Global Harmonization of Connected Vehicle Communication Standards

January 12, 2016

Michigan Department of Transportation

CENTER FOR AUTOMOTIVE RESEARCH

Sponsoring Organization:
Michigan Department of Transportation (MDOT)
425 Ottawa Street
P.O. Box 30050
Lansing, MI 48909

Performing Organization:
Center for Automotive Research (CAR)
3005 Boardwalk, Ste. 200
Ann Arbor, MI 48108

Global Harmonization of Connected Vehicle Communication Standards
January 12, 2016

MDOT REQ. NO. 1259, Connected and Automated Vehicle Industry Coordination
Task D.4. Global Harmonization of Connected Vehicle Communication Standards

Author(s):
Qiang Hong (CAR)
Eric Paul Dennis (CAR)
Richard Wallace (CAR)
Joshua Cregger (CAR)

Additional Contributor(s):
Valerie Sathe Brugeman (CAR)
MacPherson Hughes-Cromwick (CAR)

ACKNOWLEDGMENTS

This document is a product of the Center for Automotive Research under a *State Planning and Research Grant* administered by the Michigan Department of Transportation.

TABLE OF CONTENTS

MDOT
Michigan Department of Transportation

CAR
CENTER FOR AUTOMOTIVE RESEARCH

EXECUTIVE SUMMARY

Intelligent Transportation System (ITS) developers envision deploying infrastructure-augmented connected vehicle systems, also known as Cooperative ITS (C-ITS), to improve the safety, mobility, and sustainability of transportation systems across whole networks. Connected-ITS applications combine traditional aspects of connected vehicle systems and ITS infrastructure. For C-ITS to function most effectively, interoperability between the ITS infrastructure and vehicle equipment is needed. Automakers and infrastructure operators must deploy equipment conforming to a harmonized set of standards. Such cross-organizational standards usually are developed through independent standards-development organizations (SDOs) in coordination with effected government and private interests.

Currently, efforts are underway to develop "harmonized" connected vehicle standards so that automakers, governments, and technology developers can adopt analogous conceptual and technological frameworks across markets. C-ITS stakeholders widely believe that such harmonization of ITS standards will accelerate the deployment of C-ITS systems across the globe by leveraging economies of scale for research, development, and manufacturing activities. The accelerated deployment of C-ITS applications could have broad public benefit; therefore, technologies are being developed with the intent of improving the safety, mobility, and efficiency of the transportation system. This potentially broad social benefit has encouraged the U.S. Department of Transportation (USDOT) to coordinate with international agencies in pushing for the greatest possible harmonization of C-ITS standards.

While public transportation agencies are encouraging internationally harmonized C-ITS, standards-development is primarily a private-sector activity. Even federal agencies, such as USDOT, must typically wait for appropriate standards to be developed by independent SDOs; only when standards are formally adopted by SDOs can they be effectively integrated into policy. Regional governments such as Michigan Department of Transportation (MDOT) may have eventual authority over C-ITS infrastructure, and thus have some interest in C-ITS standardization. However, it is difficult to envision how regional governments could have much direct influence over standards development or harmonization processes. If regional governments have well-defined and specific insight to contribute to ongoing standards developments and harmonization activities, they may consider assigning knowledgeable representatives to participate in such activities.

Otherwise, regional governments are generally involved in the eventual *implementation* of adopted standards. Until USDOT successfully adopts a nationwide C-ITS policy including specific standards, state transportation agencies are generally relegated to observer status as SDOs, industry groups, and national governments work towards standards-harmonization and adoption.

The Michigan Department of Transportation is positioned to be a leading adopter of connected vehicle technology if/when USDOT adopts and implements a standardized connected vehicle platform. MDOT has participated in several connected vehicle research and test-bed projects, including the installation of roadside infrastructure conforming to the latest available standards. While MDOT is not in a position to directly influence the development or harmonization of connected vehicle standards, MDOT will sustain a leadership position by actively following standards development and harmonization processes and maintaining in-house expertise on the latest advancements in standards development.

1 INTRODUCTION

Stakeholders in many nations across the globe believe that connected vehicle (CV) systems, also known as Cooperative Intelligent Transportation Systems (C-ITS), have the potential to improve transportation systems in terms of safer and more efficient transportation. Deploying connected vehicle systems would be easier if manufacturers could minimize variations between markets. Having a common hardware and software module (e.g., chip sets and security foundation) is high priority as it translates to cost savings for the manufacturers.[1] To date, stakeholders have been trying to harmonize the equipment and architectures so that CVs can be developed and deployed globally based on a set of standards harmonized to the greatest extent feasible.

Connected vehicles require consistent standards to protocols to work internationally. For example, international harmonization is needed for cross border operations and requires government level coordination.[2] Intercontinental harmonization may also decrease costs because of economies of scale. Main developments are emerging from the USA, Europe, Japan and South Korea. While there are memorandums of understanding between some of these regions and harmonization efforts in place, the result is that there are different C-ITS platforms and communication protocols emerging that correspond with different regions.

With harmonization, automakers could use a single system, rather than installing different systems for vehicles being sold in different markets. Using information gathered from available literature and expert interviews, this report discusses harmonization efforts, including specific areas of focus, stakeholders involved, and various standards being considered. The report also discusses the implications and opportunities these harmonization efforts present for Michigan and Michigan Department of Transportation (MDOT).

[1] Bishop 2013.
[2] VIIC 2013.

2 DEFINING CONNECTED VEHICLE SYSTEMS

Various uses of the term "connected vehicle" may refer to a variety of different types of connected vehicle systems. Connected vehicles include a wide variety of platforms using different communication and data standards for a range of applications. The scope of this report is limited to a specific category of connected vehicle systems often referred to as C-ITS.[3] C-ITS systems require central coordination between vehicles and infrastructure. Intelligent Transportation Systems (ITS) developers envision deploying C-ITS systems to improve the safety, mobility, and sustainability of transportation systems. Such systems must generally be coordinated by a central government agency. In the United States, C-ITS connected vehicle research, development, and regulations are led by the ITS Joint Program Office (ITS JPO) within the Office of the Assistance Secretary for Research and Technology (OST-R) and the National Highway Traffic Safety Authority (NHTSA) of the U.S. Department of Transportation (USDOT).

2.1 CONNECTED VEHICLE APPLICATIONS

There are three broad categories of communication-based automotive applications of connected vehicle systems. These applications present varying characteristics themselves: [4]

- Safety-oriented (e.g., stopped or slow vehicle advisor, emergency electronic brake light, V2V post-crash notification, road feature notification, and cooperative collision warning)
- Convenience-oriented (e.g., congested road notification, traffic probe, free flow tolling, parking availability notification, and parking spot locator)
- Commercial-oriented (e.g., remote vehicle personalization/diagnostics, service announcement, content download, and real-time video broadcasts)

Different applications have different networking criteria and network attributes, as summarized in Table 1.

[3] Our scope omits non-ITS connected vehicle systems such as infotainment, fleet telematics, etc.
[4] *Vehicular Networking* (2010).

TABLE 1: CONNECTED VEHICLE APPLICATION ATTRIBUTES[5]

Application Attributes	Description	Choices
Channel frequency	What channel does the application use?	DSRC-CCH, DSRC-SCH, Wi-Fi
Infrastructure	Is infrastructure required?	Yes, No
Message time-to-live	How far do messages propagate?	Single-hop, Multi-hop
Packet format	What type of packet is used?	WSMP, IP
Routing protocol	How are messages distributed?	Unicast, Broadcast, Geocast, Aggregation
Network protocol initiation mode	How is a network protocol initiated?	Beacon, On-demand, Event-triggered
Transport protocol	What form of end-to-end communication is needed?	Connectionless, Connection-oriented
Security	What kind of security is needed?	V2V security, V2I security, Internet security

Other criteria that can be used to classify applications include:[6]

- Application trigger condition: periodic, event-driven, and user-initiated
- Recipient pattern of application message: one-to-one, one-to-many, one-to-a-zone, and many-to-one
- Event lifetime: long or short
- Event detector: single host or multiple hosts

Recently, vehicle to vehicle/infrastructure (V2X) communication-based applications have attracted more attention from industry and governments in the United States, Europe, Japan, and Australia because of their unique potential to address vehicle safety, traffic efficiency improvements, and commercial-oriented applications. In the next section we will discuss characteristics of connected vehicle communications systems.

2.2 CONNECTED VEHICLE COMMUNICATION SYSTEMS

WIRELESS VEHICULAR COMMUNICATIONS

There are varieties of wireless technologies in a modern vehicle, such as wireless AM/FM and satellite radio, multi-media device USB, Bluetooth, Wi-Fi, and remote direct-access telematics (cellular 2G-4G). Dedicated Short Range Communications (DSRC) technology supports both vehicle-to-vehicle

[5] *Vehicular Networking* (2010). *Note: Packet format generally expected to be WAVE Short Message Protocol (WSMP) for safety and convenience, and IP for commercial applications.*
[6] *Vehicular Networking* (2010).

(V2V) and vehicle-to-infrastructure (V2I) applications. Figure 1 shows the variety of utilized vehicle commutations, navigation and active sensors that are available.

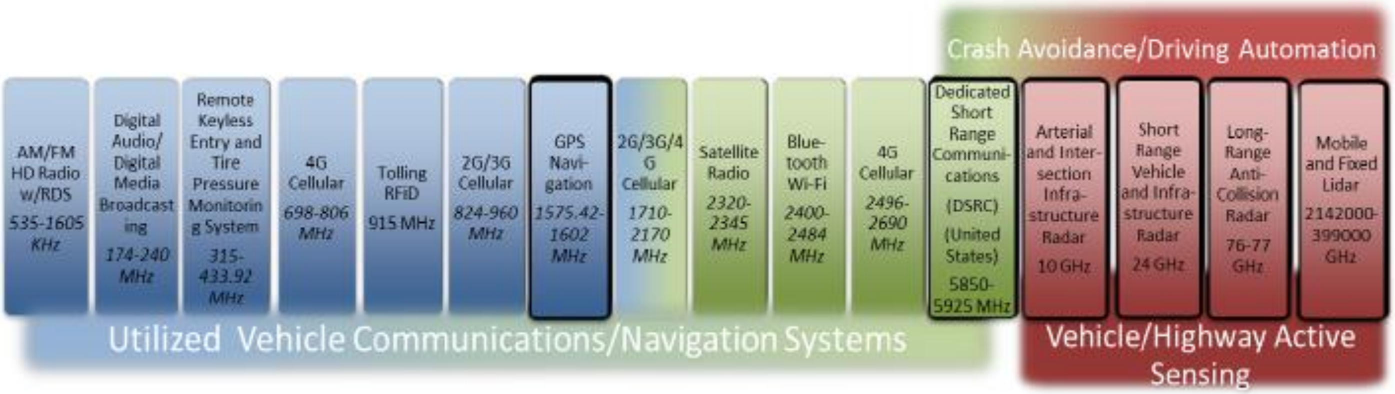

FIGURE 1: VEHICLE AND INFRASTRUCTURE COMMUNICATIONS, NAVIGATION, AND ACTIVE SENSING TECHNOLOGIES[7]

The classification of applications implies network design principles, as illustrated in Figure 2.

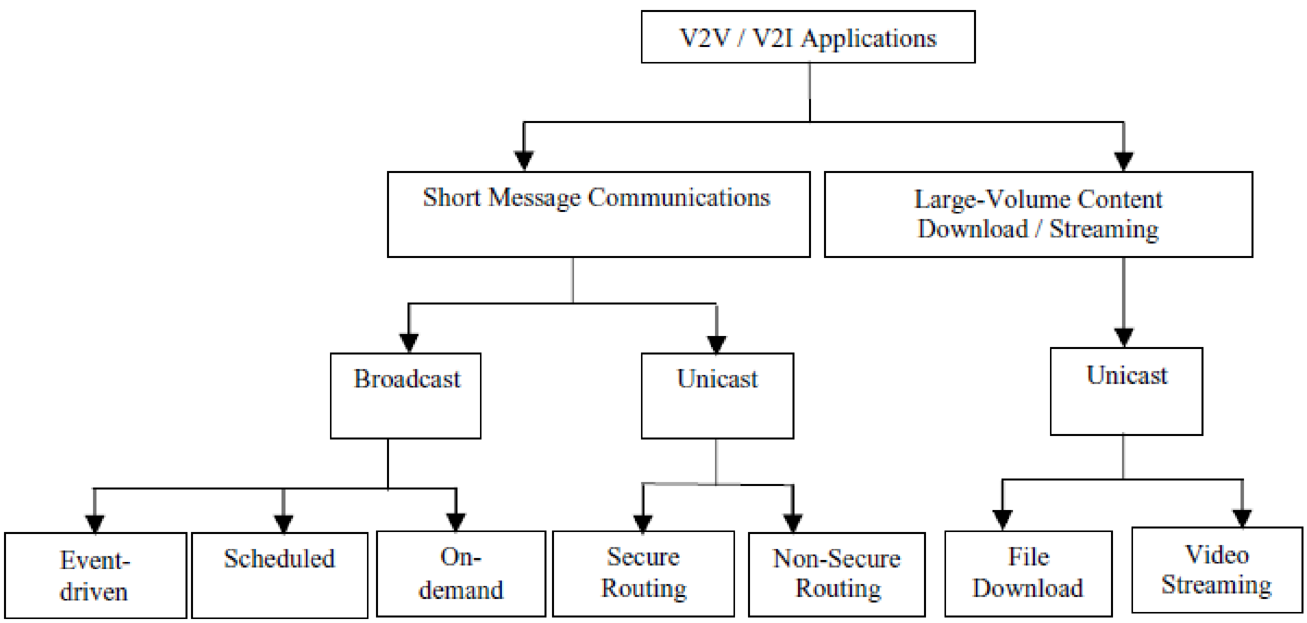

FIGURE 2: CLASSIFICATION FROM THE PERSPECTIVE OF NETWORK DESIGN[8]

---

[7] Source: ITS America 2015.
[8] Source: *Vehicular Networking* 2010.

Conceptualization of wireless protocol functions into seven-layer model as shown in Figure 3:

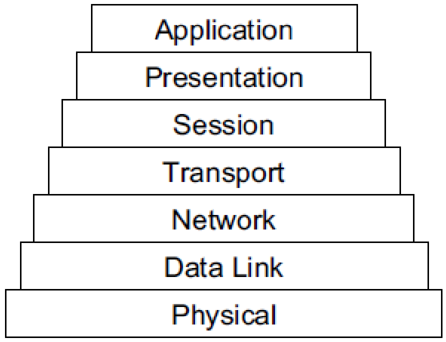

FIGURE 3: OSI ITU-T X.200 1994 SEVEN-LAYER MODEL

Standards activities related to layers:

- Layer 1 (Physical) and 2 (Data Link): IEEE 802.11 wireless, ISO 11898 CAN
- Layer 3 (Network): IETF RFC 1122 1989 Internet protocol (IP)
- Layer 4 (Transport) and 5 (Session): IETF RFC 793 1981 transmission control protocol (TCP) and IETF RFC 768 1980 user datagram protocol (UDP)

International standard ISO 11898 2007 for vehicle serial data exchange at lower protocol layers is Control Area Network (CAN) over twisted pair. CAN is widely adopted but not mandated.[9] The upper layer portion of CAN protocol implemented on a vehicle is likely manufacturer proprietary.

DSRC SPECTRUM

Spectrum requirements for DSRC networks vary substantially from conventional wireless networks. Most V2I applications (e.g., tollbooth) use 915 MHz unlicensed band. Not all bands are equivalent, as shown below and in Table 2.

- North America is using 5.850-5.925 GHz as DSRC band for ITS (IEEE 802.11p for base layers, IEEE 1609 for middle layers, and SAE J2735 for message set).

[9] Except for certain emissions-related information.

- Europe has agreed on a spectrum around 5.9 GHz to be used across the EU. Though not the exact same as North America, it is sufficiently close that the same chipset could likely be used.
- Japan has over 23 million toll collection devices in the 5.8 GHz band. Japan's Association of Radio Industries and Businesses (ARIB) is studying using this band, as well as 700 MHz band, for V2V. ARIB's standards are significantly different than U.S. and EU standards.

TABLE 2: DSRC BANDS AROUND THE WORLD

Region	Standard	Frequency (GHz)
Europe	EN 12253	5.795–5.815
ITU-R	ITU-R M.1453-2	5.725–5.875
Japan	ARIB T55	5.770–5.850
North America	ASTM E 2213-02	5.850–5.925

VEHICULAR AD HOC NETWORK (VANET)

VANET is a communications system for moving vehicles at high speed, which are equipped with wireless communication devices, together with additional wireless roadside units, enabling communications among nearby vehicles (V2V) as well as between vehicles and nearby fixed equipment (V2I) for safety and non-safety purposes. VANET has become an important communication infrastructure for ITS (Figure 4).

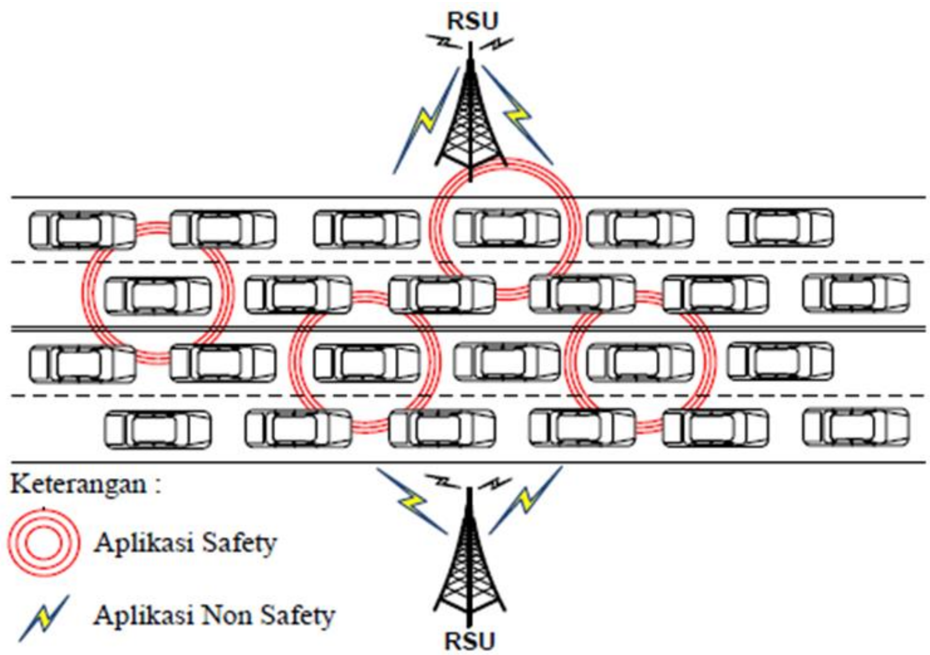

FIGURE 4: VEHICULAR AD-HOC NETWORK[10]

MULTICHANNEL OPERATION

In VANET, one primary issue is Medium Access Control (MAC), which aims to utilize the radio spectrum efficiently, to resolve potential contention and collision among vehicles for using the medium. Multi-channel operation IEEE 1609.4 is a standard of the IEEE 1609 protocol family, which manages channel coordination and supports MAC service delivery.

In the United States, the Federal Communications Commission (FCC) has allocated 75 MHz of DSRC spectrum for vehicular usage at 5.9 GHz in 1999. The bandwidth of each channel is 10 MHz. There are six service channels (SCH) and one control channel (CCH). The control channel is used for system control and safety data transmission. On the other hand, service channels are assigned for exchange of non-safety related data. In addition, these channels use different frequencies and transmit powers.[11]

Multiple channels have been allocated in the 5 GHz spectrum for vehicular communications in United States and in Europe. Due to the limited spectrum, simultaneous communications may occur over nearby channels and be

[10] Ahyar et al. 2014.
[11] The FCC and other interests are currently investigating opening up this band for non-licensed uses.

affected by adjacent channel interference (ACI). To protect safety messages delivered on the control channel (CCH), the most likely approach is to prevent the use of adjacent channels with the consequence of spectrum resources wasting.

DEPLOYMENT OPTIONS

Opinions on best approaches to deployment vary widely. Commercial and convenience applications may be implemented before safety applications since safety applications require high penetration rate. Below are some sample options of deployment:

- Standalone system solution: self-contained V2X module built-in to vehicles. This is the most costly solution.
- Navigation system solution: add V2X capability to navigation systems. This might limit growth potential.
- Aftermarket transceiver: may be passive (transmit only) or active. This can be integrated via OBD II or not.

INTEROPERABILITY

Active safety requires thorough, open standards that are stable over decades-long time horizon. Because of regional differences, there is unlikely to be a global agreement on spectrum. But if there could be global agreement on general frequency range (e.g., 'around' 5.8 GHz), channel widths, and over-the-air (OTA) protocol, regional difference may be accommodated with same chipsets but slightly different programming. Bluetooth is a good example of how standardization and cooperation can lead to broad interoperability.

Critical safety messages must be on a particular frequency to minimize packet loss. A message set needs to be standardized, but a standardized message set is not sufficient in itself, to ensure interoperability.[12] In addition to standards, interoperability requires additional 'rules of use,' such as:

- the spectral envelop of channel filtration
- priorities for messages
- creation of intentional interference

In the next chapter we will discuss international connected vehicle harmonization efforts.

[12] Schnaffnit 2010.

3 INTERNATIONAL CONNECTED VEHICLE APPROACHES AND HARMONIZATION EFFORTS

One of the key components of connected vehicle system is the ability for vehicles and infrastructure to be able to talk to one another in an interoperable manner. As such, standards need to be created centrally and adopted widely. Standards are also required in order to ensure connected vehicle components made by different manufacturers work together.

Specifically, for a message to be sent from one vehicle and received by another vehicle, the on-board units (OBUs) in the vehicles must abide by key standards. Similarly, for roadside infrastructure, e.g., an intersection equipped with a roadside unit (RSU) to communicate with passing vehicles, the communication device must be based on the same communication standards as the OBUs in those vehicles. These standards are important to resolve questions such as:

- which entities communicate and to whom (e.g., vehicle, pedestrian, roadside infrastructure, central servers)
- which message set is used within the communication
- what media and channel allocation (if applicable) is used (e.g., 5.9 GHz and the applicable channel allocation)
- which protocol is used (e.g., IPv6)
- what application is implemented and how

A system may include multiple standards as long as they are harmonized and do not impede innovation and performance.[13] Harmonization requires minimizing differences in the technical content of standards having the same scope.[14]

3.1 RELEVANT STANDARDS ORGANIZATIONS

Standards are developed at various levels and by many different SDOs at the global, regional, and national level.[15] Connected vehicles standards are

[13] Gouse 2015.
[14] http://www.bptrends.com/publicationfiles/11-05-ART-StandardizationorHarmonizationv-RickenSteinhorst.pdf, accessed April 2015.
[15] Evensen and Csepinszky 2013.

emerging from many countries, including the United States, Europe, Japan, China, and South Korea. Examples of relevant SDOs include:

- International Organization for Standardization (ISO)
- ASTM International[16]
- SAE International[17]
- Institute of Electrical and Electronics Engineers (IEEE)
- National Transportation Communications for Intelligent Transportation System Protocol (NTCIP)
- American National Standards Institute (ANSI)
- European Committee for Standardization (CEN)
- European Committee for Electrotechnical Standardization (CENELEC)
- European Telecommunications Institute (ETSI)

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

The International Organization for Standardization (ISO) is an independent, non-governmental membership organization and the world's largest developer of voluntary international standards. ISO is based in Geneva, but it has 163 member nations. The United States participates in ISO through the American National Standards Institute (ANSI).[18]

ISO defines a standard as a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose. Standards ensure that conforming products are safe, reliable, and high-quality.[19] International standards can also make industry more efficient and break down trade barriers by harmonizing technical specifications of products and services.[20]

ISO Technical Committee 204 (ISO TC 204) Standards Working Group was established in 1992 for the standardization of information, communication, and control systems in the field of urban and rural surface transportation,

---

[16] Historically, ASTM was an initialism for the American Society for Testing and Materials, but the organization formally changed its name to ASTM International in 2001, to reflect the international nature of the organization.
[17] Historically, SAE was an initialism for the Society of Automotive Engineers, but the organization formally dropped the full moniker in 2006 to reflect the expanded scope of its activities.
[18] http://www.iso.org/iso/home/about.htm
[19] http://www.iso.org/iso/home/standards.htm, accessed April 2015.
[20] http://www.iso.org/iso/home/standards/benefitsofstandards.htm, accessed April 2015.

including intermodal and multimodal aspects thereof, traveler information, traffic management, public transport, commercial transport, emergency services, and commercial services in ITS field. The group is led by ANSI, with 26 countries participating and an additional 27 countries observing.[21]

ISO TC 204 is responsible for the overall system aspects and infrastructure aspects of ITS, as well as the coordination of the overall ISO work program in this field including the schedule for standards development, taking into account the work of existing international standardization bodies.[22] The European Committee for Standardization (CEN) has adopted multiple ISO standards into the European standardized platform for cooperative ITS.

SAE INTERNATIONAL

SAE standards are internationally recognized for their role in helping ensure the safety, quality, and effectiveness of products and services across the mobility engineering industry. The more than 10,000 standards in the SAE database now. Related connected vehicle standards include:

- SAE J2735 Version 2 (2009) Message Set Dictionary. (Needs to be updated to support interoperability.[23] 2015 update pending final acceptance.[24])
- SAE J2945.1 Version 1: Establishes performance requirements, but not standards for accuracy or test procedures. This standard is currently in draft form and the timeline to completion is unclear.[25] Recent connected vehicle projects (such as the Safety Pilot Deployment in Ann Arbor) have had to develop interim performance requirements.[26]

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE is a leading consensus-building organization that enables the creation and expansion of international markets, and helps protect health and public safety. Within IEEE, the IEEE Standards Association (IEEE-SA) is

---

[21] http://www.iso.org/iso/home/standards_development/list_of_iso_technical_committees/iso_technical_committee.htm?commid=54706, accessed April 2015.
[22] http://www.iso.org/iso/home/standards_development/list_of_iso_technical_committees/iso_technical_committee.htm?commid=54706, accessed April 2015.
[23] Harding *et al.* 2014, pp. 81.
[24] http://www.sae.org/standardsdev/dsrc/usa/, accessed April 2015.
[25] Harding *et al.* 2014, pp. 55.
[26] http://www.its.dot.gov/newsletter/VAD%20Specs.pdf , accessed May 2015.

responsible for the development of international standards related to electrical systems, electronics, and information technology. The U.S. Connected Vehicle Program has extensively adopted IEEE wireless communications standards (IEEE 802.11p and IEEE 1609 series). Related connected vehicle standards include:

- IEEE 1609.4-2010 (network standard)
- IEEE 802.11p-2010 (wireless layer standard)
- IEEE P1609.0/D5.8
- IEEE 1609.2-2013
- IEEE 1609.3-2010
- IEEE1609.12-2012

ASTM International

ASTM International (formerly known as the American Society for Testing and Materials) is an international SDO that develops technical standards. ASTM has published several standards associated with ITS and DSRC technologies.[27]

American National Standards Institute (ANSI)

The American National Standards Institute (ANSI) is a non-profit organization that facilitates standard development in the United States. ANSI is the official ISO representative for the United States. The ANSI standards store contains ITS standards set by ISO, IEEE, and SAE.[28]

Automotive Electronics Council (AEC)

The Automotive Electronics Council (AEC) was originally established by Chrysler, Ford, and GM for the purpose of establishing common part-qualification and quality-system standards. From its inception, the AEC has consisted of two Committees: the Quality Systems Committee and the Component Technical Committee. The AEC Component Technical Committee is the standardization body for establishing standards for reliable, high quality electronic components.[29]

---

[27] www.astm.org, accessed May 2015.
[28] www.ansi.org, accessed June 2015.
[29] http://www.aecouncil.com/

U.S. NATIONAL TRANSPORTATION COMMUNICATIONS FOR ITS PROTOCOL (NTCIP)

The NTCIP is a joint standardization project of AASHTO, ITE, NEMA, and Office of the Assistant Secretary for Research and Technology of USDOT. The NTCIP is a family of standards that provides both the rules for communicating (called protocols) and the vocabulary (called objects) necessary to allow electronic traffic control equipment from different manufacturers to operate with each other as a system. The NTCIP is the first set of standards for the transportation industry that allows traffic control systems to be built using a "mix and match" approach with equipment from different manufacturers.[30]

INTERNATIONAL TELECOMMUNICATION UNION (ITU-T)

International Telecommunication Union (ITU-T) is providing a forum for the creation of an internationally accepted, globally harmonized set of ITS communication standards, to enable the deployment of fully interoperable ITS communication-related products and services into the global marketplace.[31]

EUROPEAN STANDARDS ORGANIZATIONS

Europe has a series of standards organizations that may be involved:

- European Committee for Standardization (CEN)
- European Committee for Electrotechnical Standardization (CENELEC)
- European Telecommunications Institute (ETSI)
- Communications for eSafety Project
- ITS Europe (ERTICO)

CEN, CENELEC, and ETSI have been officially recognized by the European Union and by the European Free Trade Association (EFTA) as being responsible for developing and defining voluntary standards at European level. These standards are often adopted into legal frameworks and thus carry some legal authority.

[30] https://www.ntcip.org/
[31] http://www.itu.int/en/ITU-T/Pages/default.aspx

European Committee for Standardization (CEN)

CEN supports standardization activities in relation to a wide range of fields and sectors including: air and space, chemicals, construction, consumer products, defense and security, energy, the environment, food and feed, health and safety, healthcare, Information and Communications Technologies (ICT), machinery, materials, pressure equipment, services, smart living, transport and packaging.[32] In ITS-related technologies, CEN has coordinated development of standards with ISO to achieve harmonization of standards beyond European states. CEN/ISO has adopted 71 standards designed to facilitate day-1 operability across Europe.[33]

European Committee for Electro-technical Standardization (CENELEC)

CENELEC is responsible for standardization in the electro-technical engineering field. CENELEC prepares voluntary standards, which help facilitate trade between countries, create new markets, cut compliance costs, and support the development of a single European market. CENELEC adopts international standards wherever possible, most notably through collaboration with the International Electro-technical Commission (IEC) under the Dresden Agreement.[34]

European Telecommunications Standards Institute (ETSI)

ETSI produces standards for information and communications technologies, including fixed, mobile, radio, converged, broadcast, and internet technologies. ETSI is officially recognized by the EU as a European standards organization, but ETSI standards are generally globally applicable.[35] Many ETSI standards have been adopted into the CEN/ISO Release 1 set of standards for C-ITS.[36] ETSI developed and adopted a set of standards harmonized with the CEN/ISO Release 1 to facilitate day-1 operability of C-ITS.[37]

In early 2014, ETSI and CEN issued "Release 1" specifications, the basic set of standards for Cooperative Intelligence Transport Systems (C-ITS). The

---

[32] https://www.cen.eu
[33] CEN/ISO 2013.
[34] http://www.cenelec.eu
[35] http://www.etsi.org/about
[36] CEN/ISO 2013.
[37] http://www.etsi.org/technologies-clusters/technologies/intelligent-transport, accessed April 2015.

ETSI and CEN/ISO release 1 comprises 157 standards. These standards were the European SDOs response to a 2009 request (Mandate M/453) from the European Commission.[38]

The technical committees of CEN and ETSI are continuing to develop C-ITS standards and will issue Release 2, which will support the deployment of more complex use cases, enable a large installed base of cooperative systems, and support additional available networks.[39] The technical committees, which involve key stakeholders and experts, draw on Europe's extensive deployment projects, such as COMeSafety, Drive C2X, and eCoMove.[40]

The two SDOs divided responsibility for developing standards. ETSI is focused on developing vehicle-to-vehicle (V2V) communications standards on the 5.9 GHz spectrum, while CEN is focused on the overall framework architecture (platform using multiple communications technologies) and on vehicle-to-infrastructure (V2I) applications related to roadside and traffic management applications.[41]

JAPAN

In Japan, the Japanese Industrial Standards committee (JISC) serves as a lead organization based on the approval of the cabinet. An international standardization committee and several technical committees carry out the international standardization activities for ISO/TC 204 on behalf of the JISC. These activities are led by the Society of Automotive Engineers of Japan (JSAE).

The V2V and V2I communication system compatibility team is one of the technical committees that is responsible for DSRC radio communications used in ITS applications including electronic toll collection (ETC). There are also discussions on standards based on V2V and V2I communications. On the contrary, research and development of applications and communications technologies has been separately, concretely and steadily preceded concerning inter-vehicle communications including V2V and V2I communications.

[38] ETSI 2014.
[39] ETSI. 2013.
[40] Cregger 2014.
[41] CEN and ETSI 2010.

However, strategies for standardization as a whole nation have not been identified in Japan so far.[42]

In terms of bandwidth, 5.8 GHz is used for tolling. 760 MHz band is also being used for DSRC (Toyota). They are not compatible with IEEE 802.11p, and law exists that requires continuity of legacy protocols.[43]

KOREA

Within Korea, two organizations are involved, the Korean Agency for Technology and Standards (KATS), and the Telecommunication Technology Association (TTA) of Korea.

Korean Agency for Technology and Standards

KATS is a government agency in charge of national and international standards in Korea. KATS is a member of ISO, IEC, and the Pacific Area Standards Congress (PASC). KATS objectives include harmonizing Korean industrial standards with international standards, conducting research for standardization, and endorsing international agreements related to standardization.[44]

Telecommunication Technology Association (TTA) of Korea

TTA is a non-government organization (NGO) focused on ICT standardization, testing, and certification. TTA conducts research and establishes new standards for the ICT industry. There are currently eight technical committees, and vehicle ITC, ITS, and location-based services are grouped under the Radio/Mobile Communication committee (TC9).[45]

CHINA

China's standards are developed through formal and informal channels that vary between the type of standards and industries involved. Most national standards are drafted and revised through technical committees (TCs), which are responsible for setting priorities and work plans within their individual

[42] Society of Automotive Engineers of Japan (JSAE), ITS Standardization Activities in Japan. 2013. Accessed June 18, 2015. < http://www. jsae.or. jp/index_e.html>.
[43] Bishop 2013.
[44] KATS (2015). Korean Agency for Technology and Standards. Website. Accessed June 2015. <http://www.kats.go.kr/en/main.do>.
[45] TTA. (2015). Telecommunication Technology Association of Korea. Website. Accessed June 3, 2015. <www.tta.or.kr>.

technical standards area and for drafting and revising those standards. TCs fall under the supervision of Standardization Administration of China (SAC), though SAC can designate other agencies and organizations to oversee TC work. For example, the Chinese Electronics Standardization Institute—a research and policy group set up under the aegis of SAC, the Ministry of Industry and Information Technology (MIIT), the Ministry of Science and Technology, and the State Council Information Office—oversees TCs in the electronics sector and plays a large role in setting the industry's standards policy and direction.[46]

China Automotive Technology & Research Center (CATARC) and China National Center of ITS Engineering and Technology are two major research organizations responsible for ITS and connected vehicle related standards. The corresponding agency is National Technical Committee 268 on Intelligent Transport Systems of Standardization Administration of China, which is an active member of ISO/TC204.

China has set aside spectrum (5.795-5.815GHz) for ITS applications - mainly for ETC, traveler information systems, traffic operation, and fleet management. Connected vehicle standards are lag behind the rapid market growth driven by global auto manufactures and domestic telecommunication service providers. For example, Chinese networking supplier Huawei and German car manufacturer Audi Group recently announced a new partnership to jointly explore the future of connected car technology. Huawei's LTE modules can support 2G, 3G and 4G networks, as well as TDD-LTE and FDD-LTE standards.[47]

SINGAPORE

The Information Technology Standards Committee (ITSC) is an industry-led effort that is supported by SPRING Singapore (an enterprise development agency under the Ministry of Trade and Industry) and Infocomm Development Authority (IDA) of Singapore (a statutory board of the Singapore Government). ITSC is an open platform for collaboration between industry and government stakeholders to set technical standards. Among ITSC's many committees is the Intelligent Transport Systems Technical

[46] http://www.chinabusinessreview.com/strategies-for-participating-in-chinas-standards-regime/

[47] http://www.computerweekly.com/news/4500246908/Huawei-and-Audi-team-up-on-connected-cars

Committee (ITSTC), which tracks international ITS standardization efforts. The ITSTC facilitates education, stakeholder communication, and adoption of ITS standards for Singapore.[48]

AUSTRALIA & NEW ZEALAND

Australia and New Zealand are interested in standards and have been monitoring development of standards abroad; however, the two countries are waiting to see how international standards development proceeds before setting their own standards. Due to local spectrum management plans, it is likely that Australia and New Zealand will allocate 50 MHz of the 5.9 GHz band for use in C-ITS, in line with the EU allocation.[49]

3.2 UNITED STATES' CONNECTED VEHICLE PROGRAM

USDOT established the ITS Standards Program in 1996 to encourage adoption of those technologies.[50] USDOT seeks to harmonize the standards related to connected vehicles to reduce cost and complexity of these systems and accelerate their deployment. The ITS Standards Program works with SDOs to develop and test standards, as well as provide relevant information, training, and technical assistance. In the United States, connected vehicle technology standards are primarily released by SAE, IEEE, and NTCIP (Figure 5). The United States is also contributing to the development of standards through other SDOs, such as CEN and ISO.

[48] ITSC. Information Technology Standards Committee. Website. Accessed June 3, 2015. <www.itsc.org.sg/ >.

[49] Green 2015.

[50] USDOT. ITS Standards Program. Website. Intelligent Transportation Systems Joint Program Office, Office of the Assistant Secretary for Research and Technology, U.S. Department of Transportation. Accessed February 25, 2015. <http://www.standards.its.dot.gov>.

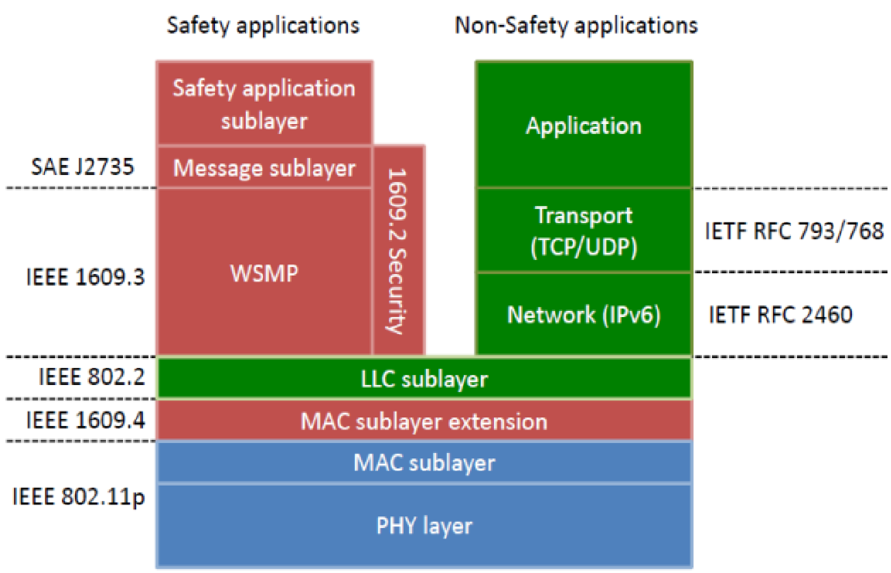

FIGURE 5: USDOT CONNECTED VEHICLE PROGRAM LAYER STANDARDS[51]

WIRELESS ACCESS IN VEHICULAR ENVIRONMENTS STANDARDS

The Wireless Access in Vehicular Environments (WAVE) standards are within the DSRC suite and define a set of protocols, services, and interfaces to enable secure V2V and V2I wireless communications.[52] The WAVE protocol is made up of the combination of IEEE 802.11p and the IEEE 1609 family of standards. IEEE 802.11 is a set of specifications for implementing wireless local area networks (WLAN), and IEEE 802.11p is an amendment that supports vehicular communications. The IEEE 1609 family of standards address the management and security aspects of the network.

DSRC MESSAGE SET

While IEEE defined WAVE/DSRC technology standards, SAE has been responsible for standardizing the message content used in V2V and V2I communications. The SAE J2735 standard specifies a message set applications based on DSRC. Though the standard is focused on DSRC, it has been designed to enable its use by applications based on other wireless communications technologies.[53]

[51] Source: Misener 2014.
[52] Ibid. USDOT. (2015).
[53] SAE. (2009). "Dedicated Short Range Communications (DSRC) Message Set Dictionary." Society of Automotive Engineers. November 19, 2009. <http://standards.sae.org/j2735_200911/>.

CONNECTED VEHICLE REFERENCE IMPLEMENTATION ARCHITECTURE

The Connected Vehicle Reference Implementation Architecture (CVRIA) project is focused on developing a connected vehicle reference implementation architecture for applications and systems, as well as develop an integrated standards strategy and action plan.[54] The project is systematically documenting and prioritizing interfaces, standards, and gaps. As part of this process, CVRIA is engaging key stakeholders for input and communication through opportunities such as workshops, websites, and review of documents. The project will also identify relevant policy issues and consider opportunities for harmonization.

UNITED STATES DEPARTMENT OF TRANSPORTATION

United States federal agencies are not explicit SDOs. However, these agencies (e.g., NHTSA, FTA, FHWA) have regulatory authority that includes the ability to mandate certain standards be implemented into vehicle and infrastructure technology. Because of this inherent interest in the standards development process, USDOT has been an active participant in standardization and harmonization activities.

3.3 DIFFERENCES BETWEEN THE UNITED STATES AND EUROPEAN UNION STANDARDS

Different types of standards that are of prime importance include standards associated with the applications (i.e. application layer), 5.9 GHz spectrum allocation (i.e. access layer) and security (i.e. security layer). This is because some standards will be dependent on the applications and functionality that need to be deployed. It is considered that a minimum set of standards is required in order to deploy the core functions of C-ITS and to deliver the applications which local stakeholders wish to deploy early.

As discussed in previous chapter, the United States is currently developing a WAVE Protocol architecture (IEEE 1609.0) that is focused on a 5.9 GHz radio interface as opposed to supporting multiple network stacks proposed by the European Union (e.g., ETSI set of standards which focus on 5.9 GHz

[54] CVRIA (2015). Connected Vehicle Reference Implementation Architecture. Website. Accessed February 25, 2015. <http://www.iteris.com/cvria/>.

DSRC and the CEN/ISO which focuses on the concept of a platform using multiple communications). The WAVE protocol architecture is separate from the U.S. Connected Vehicle Reference Implementation Architecture (CVRIA) project.

The United States has set aside a 70 MHz spectrum within the 5.9 GHz band (5.855-5.925 GHz) and Europe has set aside a 50 MHz spectrum (5.855-5.905 GHz). While the spectrum set-asides are not in exact alignment, DSRC hardware will likely be able to comply with both the U.S. and European standards, though there will be some necessary software differences. It is understood the U.S. scenario aims to standardize the interfaces while the EU scenario is creating an ITS station which would manage all communications within the one platform. For example, the EU scenario will facilitate a hazard warning application being delivered via a hazard-warning message from another vehicle via V2V 5.9 GHz DSRC, from roadside infrastructure via infrastructure-to-vehicle (I2V) 5.9 GHz DSRC or from a central office via cellular communications. At this stage, it is unclear how the United States will manage C-ITS applications that could be delivered via multiple communications as its focus is on delivering critical safety (low latency) via 5.9 GHz DSRC.

Having two platforms (e.g. 5.9 GHz DSRC and cellular based) may be an issue for applications that may be delivered via either platform (e.g. hazard warning application which could obtain a hazard warning message from another vehicle via V2V 5.9 GHz DSRC, from roadside infrastructure via I2V 5.9 GHz DSRC or from a central office via cellular communications). In this case, the application may need to identify the communication platform (or technology) it will transmit a message. U.S. standards use the basic safety message (BSM), while European standards use a cooperative awareness message (CAM) and a decentralized environmental notification message (DENM).

Both the U.S. and EU scenarios concentrate on 5.9 GHz communications, however, the EU scenario has a clearer path towards the use of hybrid communications (through the proposed CALM approach) than does the U.S. scenario. As such, the EU scenario is considered more integrated and scalable.

3.4 INTERNATIONAL HARMONIZATION EFFORTS

Though some of the key stakeholders and regions have signed memorandums of cooperation (MOCs) to work together and harmonize connected vehicle standards where possible, different platforms are emerging in different countries. The United States and Europe signed a joint declaration in 2009 pledging to use global standards when possible.[55] The U.S. signed similar agreements with Canada and Japan in 2010 and one with South Korea in 2012.[56] There is also active cooperation between the IEEE, SAE, and ISO groups to harmonize and work towards developing a single harmonized set of standards, with possible regional options where needed.[57]

The adoption of multiple standards within a given area of interest should be limited to those cases where there are demonstrated technical needs, such as differing frequency spectrum allocations, and legal requirements, such as privacy protection laws. The parties welcome participation of other countries and regions, particularly those of the Asia Pacific region, in the development of global open, harmonized standards for C-ITS.

From the perspective of all three sets of standards and the standardization of C-ITS, standards are considered to be either:

- Not yet available (i.e. gaps): These will be completed as part of the finalization of the release 1 set of standards and as part of additional standards releases as C-ITS evolves (discussed further in Section 2.9). Further, while there may be regional differences in C-ITS hardware, it should function irrespective of the region in which it is deployed. The main gaps will be software.
- Competing but compatible with one another: Standards within opposing sets that deal with the same element of C-ITS but in a harmonized and compatible manner.
- Competing and non-compatible with one another: Standards within opposing sets that deal with the same/similar element of C-ITS but in a non-compatible manner.
- Complementary to one another: Standards that should be complementary to one another.

USDOT coordinates, collaborates, and generally exchanges information with transportation agencies from around the world. USDOT has also entered into

[55] RITA 2009.
[56] RITA 2010.
[57] Evensen and Schmitting 2014.

formal cooperative agreements to coordinate ITS research and development efforts.[58]

EU-U.S. JOINT DECLARATION OF INTENT ON RESEARCH COOPERATION IN COOPERATIVE SYSTEMS

Transportation agencies representing both the European Union and United States released a Joint Declaration of Intent on Research Cooperation in Cooperative Systems in 2009.[59] As outlined by Evensen (2013) harmonization is happening rapidly. As part of the EU-U.S. activities, the task group is considering work that will outline gaps and areas of overlap with respect to standards harmonization.

One essential component of this agreement was a passage directed at independent standards organizations encouraging global harmonization of standards. The related passage is outlined in Cadzow et al. (2012) as follows:

> Globally harmonized standards are essential to support and accelerate the deployment and adoption of Cooperative Systems. The parties strongly support development of global open standards which ensure interoperability through appropriate actions including, but not limited to, coordinating the activities of standardization organizations. In particular, the parties intend to preclude the development and adoption of redundant standards.[60]

Further, the European Union and United States have agreed to cooperate in ITS research in order to achieve interoperability on a national/regional level with a focus on creating a global market for ITS products and services with minimal trade barriers.[61] The key goals of the EU-US harmonization activities are:

- a globally harmonized message containing all radio frequency parameters subject to regulation
- a globally harmonized message containing all security, privacy, and authenticity-related parameters
- a globally harmonized protocol for the exchange of such information between ITS stations and the appropriate regulatory authorities.

---

[58] http://www.its.dot.gov/connected_vehicle/international_research.htm
[59] http://its-standards.info/eu_us_joint_decl_on_coop_systems.pdf, accessed April 2015.
[60] Cadzow et al. 2012.
[61] Cadzow et al. 2012.

To move forward with harmonization, the EU and U.S. ITS Standards Program has facilitated activities launching harmonization efforts, established relevant relationships with appropriate U.S. and international entities, and reached out to new entities. At the technical level, established six Harmonization Task Groups (HTGs) to jointly execute activities:

- HTG #1: Service and security management to support joint applications.
- HTG #2: Harmonization of the core safety message set.
- HTG #3: Joint protocols for safety and sustainability services.
- HTG #4/5: Harmonization of broader message sets and data dictionaries, including interface standards supporting applications for signalized intersections.
- HTG #6: Harmonization of relevant aspects of security policies

HTG #1, #2, and #3 completed work during 2013.[62]

U.S.-JAPAN TECHNICAL COOPERATION AND INFORMATION EXCHANGE

USDOT has a long history of research exchange and collaboration with Japan's Ministry of Land, Infrastructure, Transport, and Tourism (MLIT). In 2010, USDOT and MLIT signed a Memorandum of Cooperation regarding ITS.[63] The four high-priority areas of collaboration are:[64]

- Probe Data
- Evaluation Tools and Methods
- International Standards Harmonization
- Automation in Road Transport (trilateral with the European Union).

U.S.-SOUTH KOREA COLLABORATIVE AGREEMENT

In 2012, USDOT signed an Implementing Arrangement with the Korean Ministry of Land, Transport, and Maritime Affairs (MLTM) to collaborate on ITS research.[65] Initial collaboration regards information sharing and lessons learned from pilot deployments.[66]

[62] http://www.its.dot.gov/connected_vehicle/connected_vehicle_standards_progress.htm
[63] Cronin 2012.
[64] USDOT. Web Site. Connected Vehicle Technology/International Research.
[65] Cronin 2012.
[66] Leonard 2014.

CANADA-U.S. REGULATORY COOPERATIVE COUNCIL

Transport Canada (TC) and USDOT established a mechanism for coordinating updates to their national ITS architectures to ensure that technology deployments in both countries adhere to the same manufacturing and operating standards, thereby reducing development and implementation costs. Ongoing alignment work on ITS is supported by two Memoranda of Cooperation signed in 2010. TC and the FHWA jointly developed an implementation plan for the installation of Border Wait Time measurement systems at priority international border crossings and completed pilot projects at two bridge crossings in the Buffalo/Niagara Falls area, which will facilitate additional deployments on the Canada-U.S. border. TC and USDOT worked with the American Association of State Highway and Transportation Officials (AASHTO) on the field infrastructure footprint analysis project which will help ensure coordinated deployment of connected vehicles technology with state departments of transportation (DOTs). V2V communication technology for light-duty vehicles could become a potential area of Regulatory Cooperative Council (RCC) focus moving forward.[67]

[67] U.S.-Canada Regulatory Cooperation Council. *Joint Forward Plan.* August 2014.

4 CONNECTED VEHICLE STANDARDS HARMONIZATION SURVEY

The Connected Vehicle Standards Harmonization Survey was sent to targeted individuals known for their expertise in connected vehicles and familiarity with standards harmonization. The survey used a combination of Likert scale, multiple choice, and open-ended responses to determine the status and implications of connected vehicle standards harmonization. The survey was completed by nineteen individuals, ten of whom gave permission to be identified in this report. A list of these individuals and their affiliation is provided in Appendix B. This section provides a summary of responses to each question.

4.1 IMPORTANCE OF HARMONIZATION

Question 1: "How important is it to develop internationally harmonized connected vehicle standards?"

This question asked respondents to rate the importance of developing internationally harmonized connected vehicle standards on a 1-7 Likert scale, with one meaning "not important," and seven meaning "very important." Thirteen of the nineteen respondents chose a six or seven—implying that respondents generally believe international harmonization to be a very important activity (Figure 6). One respondent described international harmonization as "not important."

4.2 CURRENT STATE OF HARMONIZATION

Question 2: "How would you describe the state of connected vehicle interoperability and standards harmonization between vehicle markets (e.g., European Union, Japan, China, etc.)?"

This question asked respondents to rate the state of harmonization on a 1-7 Likert scale, with one meaning "no harmonization," and seven meaning "ideal harmonization." Most respondents chose a neutral value, indicating "some harmonization" (Figure 7).

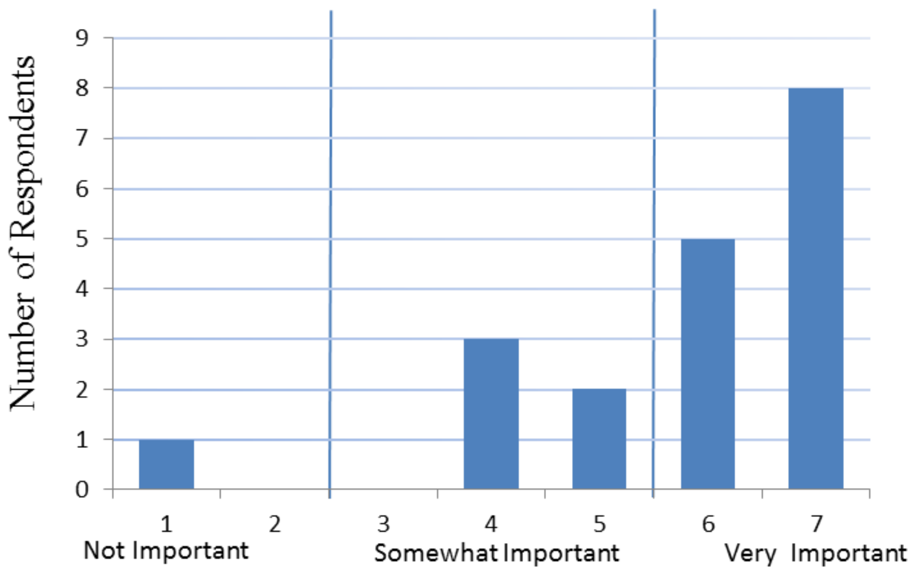

FIGURE 6: SURVEY RESULTS: IMPORTANCE OF INTERNATIONAL HARMONIZATION OF CONNECTED VEHICLE STANDARDS

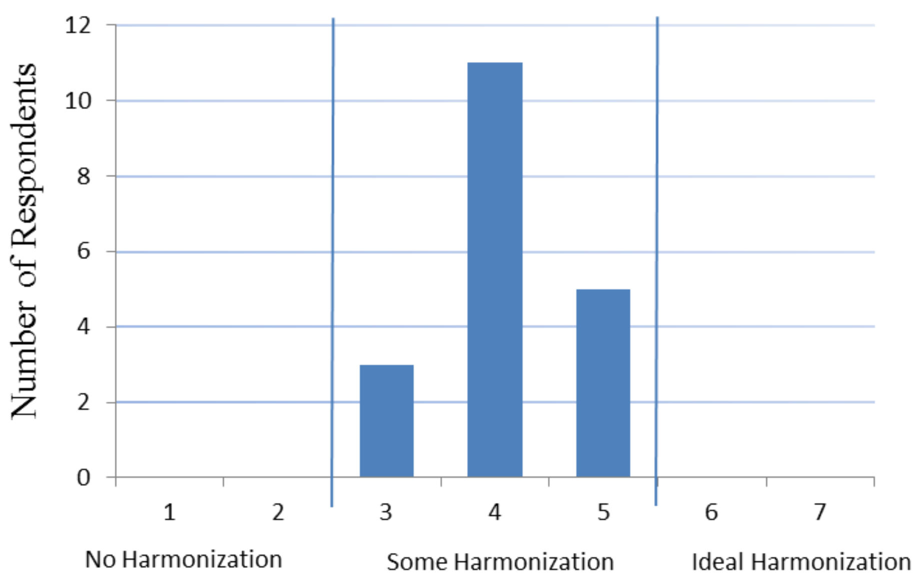

FIGURE 7: SURVEY RESULTS: STATE OF CONNECTED VEHICLE STANDARDS HARMONIZATION

4.3 BEST APPROACH

Question 3: "Do you perceive any specific set of connected vehicle/C-ITS standards as preferable for successful V2X/C-ITS?"

This question asked respondents to determine which approach to connected vehicle standards is preferable between U.S., EU, and Japanese approaches. Ten of the nineteen respondents chose the U.S. approach as preferable. Four chose the EU approach as preferable. No respondents indicated the Japanese approach is preferable. The remaining five reported than none of the approaches was clearly better. It is important to note that U.S. interests were far more represented in this survey than EU, and none of the respondents are known to be based in Japan.

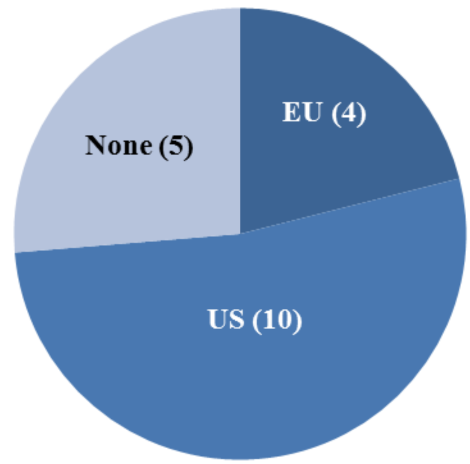

FIGURE 8: SURVEY RESULTS: PREFERRED SET OF CONNECTED VEHICLE STANDARDS

4.4 EFFECT ON CONNECTED VEHICLE APPLICATIONS

Question 4: "How might international harmonization (or lack thereof) affect development of connected vehicle applications?"

Respondents generally indicate that the primary benefit of harmonization is to develop a global marketplace for connected vehicle technologies and applications, allowing the connected vehicle industry to take advantage of economies of scale. If automakers and technology developers can target a broad global market, there will be reduced production costs and thus accelerated deployment and adoption of connected vehicle technologies. While most respondents indicate that this is primarily an issue for the private sector, one respondent pointed out that non-harmonization also increases the amount of public funds necessary to develop, test, and deploy connected vehicle systems because "different message sets and interfaces will impede the ability to transfer applications and lessons learned between different regions."

One respondent (representing a Tier 1 supplier) offered a different perspective: "I do not see [lack of harmonization] as a big concern, as many factors can work against effective harmonization, such as road conditions, bldg., infrastructure, etc."

Two respondents did not provide a response to this question.

4.5 SPECIFIC CONFLICTS

Question 5: "Please list any specifically conflicting standards that are complicating connected vehicle application development and/or deployment."

Nine of the nineteen respondents provided a response to question five, which requested specific conflicting standards complicating connected vehicle technology development. Three respondents referenced general mismatch of spectrum and channel allocation. One respondent indicated that there should be more work determining how cellular networks will be integrated. Specific answers include the following:

- "IEEE 1609.2 conflicts with ETSI TS 103 097"
- "IEEE 1609.3 conflicts with the ETSI geonetworking standards"
- "SAE J2735 and IEEE 1609 vs. ETSI"
- "SAE J2735 vs. ETSI TS 102 637-2"

Additionally, one respondent mentioned that the Japanese approach uses an entirely different set of standards from either the EU or U.S. approaches.

4.6 FEDERAL GOVERNMENT INVOLVEMENT

Question 6: "Please note the extent to which you agree or disagree with the following statement: Involvement of central governments will be essential to achieving desirable levels of connected vehicle standards harmonization."

Respondents generally indicated a belief that government involvement will be advantageous, if not essential to developing connected vehicle standard harmonization. Though two respondents disagreed, most were on the neutral to agreeable end of the Likert scale (Figure 9).

4.7 STATE/LOCAL GOVERNMENT INVOLVEMENT

Question 7: "Please note the extent to which you agree or disagree with the following statement: Involvement of regional governments (e.g., U.S. states) will be essential to achieving desirable levels of connected vehicle standards harmonization."

Respondents generally disagreed, or were neutral, towards the idea that regional governments like state government involvement would be necessary to develop connected vehicle standards harmonization (Figure 10).

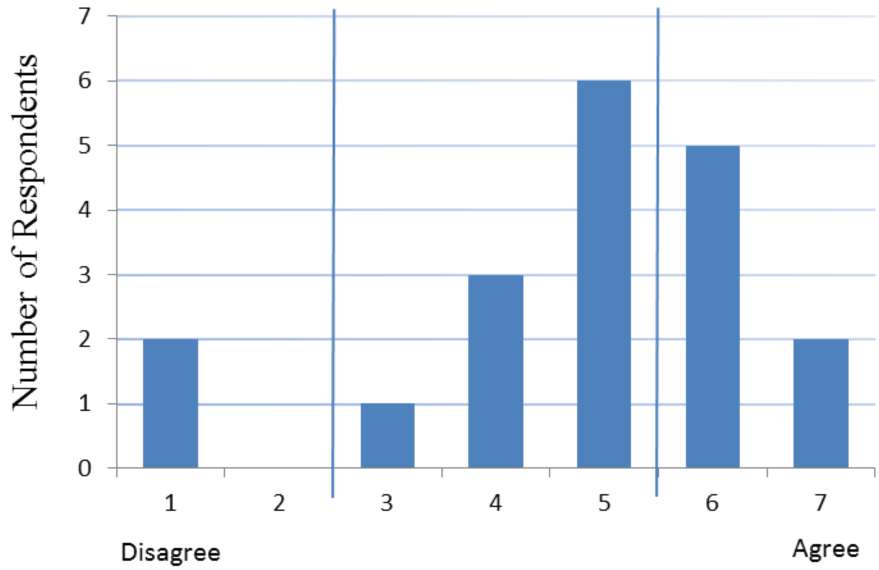

FIGURE 9: SURVEY RESULTS: RESPONDENT AGREEMENT THAT *CENTRAL* GOVERNMENT INVOLVEMENT WILL BE ESSENTIAL TO CONNECTED VEHICLE HARMONIZATION.

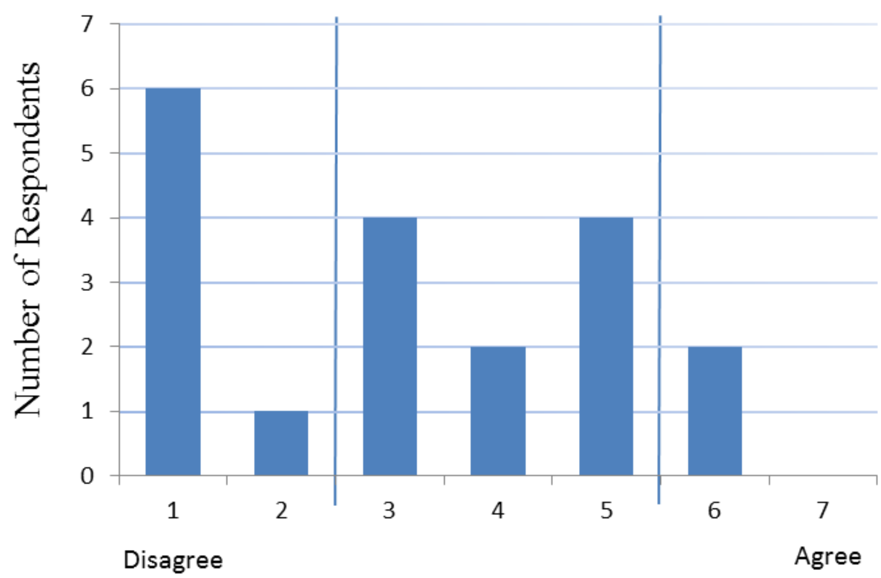

FIGURE 10: SURVEY RESULTS: RESPONDENT AGREEMENT THAT *REGIONAL* (I.E., STATE) GOVERNMENT INVOLVEMENT WILL BE ESSENTIAL TO HARMONIZATION.

4.8 IMPORTANCE OF PUBLIC-PRIVATE PARTNERSHIPS

Question 8: "How important are public-private partnerships to the deployment of connected vehicle technology?"

Respondents rated public-private partnerships as relatively important to deployment of connected vehicles (Figure 11).

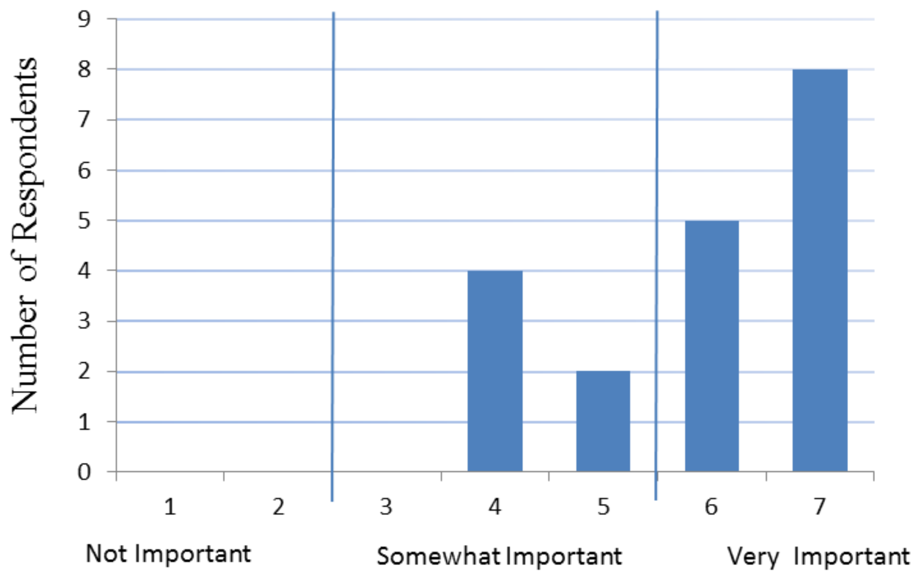

FIGURE 11: SURVEY RESULTS: IMPORTANCE OF PUBLIC-PRIVATE PARTNERSHIPS

4.9 OPEN COMMENTS

Question 9: "In the space below, please provide any additional comments you have regarding connected vehicle standards harmonization."

Respondents were allowed to provide any additional information they considered important regarding standards harmonization. Nine respondents took advantage of this opportunity. Most respondents indicated that standards harmonization is important for connected vehicle deployment and is beneficial to many parties (consumers, producers, regulators). The role of the government in developing these standards is debated (funding and outreach vs. development). A minority expresses concern over harmonization as being harmful to other standards and to the deployment of connected vehicles. All responses are provided below in no particular order.[68]

[68] Some comments were lightly edited for punctuation and grammar only.

"Harmonization of certification testing standards and processes is essential to the ability to bring a device from one region to another and have it stay trusted."

"The standards should be forward-looking and allow for easy migration from current standards to future ones."

"The opportunity for private enterprises, consumers, and governments is almost unimaginable. Harmonizing these efforts will lead to tremendous value for consumers and immense revenue opportunities for all constituents."

"Aside from spectrum, government should not be significantly involved in standards (aside from pushing/funding them). This is an industry issue. The state and local governments should not be involved in standards development; they should be involved in standards *implementation* for V2I."

"For harmonization of standards the governments have a role but not necessarily the central role. On the other hand, governments do need to discuss and harmonize *policies* that will, in turn, affect connected vehicle deployment and standards harmonization."

"International standards harmonization activities should not be allowed to slow the deployment of connected vehicles, and should also not subsequently strand an installed base of connected vehicles."

"The broadcast-enabled TPEG Standards (www.tisa.org) need to be considered as one important part—even in pure connected scenarios.

"Attempts to "harmonize" IEEE and ISO ITS standards are slowing, complicating, and compromising the development of quality IEEE standards."

"Significant work is already being undertaken by USDOT and automobile OEMs. Difficulty is in the breadth of required work and resource availability."

5 CONCLUSIONS AND RECOMMENDATIONS

Connected-ITS applications combine traditional aspects of connected vehicle systems and ITS infrastructure. For C-ITS to function most effectively, there must be interoperability between the ITS infrastructure and vehicle equipment across the fleet. All automakers and infrastructure operators must deploy equipment conforming to a harmonized set of standards. Such cross-organizational standards are usually developed through independent SDOs in coordination with effected government and private interests.

The USDOT Connected Vehicle Program is working towards deployment of a single nationwide connected vehicle network for ITS applications. USDOT does not directly set standards, but can adopt (and influence) standards developed by independent SDOs. The USDOT Connected Vehicle Program utilizes standards from SDOs such as SAE International and IEEE.

Only vehicles with connectivity equipment and software conforming to network standards would be able to operate within a specific C-ITS environment. The connected vehicle network must include security provisions to ensure that each device is valid and not malfunctioning. This implies that in addition to standardized vehicle and infrastructure equipment, the back-office network administration and security process must be standardized and integrated.

At this time, there is no movement towards establishing a truly harmonized set of standards that would allow a single connected vehicle to operate within any C-ITS network across the globe. Thus, for example, it is not likely that a connected vehicle conforming to European standards could connect to C-ITS infrastructure in the US. However, there are significant efforts towards developing connected vehicle standards that are close enough that automakers, governments, and C-ITS technology developers could adopt analogous conceptual and technological frameworks across markets.

C-ITS stakeholders widely believe that such international harmonization of ITS standards will accelerate the deployment of C-ITS systems across the globe by leveraging economies of scale to research, development, and manufacturing activities. The accelerated deployment of C-ITS applications could have broad public benefit, as such technologies are being developed with the intent of improving safety, mobility, and efficiency of the transportation system. This potentially broad social benefit has encouraged

USDOT to coordinate with international agencies in pushing for the greatest possible harmonization of C-ITS standards.

While public transportation agencies have an interest in encouraging internationally harmonized C-ITS, standards-development is primarily a private-sector activity. National governments have some direct authority over certain aspects of C-ITS, such as spectrum allocation. However, governments usually do not have the expertise or authority to directly influence industry standards. Even federal agencies, such as USDOT, must typically wait for appropriate standards to be developed by independent SDOs; only when standards are adopted by SDOs can they be effectively integrated into policy.

Regional governments such as MDOT may have eventual authority over C-ITS infrastructure, and thus have some interest in the standards integrated into C-ITS systems. However, it is difficult to envision how regional governments could have much direct influence over standards development or harmonization processes at this time. If regional governments have well-defined and specific insight to contribute to ongoing standards developments and harmonization activities, they may consider assigning knowledgeable representatives to participate in such activities. Otherwise, regional governments are generally involved in *implementation* of standards. Until USDOT successfully adopts a nationwide C-ITS policy including specific standards, state transportation agencies are generally relegated to observer status while SDOs, industry groups, and national governments work towards standards harmonization and adoption.

The Michigan Department of Transportation is positioned to be a leading adopter of connected vehicle technology if/when USDOT adopts and implements a standardized connected vehicle platform. MDOT has participated in several connected vehicle research and test-bed projects, including the installation of roadside infrastructure conforming to the latest available standards. While MDOT is not in a position to directly influence the development or harmonization of connected vehicle standards, MDOT will sustain a leadership position by actively following standards development and harmonization processes, as well as maintaining in-house expertise on the latest advancements in standards development.

REFERENCES

Ahyar, M., Irfan Syamsuddin, Hafsah Nirwana, Ibrahim Abduh, Lidemar Halide, Nuraeni Umar. "Impact of Vehicle Mobility on Performance of Vehicular Ad Hoc Network IEEE 1609.4." International Journal of Engineering Research and Applications. ISSN : 2248-9622, Vol. 4, Issue 1(Version 3), January 2014, pp.191-195

ANSI. (2015). American National Standards Institute. Website. Accessed June 3, 2015. <www.ansi.org>.

ASTM. (2015). ASTM International. Website. Accessed June 3, 2015. <www.astm.org>.

Bishop, Richard. "Global V2X Deployment: Contrasts with U.S. Approach." Bishop Consulting. January 21, 2013.

Cadzow, Scott, Paul Eichbrecht, Knut Evensen, Hans Davila-Gonzalez, Wolfgang Hoefs, Frank Kargl, John Moring, Richard Roy, Steve Shladover, Turksma, and William Whyte. (2012). "EU-US Standards Harmonization Task Group Report: Overview of Harmonization Task Groups 1&3." Report FHWAJPO-13-073. Research and Innovative Technology Administration, U.S. Department of Transportation. November 21, 2012. <http://ntl.bts.gov/lib/48000/48500/48524/4487DD4C.pdf>.

CEN and ETSI. (2010). "Joint CEN and ETSI Response to Mandate M/453." European Committee for Standardization and European Telecommunications Standards Institute. April 15, 2010. <http://www.etsi.org/website/document/technologies/first_joint_cen_and_etsi_response_to_mandate_453.pdf>.

CEN/ISO (European Commission for Standardization and International Standards Organization). "C-ITS Release 1 list of standards." N196 v2.0. December 14, 2013.

Cregger, Joshua. (2014). "International Survey of Best Practices in Connected and Automated Vehicle Technologies: 2014 Update." Prepared for the Michigan Department of Transportation. Center for Automotive Research. Ann Arbor, Michigan. September 26, 2014. <http://www.michigan.gov/documents/mdot/09-26-2014_International_Survey_of_Best_Practices_in_CV_and_AV_Technologies_471194_7.pdf>.

Cronin, Brian. "USDOT International Collaboration." Presentation to ITS World Congress, October 2012. Accessed April 2015 at http://www.its.dot.gov/presentations/pdf/ES07.pdf.

ETSI. (2013). "Release Process within ETSI TC ITS for Stakeholder Consideration at the

ETSI TC ITS Workshop in Vienna 5-6 February 2013." European Telecommunications Standards Institute. February 5, 2013. <http://www.etsi.org/images/files/Events/2013_its_ws/ETSI_TC_ITS_Release_Process.pdf>.

ETSI. (2014). "CEN and ETSI deliver first set of standards for Cooperative Intelligent Transport Systems (C-ITS)." European Telecommunications Standards Institute. February 12, 2014. <http://www.etsi.org/news-events/news/753-2014-02-joint-news-cen-and-etsi-deliver-first-set-of-standards-for-cooperative-intelligent-transport-systems-c-its>.

Evensen, Knut and Peter Schmitting. (2014). "D3.5b – Standardisation Handbook." iMobility Support. September 12, 2014. <http://www.imobilitysupport.eu/library/imobility-support-activities/its-deployment-deliverables/standardisation/deliverables-2/2672-d3-5b-standardisation-handbook/file>.

Evensen, Knut; Andras Csepinszky. "D3.6 Report on standardization activities." ERTICO – ITS Europe. January 20, 2014.

Gouse, Bill. "SAE Standards Activities for the Introduction of Connected/Automated Vehicles on the Road?" AAMVA. March 25, 2015.

Green, David, Charles Karl, and Freek Faber. (2015). "Cooperative Intelligent Transport Systems (C-ITS) Standards Assessment." Austroads. January 2015. <www.onlinepublications.austroads.com.au/items/AP-R474-15>.

Harding, John; Gregory Powell; Rebecca Yoon; Joshua Fikentscher; Charlene Doyle; Dana Sade; Mike Lukuc; Jing Wang. Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application.. Report No. DOT HS 812 014. National Highway Traffic Safety Administration (NHTSA). Washington, D.C. August 2014.

ITS America. Connected Vehicle Technical Insights: Vehicle Applications and Wireless Interoperability Heterogeneous Networks. Technology Scan Series 2011-2015.

ITSC. (2015). Information Technology Standards Committee. Website. Accessed June 3, 2015. <www.itsc.org.sg/ >.

KATS (2015). Korean Agency for Technology and Standards. Website. Accessed June 2015. <http://www.kats.go.kr/en/main.do>.

Leonard, Ken. (2013). "Policy Implications for Connected Vehicles." Global Connected Vehicle Symposium, University of Michigan Transportation Research Institute, Ann Arbor, Michigan. May 14-16, 2013. <http://global2013.umtri.umich.edu/images/Leonard.Session.I%20copy.pdf>.

Leonard, Ken. Director, ITS, JPO, USDOT. "Executive Session: Trans-National Cooperation on ITS. Presented to 10th ITS European Congress, June 18, 2014. Accessed April 2015 at http://www.its.dot.gov/presentations/pdf/Leonard_ITS_Europe_Transnational_CooperationITS.pdf.

Misener, Jim. (Chair, SAE DSRC Technical Committee.) "Update of SAE Dedicated Short Range Communication (DSRC) Standardization Activities." SAE-ITU Discussion of ITS Communication Requirements. Presentation, October 23, 2014. Accessed April 2015. <http://www.itu.int/en/ITU-T/extcoop/cits/Documents/Meeting-201410-Troy/008%20-%20SAE%20DSRC.pdf>.

RITA. (2009). "Bilateral ITS Research Activities between RITA and the European Commission Directorate General for Information Society and Media." Research and Innovative Technology Administration, U.S. Department of Transportation. November 13, 2009. <http://www.its.dot.gov/strat_plan/eu_directorate.htm>.

RITA. (2010). "Japan MOU-Stakeholder Agreement." Research and Innovative Technology Administration, U.S. Department of Transportation. October 23, 2010. <http://www.its.dot.gov/press/2010/japan_mou.htm>.

Shaffnit, Tom. “Automotive Standardization of Vehicle Networks.” Chapter 7 of *Vehicular Networking: Automotive Applications and Beyond*. pp. 149-169. Ed. Marc Emmelman; Bernd Bochow; C. Christopher Kellum. John Wiley & Sons Ltd. 2010.

TTA. (2015). Telecommunication Technology Association of Korea. Website. Accessed June 3, 2015. <www.tta.or.kr>.

Vehicular Networking: Automotive Applications and Beyond. Ed. Marc Emmelman, Bernd Bochow, and C. Christopher Kellum. John Wiley and Sons, Ltd. ISBN: 978-0-47074151-2. 2010

VIIC (Vehicle Infrastructure Integration Coalition). VIIC Assessment of Key Governance Policy Considerations for a Connected Vehicle Cooperative Safety Communications System – Part 1. VIIC Deployment Analysis and Policy Support , Work Order #4, Task 13 Roadmap General Support, Addendum 09-22-2009 v2. March 12, 2013.

Young, Angela. (2015). “Self-Driving Cars: Japan Wants To Establish Global Standard For Autonomous Vehicle Technology, Safety, Infrastructure.” International Business Times. February 26, 2015. <http://www.ibtimes.com/self-driving-cars-japan-wants-establish-global-standard-autonomous-vehicle-technology-1829404>.

APPENDIX A: LIST OF ABBREVIATIONS

2/3/4G	Second/Third/Fourth Generation (cellular technology)
AASHTO	American Association of State Highway and Transportation Officials
ACI	Adjacent Channel Interference
AEC	Automotive Electronics Council
ANSI	American National Standards Institute
ARIB	Association of Radio Industries and Businesses [Japan]
ASTM	[Formerly] American Society for Testing and Materials
BSM	Basic Safety Message
C2C-CC	Car-to-Car Communications Consortium
CALM	Communications Access for Land Mobiles
CAM	Cooperative Awareness Message
CAMP	Crash Avoidance Metric Partnership
CAN	Controller Area Network
CATARC	China Automotive Technology and Research Center
CCH	Control Channel
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardizations
C-ITS	Cooperative Intelligent Transportation System
CV	Connected Vehicle
CVRIA	Connected Vehicle Reference Implementation Architecture
DENM	Decentralized Environmental Notification Message
DSRC	Dedicated Short-range Communications
EAN	Extended Area Network
EFTA	European Free Trade Agreement
ERTICO	ITS Europe
ETC	Electronic Toll Collection
ETSI	European Telecommunications Institute
EU	European Union

FCC	Federal Communications Commission
FDD-LTE	Frequency Division Duplex LTE
FHWA	Federal Highway Administration
FTA	Federal Transit Authority
HAP	Harmonization Action Plan
HD	High Definition
I2V	Infrastructure-to-Vehicle
IAN	Incident Area Network
ICT	Information and Communications Technology
IDA	Infocomm Development Authority (Singapore)
IEC	International Electro-technical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEEE-SA	IEEE Standards Association
IETF	Internet Engineering Task Force
IP	Internet Protocol
ISO	International Organization for Standardization
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITS JPO	ITS Joint Program Office
ITSC	Information Technology Standards Committee (Singapore)
ITSTC	Intelligent Transport Systems Technical Committee (Singapore)
JAN	Jurisdictional Area Network
JARI	Japan Automobile Research Institute
JSAE	Society of Automotive Engineers of Japan
KATS	Korean Agency for Technology and Standards
LLC	Logical Link Control [layer]
LTE	Long-term Evolution [cellular technology]
MAC	Medium Access Control
MDOT	Michigan Department of Transportation

MIIT	Ministry of Industry and Information Technology
MLIT	Ministry of Land Infrastructure Transport, and Tourism (Japan)
MLTM	Ministry of Land, Transport, and Maritime Affairs (South Korea)
MOC	Memorandum of Cooperation
NEMA	National Electrical Manufacturers Association
NHTSA	National Highway Traffic Safety Authority
NTCIP	National Transportation Communications for Intelligent Transportation Systems Protocol
OBD	On-board Diagnosis
OBU	On-board Unit
OEM	Original Equipment Manufacturer
OST-R	Office of the Assistant Secretary for Research and Technology
OTA	Over-the-Air
PHY	Physical [layer]
RCC	Regulatory Cooperative Council
RDS	Radio Data System
RFC	Request for Comment
RFID	Radio Frequency Identification
RSU	Roadside Unit
SAC	Standardization Administration of China
SAE	[Formerly] Society of Automotive Engineers
SCH	Service Channel
SDO	Standards Development Organization
SWG	Standards Working Group
TC	Technical Committee
TC	Transport Canada
TCP	Transmission Control Protocol
TDD-LTE	Time Division Duplex LTE
TISA	Traveler Information Services Association
TPEG	Transport Protocol Experts Group

TTA	Telecommunication Technology Association [Korea]
UDP	User Datagram Protocol
U.S.	United States
USDOT	US Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	V2V + V2I
VANET	Vehicular Ad-hoc Network
VIIC	Vehicle Infrastructure Integration Coalition
WAVE	Wireless Access in a Vehicular Environment
WLAN	Wireless Local Area Network
WSMP	WAVE Short Message Protocol
ZVEI	German Electrical and Electronic Manufacturers Association

APPENDIX B: RESPONDENTS TO CONNECTED VEHICLE STANDARDS HARMONIZATION SURVEY

In addition to the eleven individuals listed in the table below, eight others completed the survey and chose to remain anonymous.

Name	Affiliation
Hongwei Zhang	Wayne State University
Scott J. McCormick	Connected Vehicle Trade Association, Inc
Ali Maleki	Ricardo Inc
Patrick Chuang	Booz Allen Hamilton
Mike Bauer	TheCarPage
Greg Krueger	Leidos
Tom Schaffnit	A2 Technology Management LLC
Martin Dreher	Bayerischen Medien Technik
Carl K. Andersen	FHWA
Dominic Paulraj	Arada Systems Inc
Name not disclosed	Security Innovation