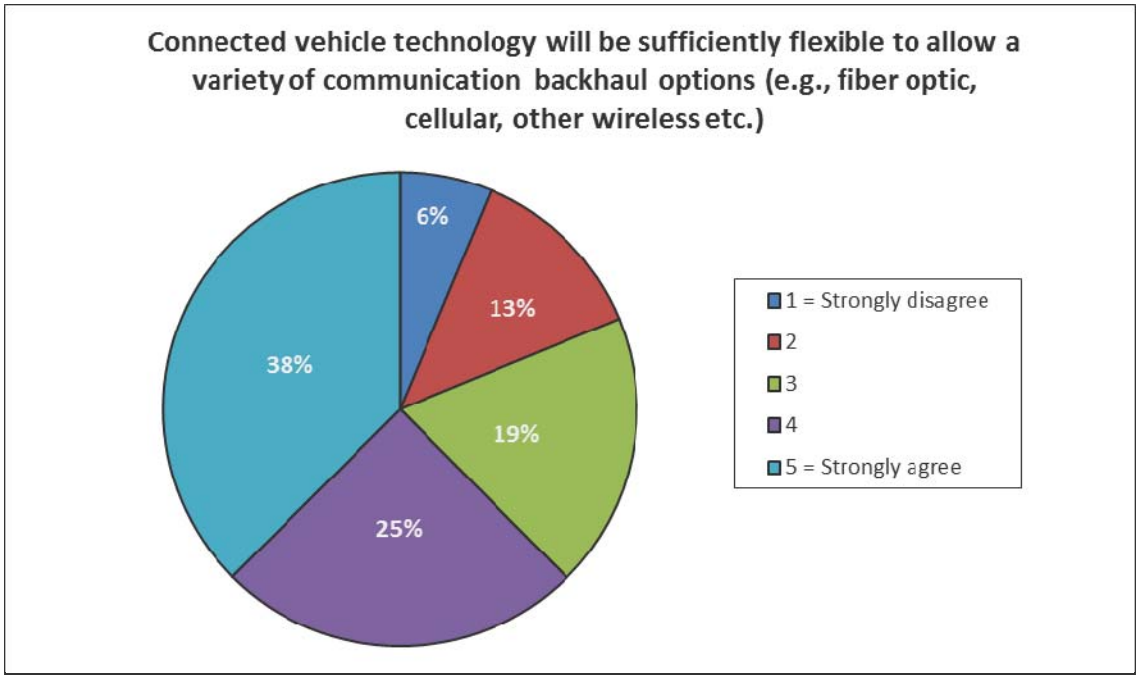

Figure 6: Connected Vehicle Technology and Backhaul Options
Source: CAR 2012

important.

V2I TECHNOLOGY IMPLEMENTATION

As Figure 10 shows, respondents believe more connected vehicle technology features will be implemented via V2I technology as time goes on. In 2017, the only features that about half of respondents thought would be implemented with V2I were road condition warnings and traveler information. Conversely, by 2022, the majority of respondents indicate that all features will be im plemented via V2I technology. Thus, they see a gradual evolution toward greater reliance on V2I technology over time.

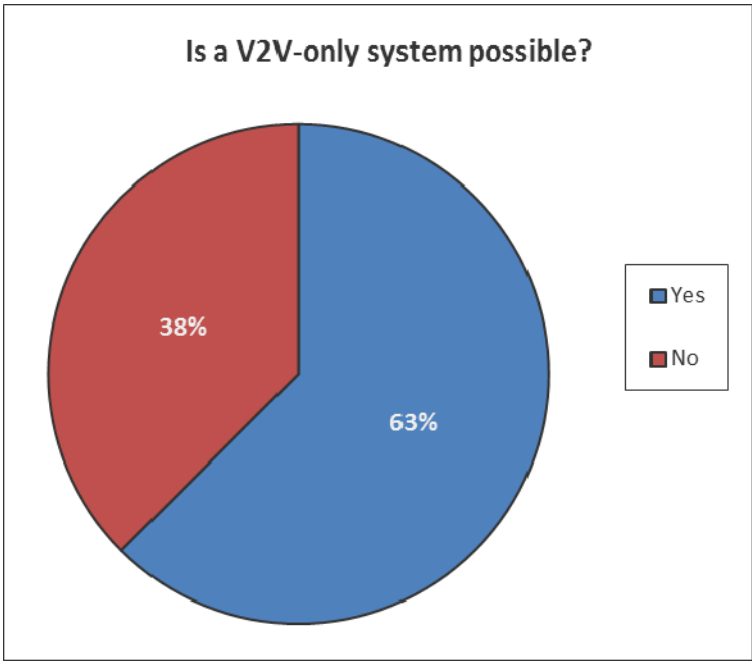

Figure 7: V2V-Only System Possibility
Source: CAR 2012

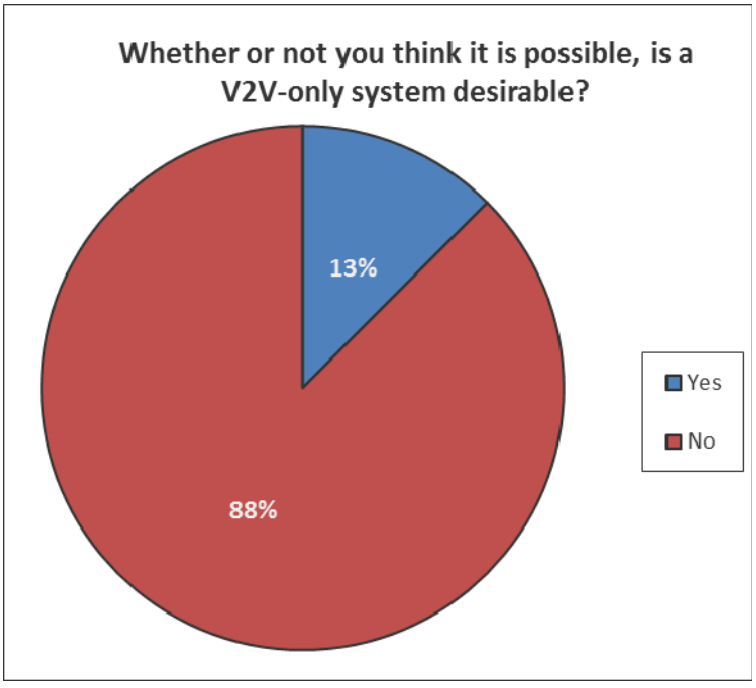

Figure 8: V2V-Only System Desirability
Source: CAR 2012

PUBLIC SECTOR AND CONNECTED VEHICLE TECHNOLOGY

The public sector faces some unique challenges and goals when it comes to connected vehicle technology, as described below. Not surprisingly, the highest priority use of connected vehicle technology for most public sector respondents was safety-related, specifically crash avoidance.

HIGHEST PRIORITY USES OF CONNECTED VEHICLE TECHNOLOGY FOR THE PUBLIC SECTOR

Respondents indicated that the highest priority use of connected vehicle technology for the public sector is crash avoidance. Traffic management and then asset management follow, as Figure 11 shows.

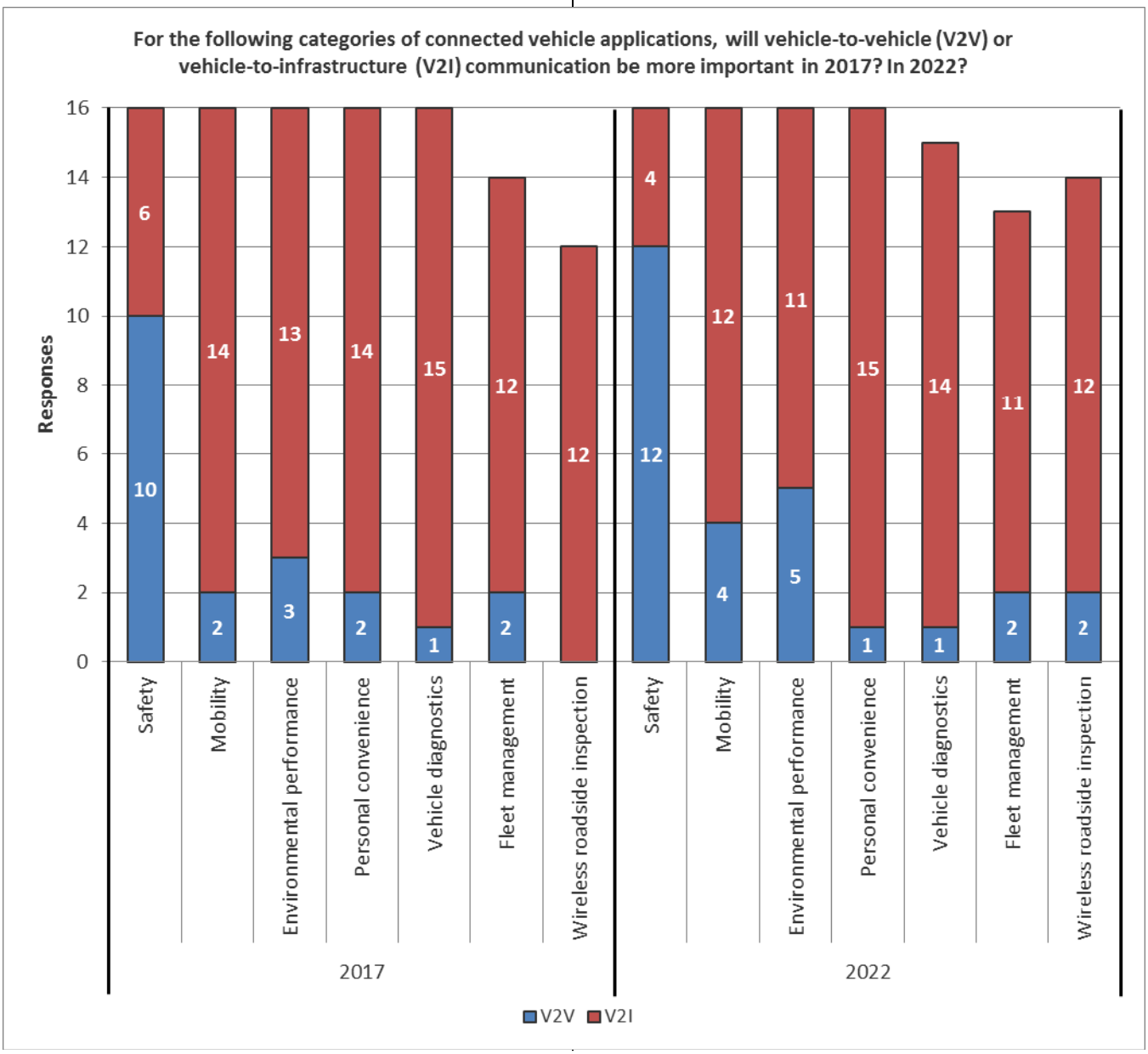

Figure 9: V2V and V2I and Applications
Source: CAR 2012

SHARING DATA WITH PUBLIC AGENCIES

First-round responses were mixed as to whether automakers would share vehicle sensor data with public agencies to support public applications and services, such as asset management and road weather information. In the second round, respondents were asked which approaches might encourage automakers to share these data. Respondents were encouraged to select all that apply, and as Figure 12 shows, most think a public/private partnership would best encourage data sharing, followed by a mandate.

DOT COST SCHEMES TO OBTAIN PROBE DATA

In general, respondents expressed the view that DOTs will have to pay for data. Respondent answers suggest that a data quantity-based fee is the most likely scenario to obtain probe data from aggregators and resellers. But 20 percent of respondents also saw the potential for a flat service fee, and 20 percent thought there may be no charge. Other written-in responses included the possibility for a flat fee for basic data with incremental increases for additional information, that users will likely buy information rather than data, and that the price will be based on quantity and frequency. Figure 13 displays these results.

ROADSIDE INFRASTRUCTURE NEEDS

Connected vehicle technology infrastructure along the roadside is of particular importance to the public sector as DOTs will likely be responsible for installing it. Respondents primarily think DSRC technology is the most likely to be used for urban intersections, and intersection safety is one of the primary benefits to make in-vehicle installation of DSRC worthwhile.

TRANSMISSION MODES AT ROADSIDE LOCATIONS

As Figure 14 shows, respondents think DSRC is most likely for urban intersections, and cellular technology is most likely for urban highways. Responses were less concrete for the transmission mode at toll roads,

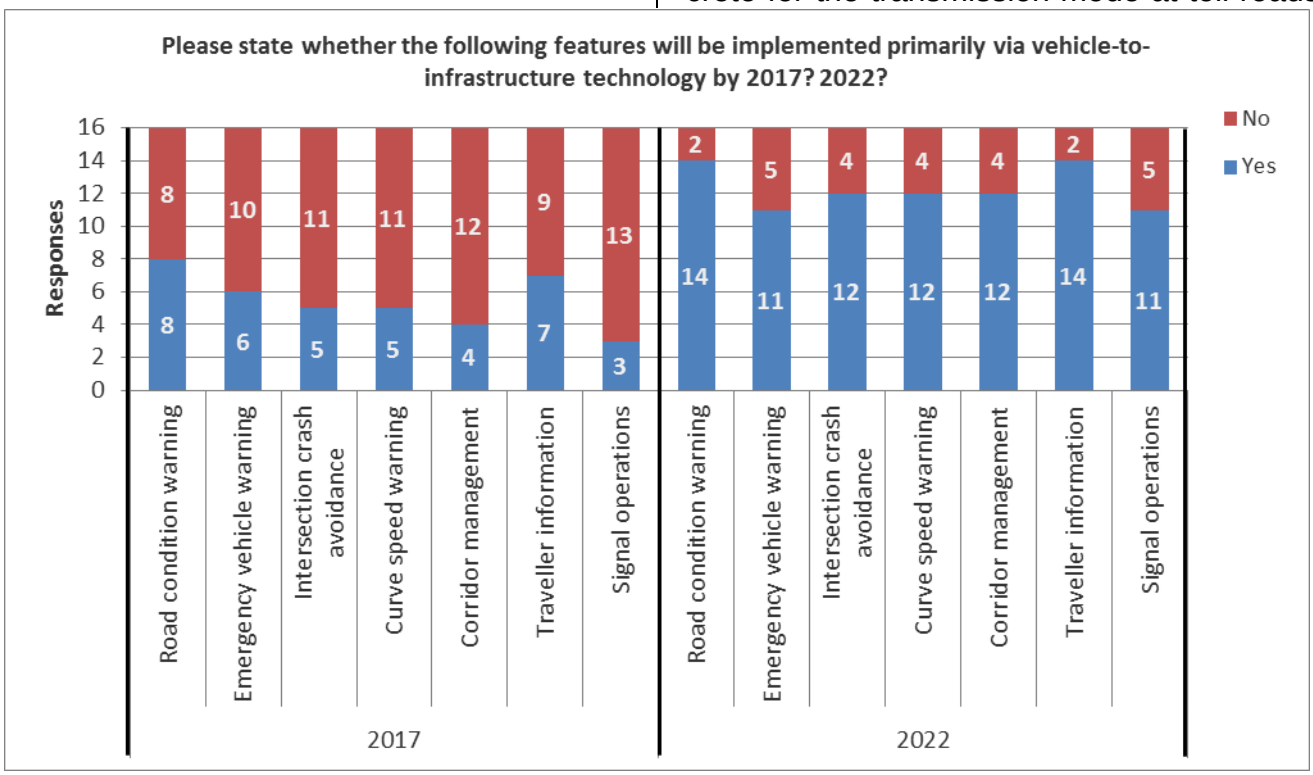

Figure 10: V2I Technology Implementation
Source: CAR 2012

though a slight majority indicated that it will be RFID.

BLUETOOTH TECHNOLOGY AND PROBE DATA

A slight majority of respondents, 53 percent, believe that Bluetooth technology deployed along the roadside would be somewhat useful for collecting traffic probe information. But in general, there is not much certainty that the technology would be a benefit. (See Figure 15.)

DSRC INFRASTRUCTURE NEEDED FOR IN-VEHICLE INSTALLATION

In the first round, respondents were asked to describe the characteristics (e.g., extent, location, etc.) of the DSRC infrastructure that they think are necessary to make in-vehicle installation of DSRC worthwhile. Several items were mentioned, but the most common responses dealt with intersection safety,

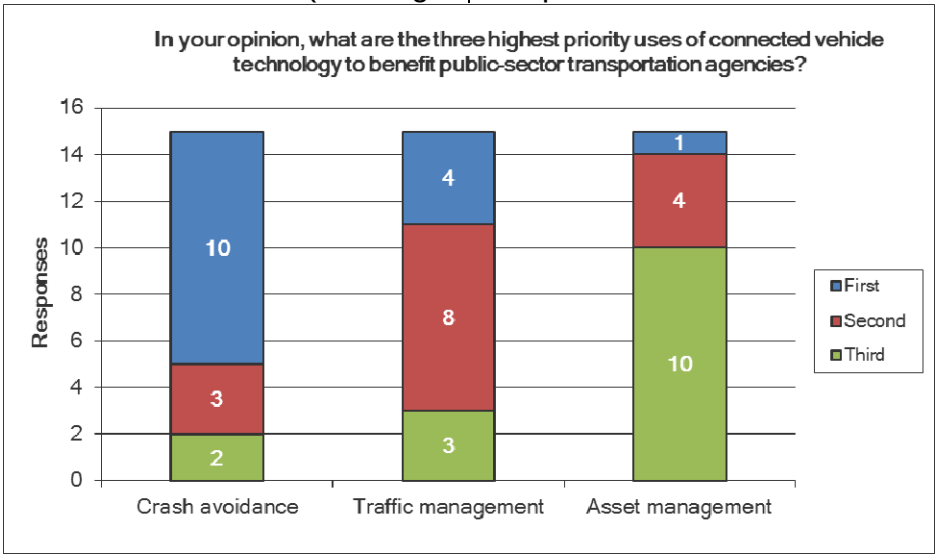

Figure 11: Highest Priority Uses of Connected Vehicle Technology for the Public Sector
Source: CAR 2012

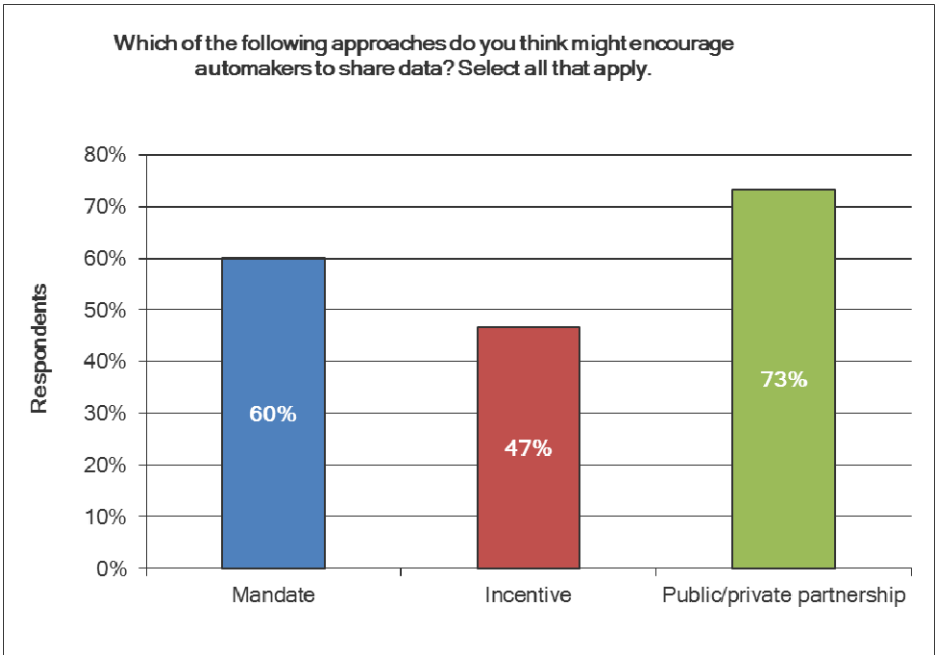

Figure 12: Sharing Data with Public Agencies
Source: CAR 2012

safety at select non-intersection areas, such as curves and road construction, and network security. When asked about these three items in the second round, intersection safety was deemed most important, followed by network security and then safety at select non-intersection areas. Figure 16 displays these results.

TRAFFIC MANAGEMENT SYSTEMS NECESSARY FOR SUCCESSFUL NATIONAL DEPLOYMENT

In the first round, respondents were asked the extent to which they agree with the following statement:

- Further development of the following traffic management systems are essential to a successful national deployment of connected vehicle technology.
  - o Roadside and/or embedded highway sensors
  - o Roadside video cameras
  - o Traffic management centers
  - o Networked traffic signal systems
  - o Electronic toll collection systems

As Figure 17 displays, there was general agreement that Traffic Management Centers (TMCs) and Networked Traffic Signal Systems are essential to national deployment, but roadside sensors and videos are not.

In the second round survey, respondents were asked the extent to which they agree that, despite V2I, TMCs and Networked Traffic Signal Systems are essential to a successful national deployment of connected vehicle technology. Respondent answers indicate that both are necessary to achieve the national deployment goal (see Figure 18).

NHTSA REGULATORY DECISION

One of the most impactful decisions on the horizon is whether or not the National Highway Safety and Transportation Administration (NHTSA) will announce its intent 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, though it will take several years for the regulatory process to play out. Although NHTSA has announced that it will make a Notice of Regulatory Intent (NRI) about this in 2013, the direction of the notice

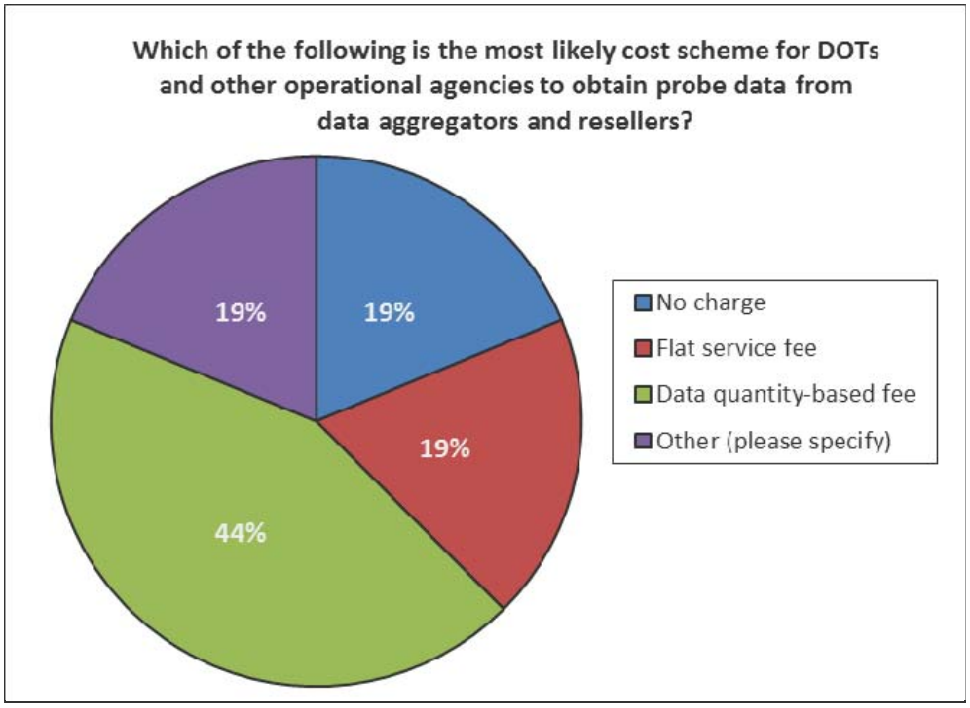

Figure 13: DOT Cost Schemes to Obtain Probe Data
Source: CAR 2012

is not known at this time, and the agency also might delay its decision. Never announcing a decision at all would be a de facto no.

NHTSA MANDATE

Respondents overwhelming think that NHTSA's likely NRI will be in the affirmative (i.e., that it does intend to mandate V2V safety technology), as shown in Figure 19.

YEARS FOR ALL VEHICLES TO HAVE TECHNOLOGY AS STANDARD EQUIPMENT

The majority of respondents (88 percent) indicated that, if NHTSA announces that it does intend to mandate safety technology, it will take five or more years for all new vehicles to be required to have the technology as standard equipment (see Figure 20).

MANDATING EXISTING VEHICLES TO BE RETROFIT WITH TECHNOLOGY

Respondents indicated that it is highly unlikely that, even if NHTSA mandates safety technology, it will also require existing vehicles to be retrofitted with an aftermarket device. (See Figure 21.)

Despite this view, respondents strongly believe that not requiring vehicle retrofits of connected vehicle technology will cause degradation of system performance. Seventy-one percent expressed the view that this degradation would be significant, and the remaining 29 percent responded that it would be moderate. No respondents answered that it would be slightly or not at all degrading to system performance. (See Figure 22.)

ENCOURAGING CURRENT OWNERS TO RETROFIT VEHICLES

By selecting all that apply respondents were asked the best ways to encourage customers to voluntarily retrofit their vehicles should a NHTSA notice of regulatory intent be affirmative. Figure 23 shows clearly that respondents view consumer incentives as the best encouragement to make this happen. Those who selected Other specified primarily con-

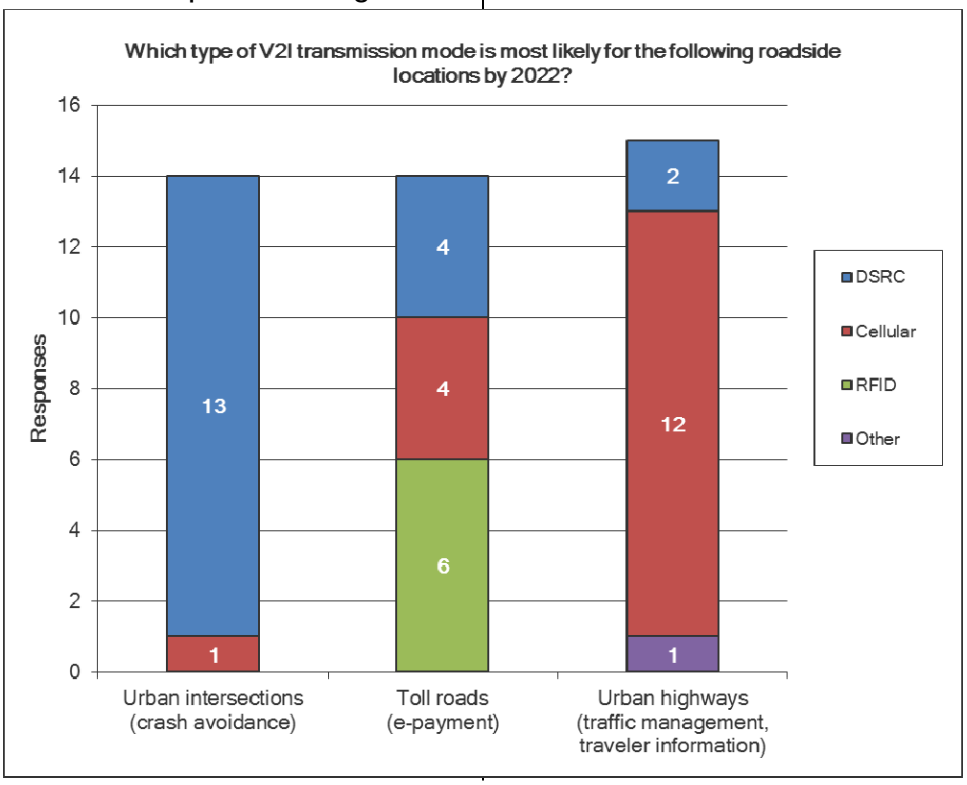

Figure 14: Transmission Modes at Roadside Locations
Source: CAR 2012

sumer incentives, though they often specified features rather than direct monetary compensation (e.g., insurance cost reduction, telematics/geo-location services and applications that users want, HOV access, and free retrofits). One respondent suggested a regulation requiring basic safety messaging abilities along with license renewal.

LIKELIHOOD OF AUTOMAKER PURSUIT OF V2V TECHNOLOGY

Respondents were split on issue of whether or not automakers will continue to pursue V2V technolog y development if NHTSA choices not to mandate V2V safety technology. As Figure 24 shows, none thinks it is very likely that the auto industry would continue, but the remaining responses were spread relatively evenly over the other four categories. Though 47 percent are on the unlikely side, there is no clear majority for either likely or not.

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 V2I applications will be mandated at a federal or state level.

FEDERAL MANDATES FOR V2V APPLICATIONS

First round responses showed a general consensus that, by 2017, no connected vehicle applications will be mandated, but responses were mixed for whether they will be mandated in 2022. When asked again in the second round whether they foresee federal mandates for V2I applications by 2022, 57 percent of respondents said no. (See Figure 25.)

STATE MANDATES FOR V2I APPLICATIONS

A stronger majority (64 percent) of respondents indicated that state-level mandates for V2I applications were even less likely by 2022, as shown in Figure 26.

CHALLENGES TO BROAD ADOPTION

Several potential challenges impede broad adoption of connected vehicle technology.

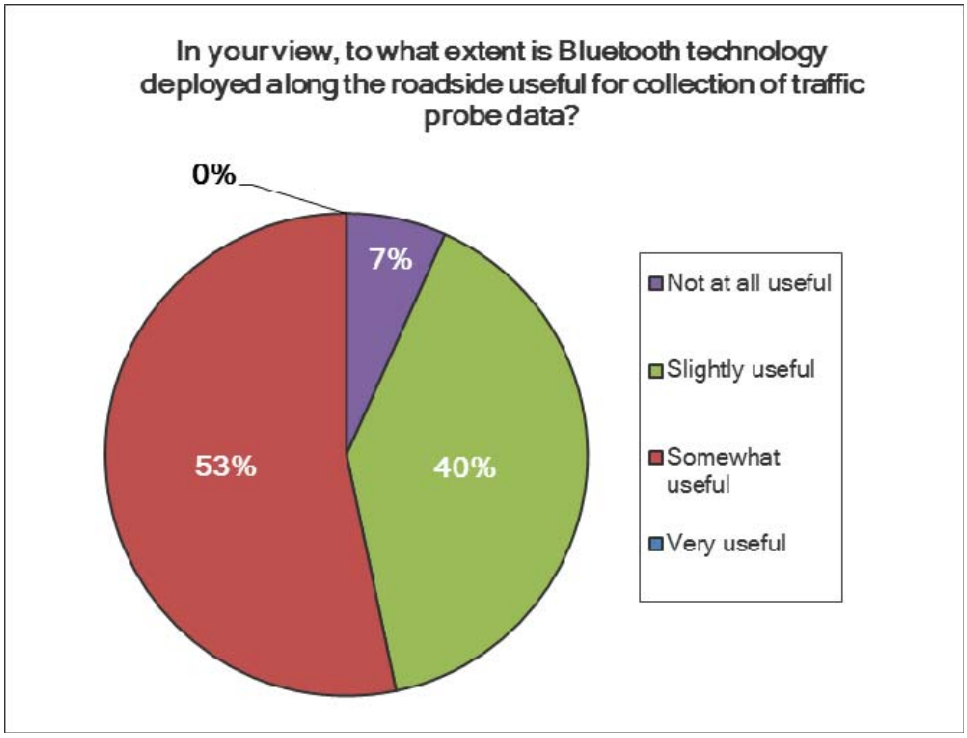

Figure 15: Bluetooth Technology and Probe Data
Source: CAR 2012

Infrastructure funding is at the top of the public sector's list of the most important ones.

CHALLENGES TO BROAD ADOPTION OF CONNECTED VEHICLE TECHNOLOGY

The biggest challenge to broad adoption is seen as finding sufficient funding for roadside infrastructure. This is followed by concerns of driver distraction and maintaining proper system functionality (See Figure 27)

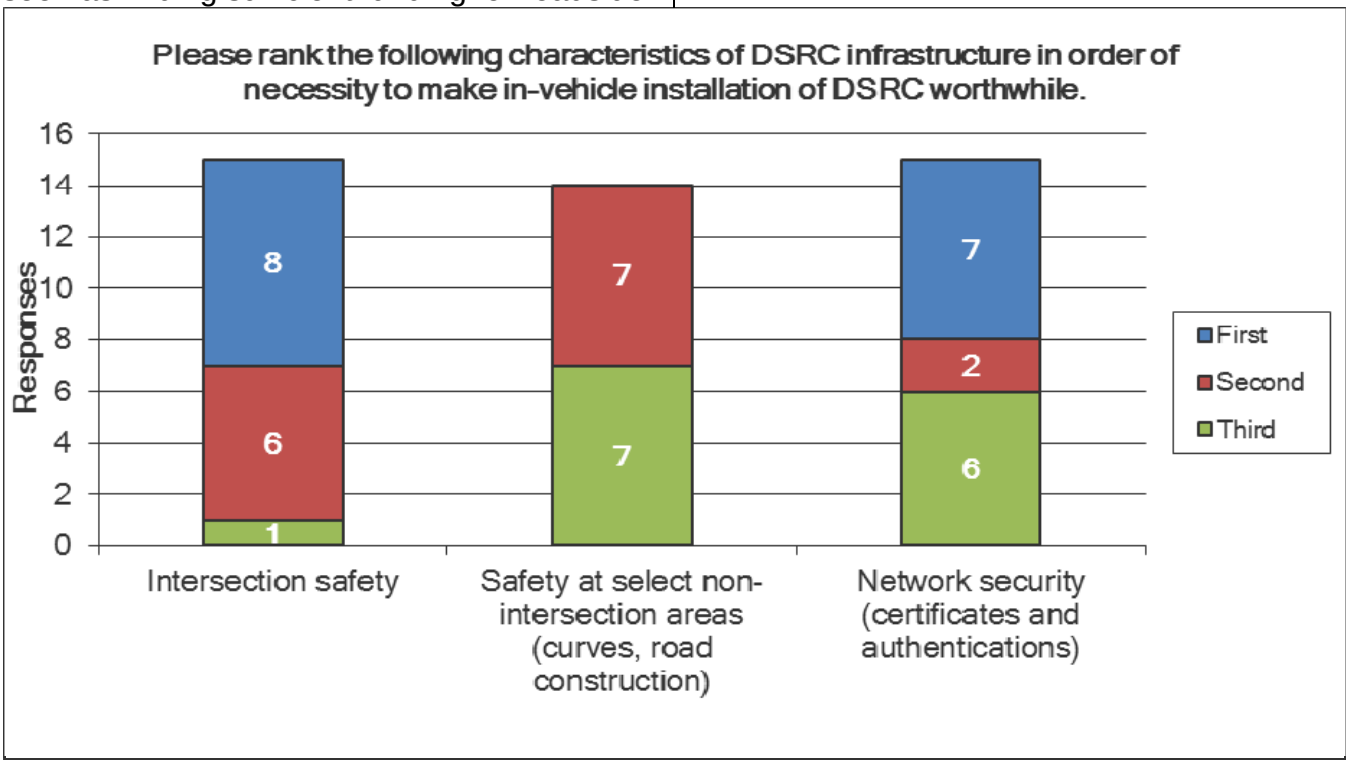

Figure 16: DSRC Infrastructure Needed for In-Vehicle Installation
Source: CAR 2012

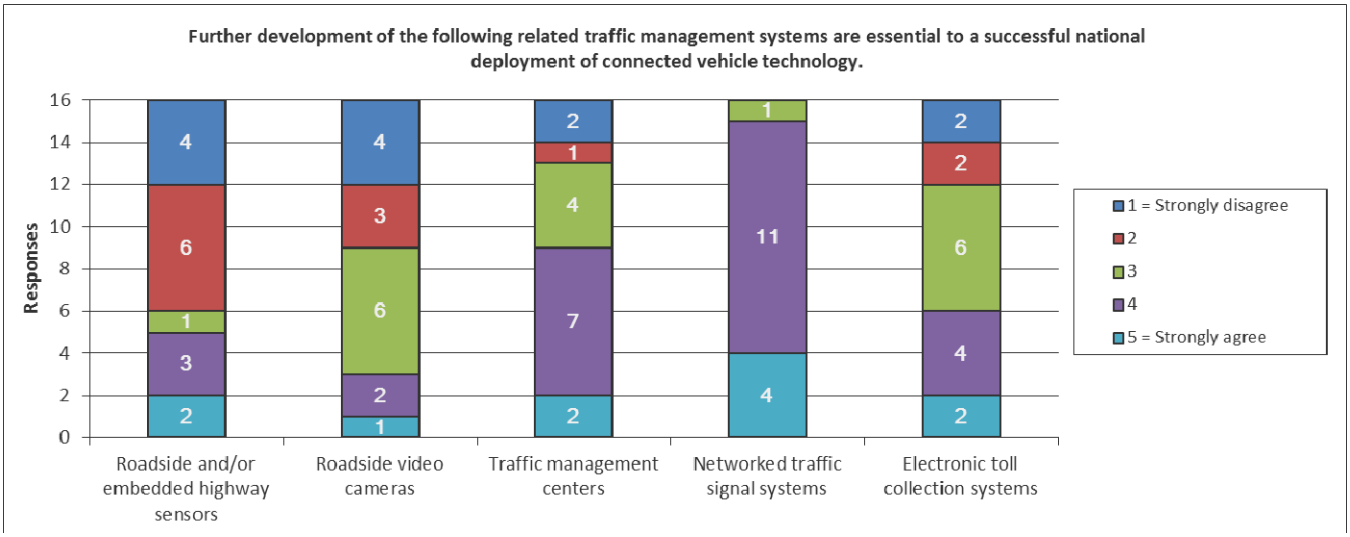

Figure 17: Traffic Management Systems Necessary for Successful National Deployment
Source: CAR 2012

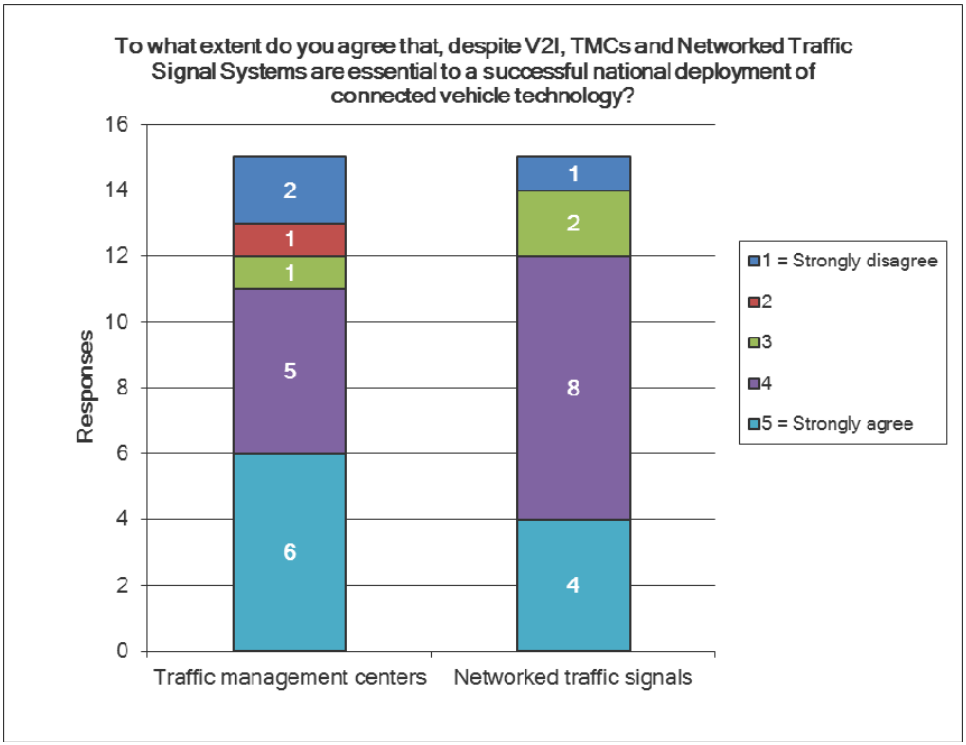

Figure 18: TMCs and Networked Traffic Signal Systems
Source: CAR 2012

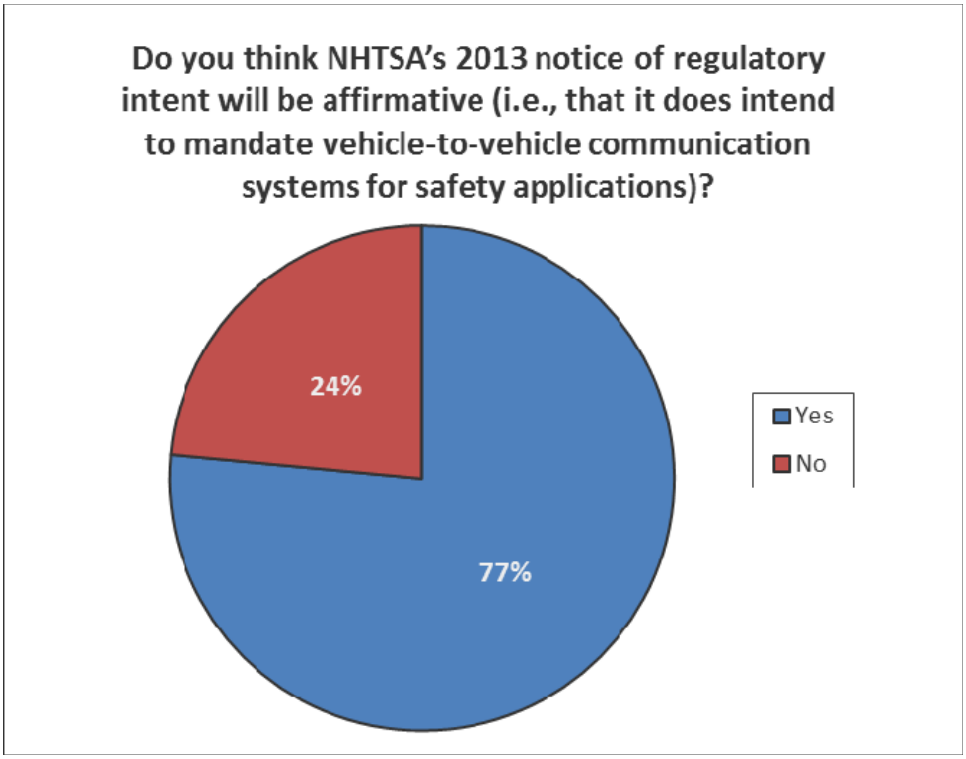

Figure 19: NHTSA NRI on V2V Technology for Safety
Source: CAR 2012

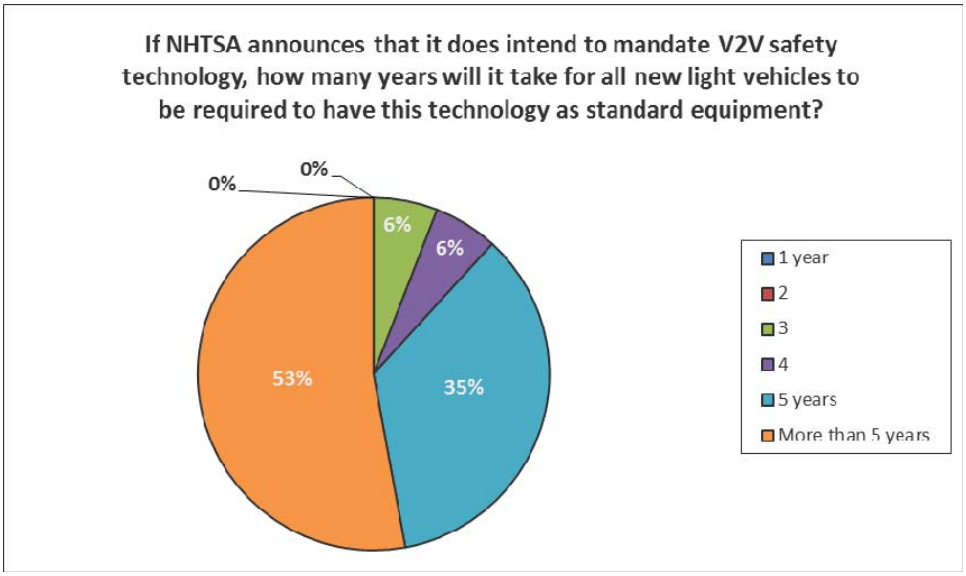

Figure 20: Years for All Vehicles to Have Technology as Standard Equipment
Source: CAR 2012

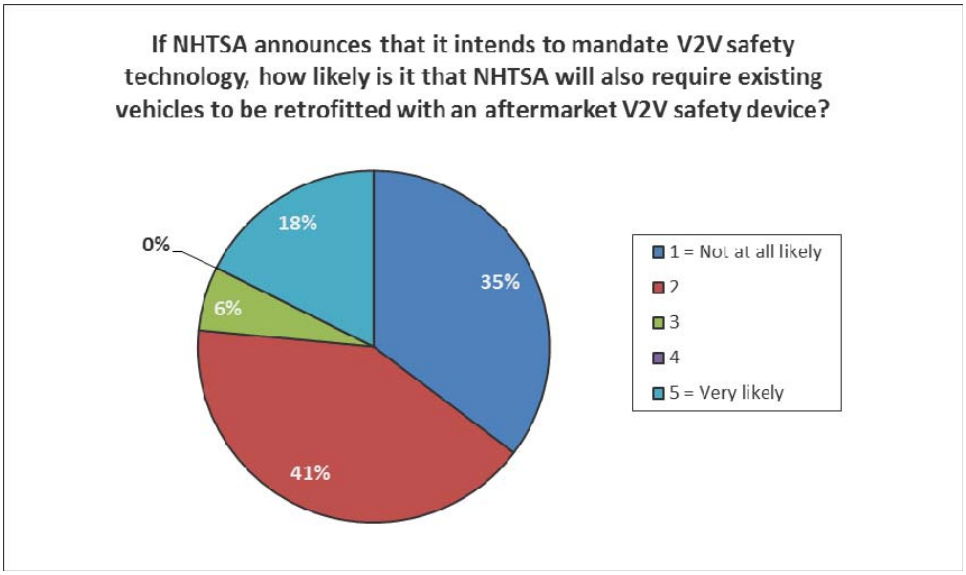

Figure 21: Existing Vehicle Retrofit Requirement
Source: CAR 2012

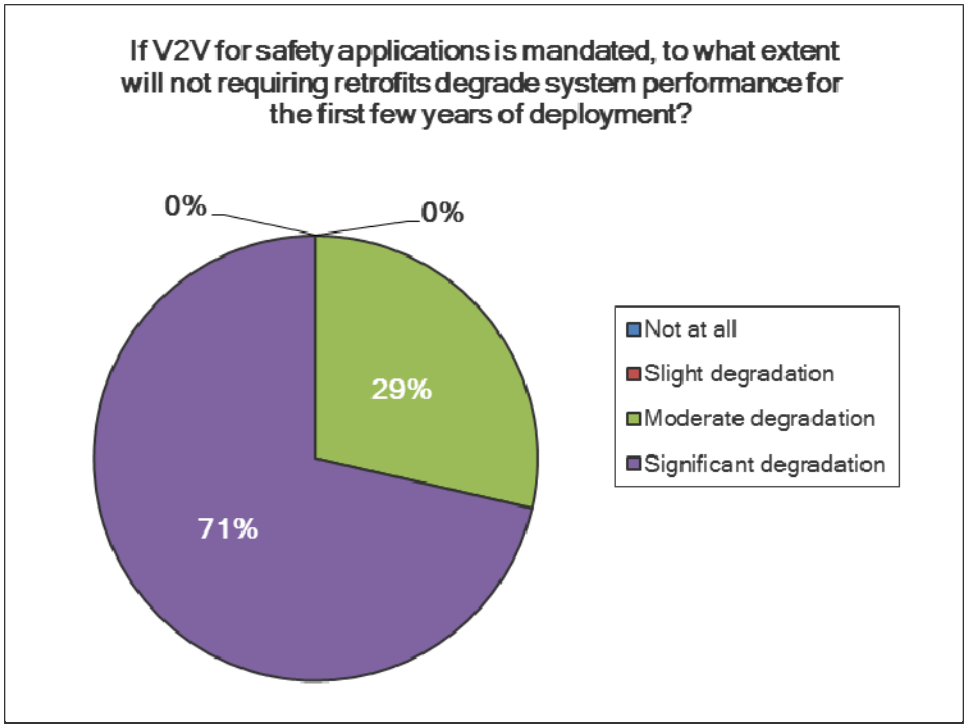

Figure 22: Possible System Degradation without Vehicle Retrofits
Source: CAR 2012

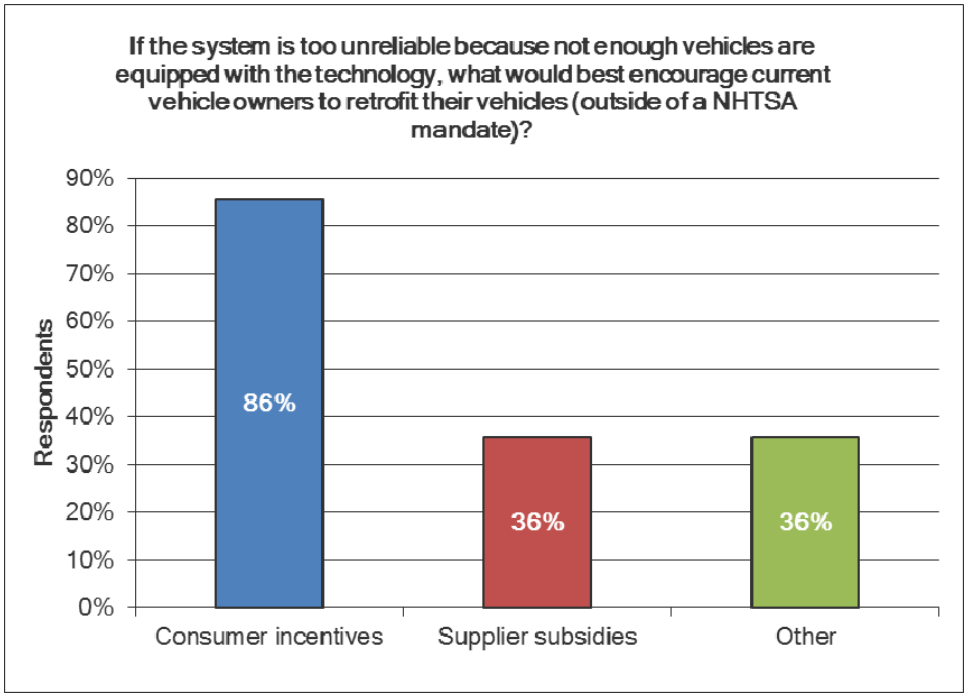

Figure 23: Encouraging Current Owners to Retrofit Vehicles
Source: CAR 2012

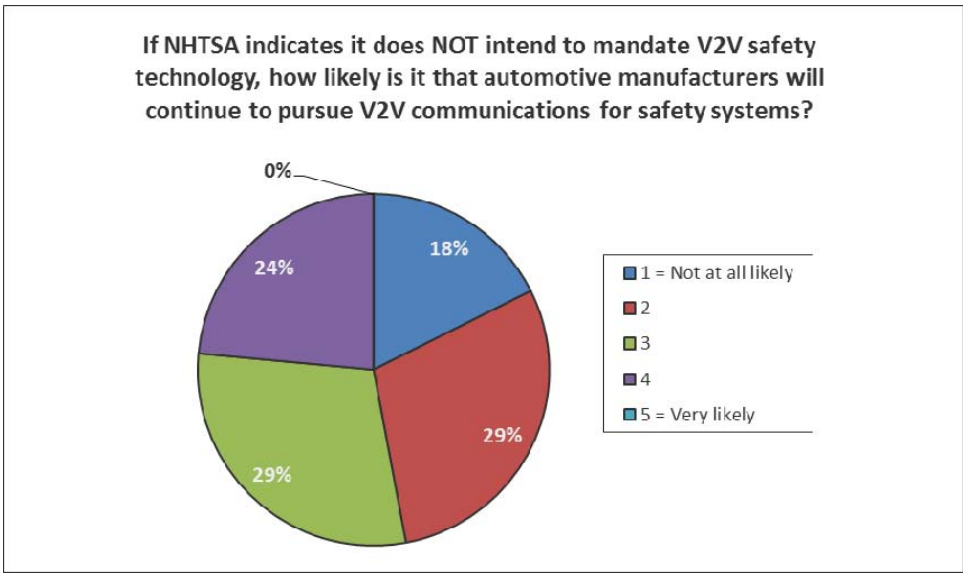

Figure 24: Likelihood of Automaker Pursuit of V2V Technology
Source: CAR 2012

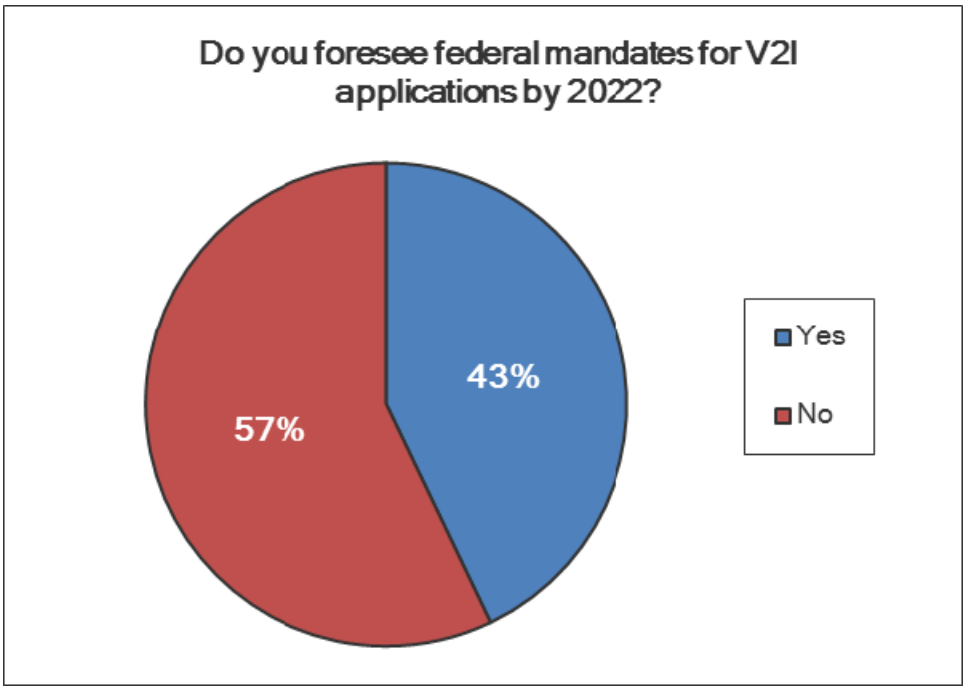

Figure 25: Federal Mandates for V2I Applications
Source: CAR 2012

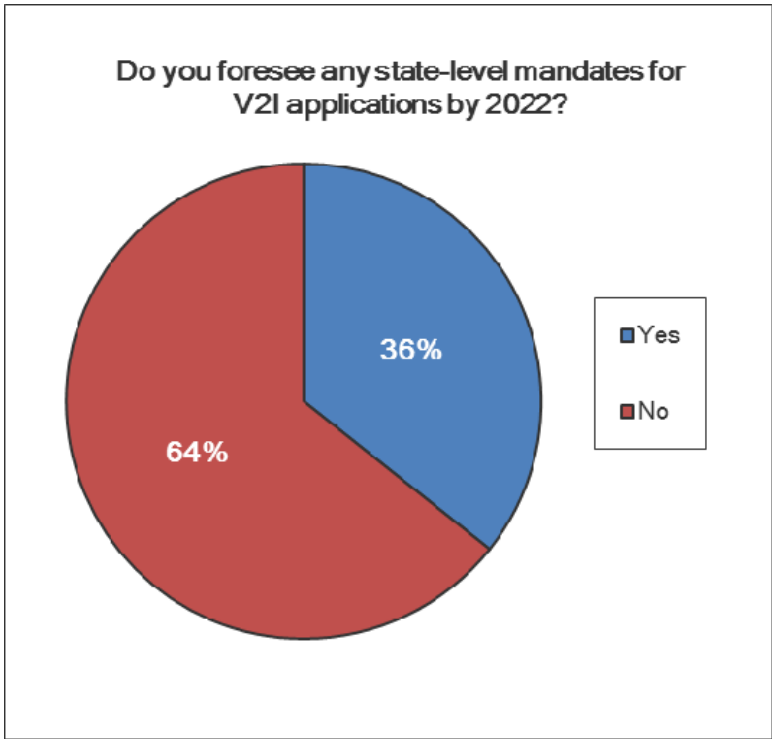

Figure 26: State Mandates for V2I Applications
Source: CAR 2012

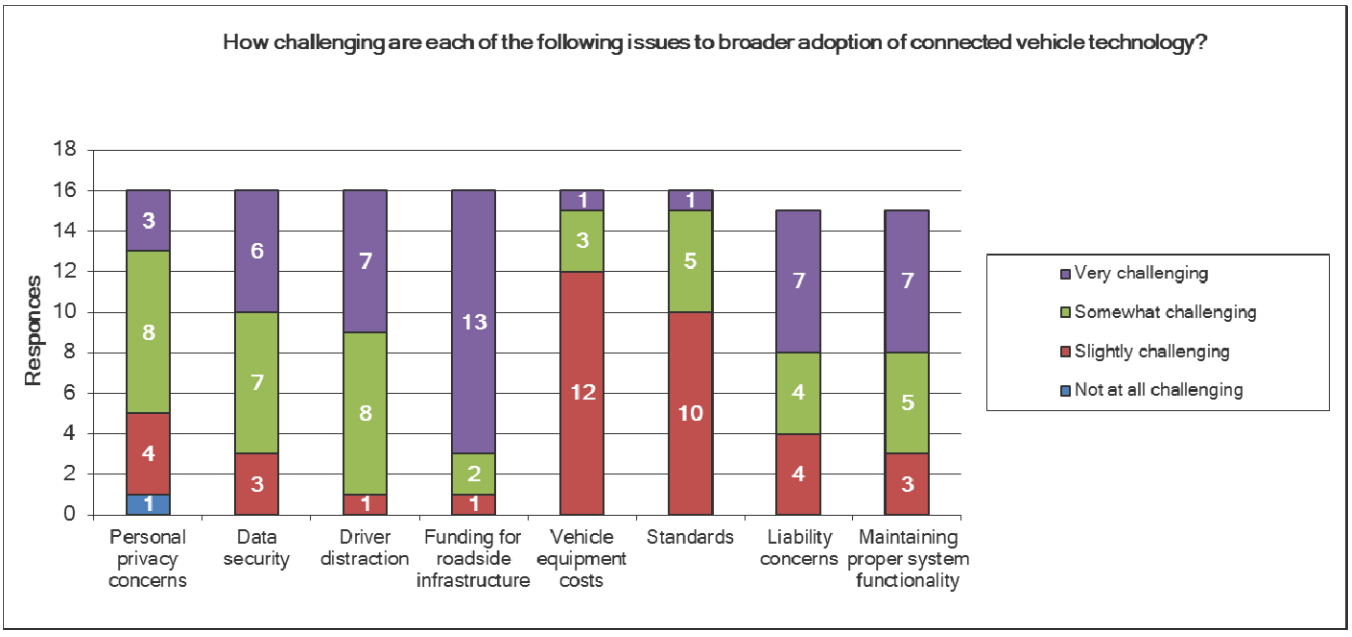

Figure 27: Challenges to Broad Adoption of Connected Vehicle Technology
Source: CAR 2012

III. CONCLUSIONS

This report provides an analysis of expert opinions from the public sector's side of the connected vehicle technology equation. The respondents were given two, iterative surveys that addressed issues such as how V2V and V2I systems compare, communication technologies for various applications, possible governmental influence, and roadside infrastructure needed for a successful deployment.

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. Respondents also think 3G and 4G cellular technology will be the primary communication pipeline for probe data collection, fleet management, commercial and private applications, and asset management, and DSRC will be used for in-vehicle warnings. DRSC was also thought capable of providing traffic incident information.

Most respondents feel that while a V2V-only system is possible, it is undesirable as it must be combined with V2I systems to maximize public benefit. However, V2V systems are seen as easier to implement; therefore concerted effort will likely have to be made to ensure appropriate V2I systems are also in place.

The highest priority use of connected vehicle technology for the public sector is to avoid vehicle crashes. Given that one of the public sectors' main charges is to enhance safety, this is not surprising. Respondents are unsure whether automakers would share sensor data with agencies, but feel that a public/private partnership would be the best way to encourage this sharing.

DSRC will be the likely transmission mode for infrastructure used in urban intersections, and correspondingly, intersection safety is seen as the highest necessity to make in-vehicle installation of DSRC worthwhile. Cellular technology is the more likely transmission mode for urban highways. According to respondents, for a successful national deployment, both Traffic Management Centers and Networked Traffic Signal Systems are essential.

Public sector respondents overwhelmingly think that the NHTSA notice of regulatory intent will be in the affirmative and, if it is, that it will take five or more years for all vehicles to be required to have the safety technology. While they do not believe vehicles will require aftermarket retrofits, they concur that not requiring retrofits will significantly degrade overall system performance, as until there is fleet turnover, most vehicles on the road will not have the safety technology. Offering some type of consumer incentive is seen as the best way to encourage drivers to retrofit their own vehicles with the technology. Respondents do not expect other federal or state-level mandates on V2I applications.

The biggest challenge to broad adoption of the technology is seen as gathering enough funding to deploy infrastructure along roadways.

REFERENCES

Bureau of Labor Statistics. (2012). "Databases, Tables & Calculators by Subject: State and Area Employment, Hours, and Earnings." Bureau of Labor Statistics, U.S. Department of Labor. Retrieved August 22, 2012. (http://www.bls.gov/data/).

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 - Public Sector

Vehicle Communication

1. Which communication technology will be the primary pipeline for direct communication between vehicles and infrastructure for the following applications by 2017?

	DSRC	Cellular (3G/4G)	Wi-Fi	RFID
In-vehicle warnings at intersections, traffic signs, and other road features	◯	◯	◯	◯
Probe data collection for traffic management, traveler information, and traffic planning	◯	◯	◯	◯
Tolls and electronic payments	◯	◯	◯	◯
Commercial and public fleet management applications	◯	◯	◯	◯
Commercial and private applications, such as remote diagnostics and media downloads	◯	◯	◯	◯
Asset management, such as pavement quality, pothole detection, and slippery road detection	◯	◯	◯	◯

2. Which communication technology will be the primary pipeline for direct communication between vehicles and infrastructure for the following applications by 2022?

	DSRC	Cellular (3G/4G)	Wi-Fi	RFID
In-vehicle warnings at intersections, traffic signs, and other road features	◯	◯	◯	◯
Probe data collection for traffic management, traveler information, and traffic planning	◯	◯	◯	◯
Tolls and electronic payments	◯	◯	◯	◯
Commercial and public fleet management applications	◯	◯	◯	◯
Commercial and private applications, such as remote diagnostics and media downloads	◯	◯	◯	◯
Asset management, such as pavement quality, pothole detection, and slippery road detection	◯	◯	◯	◯

3. One school of thought concerning the relative capabilities of cellular and 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

4. One school of thought concerning the relative capabilities of cellular and DSRC technologies holds that 3G and 4G cellular networks can handle just about all other 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

2012 Connected Vehicle Technology Forecast - Public Sector

Connected Vehicle Applications

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		
Mobility		
Environmental performance		
Personal convenience		
Vehicle diagnostics		
Other		

Other (please specify)

6. In your opinion, what are the three highest priority uses of connected vehicle technology to benefit public-sector transportation agencies?

1.

2.

3.

7. For the following, select the response that best indicates the extent to which you agree or disagree with the following statement:

Further development of the following related traffic management systems are essential to a successful national deployment of connected vehicle technology.

	1 = Strongly disagree	2	3	4	5 = Strongly agree
Roadside and/or embedded highway traffic volume, speed, and incident sensors	◯	◯	◯	◯	◯
Roadside video cameras for monitoring traffic	◯	◯	◯	◯	◯
Traffic management centers for monitoring traffic conditions, managing data servers, providing Internet access, and delivering services	◯	◯	◯	◯	◯
Networked traffic signal systems	◯	◯	◯	◯	◯
Electronic toll collection systems	◯	◯	◯	◯	◯

8. In-vehicle motorist information systems and dynamic route guidance rely on information delivered to the vehicle. Will DSRC-based connected vehicle systems support the required two-way communication systems that will deliver traffic incident information and similar public warnings to the vehicle?

◯ Yes

◯ No

9. Which of the following is the most likely cost scheme for DOTs and other operational agencies to obtain probe data from data aggregators and resellers?

◯ No charge

◯ Flat service fee

◯ Fee based on amount of data requested (e.g., pay more for larger geographic area or more frequent updates)

◯ Other (please specify)

Timetable

10. 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?

- ◯ 0%
- ◯ 10%
- ◯ 20%
- ◯ 30%
- ◯ 40%
- ◯ 50%
- ◯ 60%
- ◯ 70%
- ◯ 80%
- ◯ 90%
- ◯ 100%

11. Where are vehicle-to-infrastructure roadside transceivers most likely to be deployed first?

- ◯ Urban intersections primarily to support intersection crash avoidance and other intersection safety applications
- ◯ On toll roads primarily to support electronic payment applications
- ◯ Along dense urban highways primarily to support traffic management, traveler information, and possibly commercial applications
- ◯ Other

(please specify)

Infrastructure Challenges

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

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

- ◯ Yes
- ◯ No

Please explain the reason for your answer

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

- ◯ Yes
- ◯ No

Please explain the reason for your answer

Other Challenges

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

	Very challenging	Somewhat challenging	Slightly challenging	Not at all challenging
Personal privacy concerns	◯	◯	◯	◯
Data security	◯	◯	◯	◯
Driver distraction	◯	◯	◯	◯
Funding for roadside infrastructure	◯	◯	◯	◯
Vehicle equipment costs	◯	◯	◯	◯
Standards	◯	◯	◯	◯
Other	◯	◯	◯	◯

Other (please specify)

Data

16. One premise of connected vehicle technology is that automakers will share vehicle sensor data with public agencies to support public applications and services, such as traffic probe data and road weather information.

Please select the response that best indicates the extent to which you agree or disagree with this premise.

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

17. Select the response that best indicates the extent to which you agree or disagree with the following statement: Connected vehicle technology will be sufficiently flexible to allow a variety of communication backhaul options (e.g., fiber optic, cellular, other wireless etc.)

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

Features

18. Please state whether the following features will be implemented primarily via vehicle-to-infrastructure technology by 2017? 2022?

	By 2017	By 2022
Road condition warning (vehicle-based) environmental sensing		
Emergency vehicle approaching (or ahead) warning		
Intersection crash avoidance		
Curve speed warning		
Environmentally-oriented integrated corridor management		
Environmentally-oriented traveller information		
Environmentally-oriented signal operations		

Government Mandates

19. 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

20. 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

21. 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

22. 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

23. 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)		
Stop sign movement assist, violation warning, and highway/rail crossings		
Lane/road departure (e.g., electronic speed bumps) requiring roadside equipment		
Curve speed warning/rollover warning (infrastructure-based)		
Work zone, school zone, exit facility, icy bridges, low underclearance (bridge, parking garage, storage), wrong way warning, road features warning)		
Left turn across path and lateral gap acceptance		

Second Round: 2012 Connected Vehicle Technology Forecast - Public

Vehicle Communication

1. Which communication technology will be the primary pipeline for direct communication between vehicles and infrastructure for the following applications by 2017?

	DSRC	Cellular (3G/4G)	Wi-Fi	RFID
In-vehicle warnings at intersections, traffic signs, and other road features	◯	◯	◯	◯
Probe data collection for traffic management, traveler information, and traffic planning	◯	◯	◯	◯
Tolls and electronic payments	◯	◯	◯	◯
Commercial and public fleet management applications	◯	◯	◯	◯
Commercial and private applications, such as remote diagnostics and media downloads	◯	◯	◯	◯
Asset management, such as pavement quality, pothole detection, and slippery road detection	◯	◯	◯	◯

2. Which communication technology will be the primary pipeline for direct communication between vehicles and infrastructure for the following applications by 2022?

	DSRC	Cellular (3G/4G)	Wi-Fi	RFID
In-vehicle warnings at intersections, traffic signs, and other road features	◯	◯	◯	◯
Probe data collection for traffic management, traveler information, and traffic planning	◯	◯	◯	◯
Tolls and electronic payments	◯	◯	◯	◯
Commercial and public fleet management applications	◯	◯	◯	◯
Commercial and private applications, such as remote diagnostics and media downloads	◯	◯	◯	◯
Asset management, such as pavement quality, pothole detection, and slippery road detection	◯	◯	◯	◯

Second Round: 2012 Connected Vehicle Technology Forecast - Public

Connected Vehicle Applications

3. In the first-round survey, we asked whether vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communication will be more important for a variety of applications in 2017 and 2022.

Open-ended responses indicated we should address a few more applications. Therefore, please answer for the following two applications.

	2017	2022
Fleet management		
Wireless roadside inspection		

4. In your opinion, what are the three highest priority uses of connected vehicle technology to benefit public-sector transportation agencies?

	First	Second	Third
Crash avoidance	◯	◯	◯
Traffic management	◯	◯	◯
Asset management	◯	◯	◯

5. In the first round, respondents were asked the extent to which they agree with the following statement: Further development of a list of various traffic management systems are essential to a successful national deployment of connected vehicle technology. There was general agreement that Traffic Management Centers (TMCs) and Networked Traffic Signal Systems are essential to national deployment, but roadside sensors and videos are not.

To what extent do you agree that, despite V2I, TMCs and Networked Traffic Signal Systems are essential to a successful national deployment of connected vehicle technology?

	1 = Strongly disagree	2	3	4	5 = Strongly agree
Traffic management centers for monitoring traffic conditions, managing data servers, providing Internet access, and delivering services	◯	◯	◯	◯	◯
Networked traffic signal systems	◯	◯	◯	◯	◯

6. Responses from the first round were split regarding whether DSRC-based connected vehicle systems will support the required two-way communication systems to deliver traffic incident information and similar public warnings to the vehicle.

Regardless of whether you think cellular is the better way to send out information, will DSRC be capable of providing traffic incident information?

- ◯ Yes
- ◯ No

Timetable

7. If V2V is mandated, what and how much infrastructure-based communication will be needed to support a V2V safety system?

8. Which type of V2I transmission mode is most likely for the following roadside locations by 2022?

	DSRC	Cellular	RFID	Other
Urban intersections primarily to support intersection crash avoidance and other intersection safety applications	◯	◯	◯	◯
On toll roads primarily to support electronic payment applications	◯	◯	◯	◯
Along dense urban highways primarily to support traffic management, traveler information, and possibly commercial applications	◯	◯	◯	◯

Please specify "Other" transmission type if you selected that column

9. In your view, to what extent is Bluetooth technology deployed along the roadside useful for collection of traffic probe data?

- ◯ Not at all useful
- ◯ Slightly useful
- ◯ Somewhat useful
- ◯ Very useful

Infrastructure Challenges

10. Please rank the following characteristics of DSRC infrastructure in order of necessity to make in-vehicle installation of DSRC worthwhile.

	First	Second	Third
Intersection safety	◯	◯	◯
Safety at select non-intersection areas (curves, road construction)	◯	◯	◯
Network security (certificates and authentications)	◯	◯	◯

Other Challenges

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

	Very challenging	Somewhat challenging	Slightly challenging	Not at all challenging
Liability concerns	◯	◯	◯	◯
Maintaining proper system functionality	◯	◯	◯	◯

Data

12. In the first round, answers were mixed as to whether automakers will share vehicle sensor data with public agencies to support public applications and services, such as asset management and road weather information.

Which of the following approaches do you think might encourage automakers to share data? Select all that apply.

- [ ] Mandate
- [ ] Incentive
- [ ] Public/private partnership

Second Round: 2012 Connected Vehicle Technology Forecast - Public

Government Mandates

13. First round answers indicate respondents think NHTSA is likely to mandate V2V communication systems for safety applications, but that it is unlikely to require existing vehicles to be retrofitted with the technology.

If this holds, to what extent will this degrade system performance for the first few years of deployment?

- ◯ Not at all
- ◯ Slight degradation
- ◯ Moderate degradation
- ◯ Significant degradation

14. If the system is too unreliable because not enough vehicles are equipped with the technology, what would best encourage current vehicle owners to retrofit their vehicles (outside of a NHTSA mandate)?

- ☐ Incentives to consumers
- ☐ Subsidies to aftermarket suppliers to offer products for reduced prices
- ☐ Other

Other (please specify)

15. First round responses show a general consensus that by 2017, no connected vehicle applications will be mandated, but responses were mixed for whether they'll be mandated in 2022.

Do you foresee federal mandates for V2I applications by 2022?

- ◯ Yes
- ◯ No

16. Do you foresee any state-level mandates for V2I applications by 2022?

- ◯ Yes
- ◯ No