Automotive Technology: Greener Vehicles, Changing Skills

Electronics, Software & Controls Report

CAR
CENTER FOR AUTOMOTIVE RESEARCH

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Automotive Technology: Greener Vehicles, Changing Skills

ELECTRONICS, SOFTWARE & CONTROLS REPORT

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DRIVING CHANGE
Greening the Automotive Workforce

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1. Introduction

Vehicle electronics and communications represent a significant growth area in the motor vehicle sector. Vehicles house an increasingly complex array of electronics; electronic couplings have, over time, replaced mechanical couplings across a broad array of vehicle systems and subsystems. Today, electronics (in the form of sensors), actuators, micro-processors, instrumentation panels, controllers and displays appear in nearly all major vehicle systems, including:

- Engine controllers and sensors
- Safety systems
- Chassis control
- Measurement and diagnostic modules
- Entertainment systems
- Navigation systems
- Communication systems

In the last 20 to 30 years, electronics have introduced functionality not possible in a purely mechanical framework. Perhaps most obviously, this new functionality appears in safety systems (electronic stability control, tire-pressure monitoring, hands-free calling, etc.), navigation systems and entertainment systems (Bluetooth® interfaces, USB connections, etc.). In the next five to 10 years, these advances are likely to include even more safety features, such as lane departure warning and perhaps vehicle-to-vehicle communications, as well as more infotainment options—many brought into the vehicle through handheld devices (e.g., 3G and 4G smart phones). Indeed, the explosive growth in wireless communications presents enormous opportunities for vehicle technology that are difficult to predict at this time.

Vehicle electronics also contribute significantly to improved environmental performance of motor vehicles and are, therefore, an important enabler of "green" vehicle technology. These contributions come through several different mechanisms. At the most basic level, electronics offer improved control to a variety of vehicle systems, allowing for more efficient operation of engines and other powertrains, and heating and cooling systems, etc., resulting in less fuel (or other power) consumed and thus, lower harmful emissions. Today's complex hybrid powertrains could not be operated and managed without an array of electronics, including sensors, controllers and actuators. Furthermore, electronic components tend to be lighter than the mechanical components they replace, again leading to less demand for fuel and power options. In the next 10 years, electronics in the form of vehicle communications and connectivity will contribute in additional ways. For example, electronics will bring traffic and mobility information into the vehicle. This will allow for even more efficient powertrain operations as a result of situational awareness and more efficient vehicle routing to avoid congestion, crashes, construction zones, etc., again improving fuel economy and lowering emissions.

1.1 Methodology

To shed light on trends related to vehicle electronics and corresponding employment needs related to the automotive sector, researchers at the Center for Automotive Research (CAR) employed several different methods to gather data and information. These methods included both secondary and primary (expert interviews) research. For the secondary research, CAR studied technology and market trends for vehicle electronics via a literature search—reviewing articles, reports and other documents on the current state of the technology, the market, and what future trends may be. This review included work completed in previous CAR studies that involved primary data collection.

To supplement the data and information gathered from secondary sources, CAR researchers developed a questionnaire and interviewed 12 people representing the public, private, and nonprofit sectors. These experts have significant knowledge of vehicle electronics and provided substantial insight into the future trends, technological applications and expectations for labor skills needed. Specifically, CAR interviewed representatives of the organizations listed below:

- Automotive Insight (retired Ford engineers)
- Bosch
- DENSO
- Continental
- General Motors
- ITS America
- Michigan Department of Transportation
- Microsoft (recently retired person)
- Ricardo
- Specialty Equipment Market Association
- Vehicle Infrastructure Integration Consortium
- University of Michigan Transportation Research Institute

Furthermore, based on prior research conducted by CAR,[1,2] other interviewees representing additional organizations have offered input to assist in understanding technology trends in the vehicle electronics area. This prior research, however, did not explicitly address employment issues.

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[1] Underwood, Steve, Valerie Sathe Brugeman, and Richard Wallace. Public, Automotive, and Telematics Sector Views on the Future of Vehicle Communication Technology Expert Panel Survey and Forecast. Center for Automotive Research. June 18, 2008

[2] Smith, Brett, Richard Wallace, and Bernard Swiecki. The Specialty-Equipment Company of the Future: Guideposts for Technology Forecasting and Strategic Planning. Center for Automotive Research. September 2008.

2. Vehicle Electronic Systems: Market Overview

The electronic content in automobiles has been steadily increasing since the 1970s, with the beginning of that decade seeing the introduction of the electric voltage regulator and the electric ignition[3] and the end seeing the first use of microprocessors.[4] The trends for increased electronics continued throughout the 1980s and 1990s, making many engine and safety electronics standard equipment in vehicles. For example, the average Ford vehicle contains 60 microprocessors to run its electrical content, up from 15 devices 10 years ago.[5] In 2006, prior to the economic collapse of the late 2000s, the market for automotive electronics was forecast to grow at about 7 percent annually for at least a decade.[6] As the industry recovers, this trend can be expected to re-emerge.

In addition to being a difficult year for the automotive electronics industry as a whole, 2008 was a difficult year for the automotive electronics industry specifically, with demand for electronic systems falling by 3.0 percent to $148 billion (according to an analysis by StrategyAnalytics.)[7] The same report predicted that 2009 would be even worse, with the market falling another 14.5 percent to $126 billion. Given that increased use of electronics in new vehicles is a very realistic way of meeting future environmental and safety requirements, the industry is in a position to recover and grow rapidly when the economy begins to improve. A strong recovery for automotive electronics is forecast for 2010, with demand rising by 14.3 percent.[8] The market has been forecast to grow to $203 billion by 2013 with a compound average annual growth rate of 6.5 percent from 2008 to 2013.[9]

This growth in electronics content has also had an effect on employment to date. As shown in Figure 1, even though total U.S. employment in motor vehicle electronics has declined since 2005, the percentage of U.S. motor vehicle electronics employment as a percentage of total U.S. motor vehicle employment has shown a net upward trend since 2002. Thus, while the total number of electronics jobs in the vehicle sector has dropped along with declines in employment throughout the automotive sector, electronics jobs have fared somewhat better than the industry

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[3] IHS Global Insight. (2009). "Resistance Is Futile – Electronics Are on the Rise: Electronic Control Units and Communication Protocols." IHS Global Insight, Inc. April 2009.

[4] Turley, Jim. (2008). "Motoring with Microprocessors." Embedded Systems Design. August 11, 2003. <http://www.embedded.com/columns/significantbits/13000166?_requestid=265679>.

[5] Barkholz, David. "Fixing Cars' Brains Saves Ford Millions." Automotive News. May 10, 2010.

[6] Tils, Valentin von. (2006). "Trends and Challenges in Automotive Electronics." Proceedings of the 18th International Symposium on Power Semiconductor Devices and IC's.

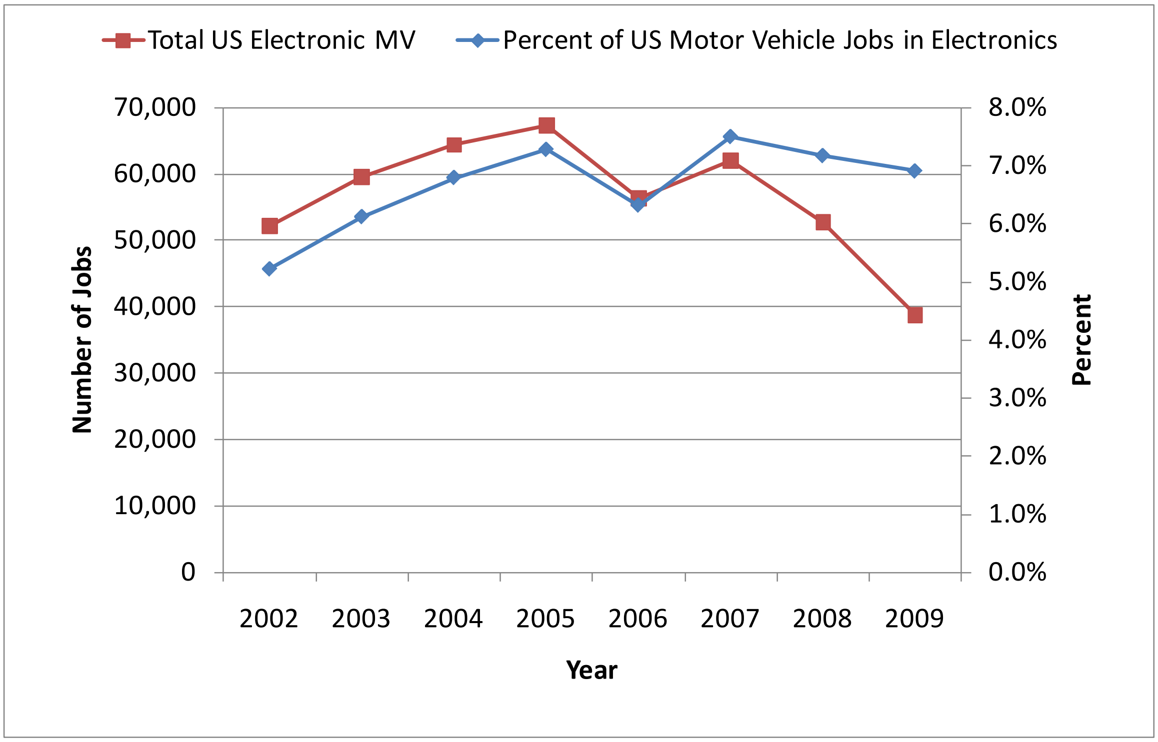
[7] Riches, Ian. (2009). "Automotive Electronics System Demand Forecast 2007 to 2016." StrategyAnalytics. April 30, 2009. <http://www.strategyanalytics.com/default.aspx?mod=ReportAbstractViewer&a0=4699>.

[8] Ibid.

[9] Ibid..

as a whole. This suggests that, as total motor vehicle employment recovers domestically, electronics employment is poised to increase at a relatively faster rate.

Figure 1: Total Number of U.S. Motor Vehicle Electronics Jobs Has Fallen in Recent Years, while the Percent of Motor Vehicle Jobs in Electronics Has Risen



Source: Bureau of Labor Statistics

Currently, the cost for vehicle electronics is as high as 40-50 percent of the total cost of the vehicle. This is up from 20 percent less than a decade ago.[10,11] The increase in electronics content has created more difficulty in repairing malfunctions. Specifically, diagnosing faults and making minor modifications is becoming more complicated due to the increasing amount of software and wiring within vehicles.[12] Ford has found a method to avoid these extra costs. The company is fixing or updating the software inside these microcontrollers instead of replacing the entire unit.[13] Dealers also have the software to repair the malfunctions.

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[10] Altera. (2010). "Automotive Industry Trends." Altera. Accessed April 13, 2010. <http://www.altera.com/end-markets/auto/industry/aut-industry.html>.

[11] Murray, Charles J. (2009). "Automakers Aim to Simplify Electrical Architectures." *Design News*. July 29, 2009. <http://www.designnews.com/article/316784-Automakers_Aim_to_Simplify_Electrical_Architectures.php>.

[12] Murphy, Niall. (2009). "Introduction to Controller Area Network (CAN)." Netrino. Accessed August 20, 2009. <http://www.netrino.com/Embedded-Systems/How-To/Controller-Area-Network-CAN-Robustness>.

[13] Barkholz, David. "Fixing Cars' Brains Saves Ford Millions." Automotive News. May 10, 2010.

In recent years, there has been a push to simplify electrical architectures within automobiles, especially since the electrical content of vehicles continues to experience dramatic growth.[14] Buses are internal communication networks that allow vehicle components to connect with each other. Although the implementation of these buses for data transfer has aided in reducing the complexity of vehicle wiring, it is difficult to keep pace with the electronic features that are continually being added. Current bus systems used to integrate control units are becoming overloaded, especially in luxury segments.[15]

The desire to reduce the complexity of the electrical architecture has largely been driven by the need for cost and weight reductions in vehicle electrical content. The thick bundles of wires within automobile are responsible for adding 45 to 65 pounds to the weight of each car, with luxury cars using even more wiring.[16] The wiring harness is the third heaviest (after the body and engine) and most expensive component of an automobile.[17] Due to additional electronic requirements in hybrid vehicles, the wiring harness for a hybrid costs 20 to 25 percent more than one for a conventional vehicle. By simplifying the electronic architecture of a car, there is potential to reduce the amount of wiring needed, providing savings to the manufacturer (in lower materials costs) and savings to the consumer (through minor improvements in fuel efficiency).

Solutions for simplifying automotive electrical architectures will likely include up-integration to multifunction microcontrollers as a major strategy. By making a single microcontroller responsible for four functions instead of just one, the total number of microcontrollers used in a car can be reduced. These up-integration solutions, if carefully implemented, can result in decreasing the use of wiring by connecting a single microcontroller to systems that are near each other.[18] Though controllers may be fewer, they will need to be more powerful to be able to handle the increased load created by handling multiple devices. By focusing on creating regional zones within the automobile and integrating features that are physically close to one another, automakers could reduce the number of microcontrollers by 40 to 60 percent. Other approaches will include the incorporation of dual-core processors into vehicle architectures, allowing a single electronic control unit to handle more operations.

Because of new electronic applications and the need to simplify electronics architectures, new suppliers formerly uninvolved with the automotive industry have become integral players in its future. Traditional semiconductor suppliers and software developers now have opportunities

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[14] Murray, Charles J. (2009). "Automakers Aim to Simplify Electrical Architectures." *Design News*. July 29, 2009. <http://www.designnews.com/article/316784-Automakers_Aim_to_Simplify_Electrical_Architectures.php>.

[15] IHS Global Insight. (2009). "Resistance Is Futile – Electronics Are on the Rise: Electronic Control Units and Communication Protocols." IHS Global Insight, Inc. April 2009.

[16] Murphy, Niall. (2009). "Introduction to Controller Area Network (CAN)." Netrino. Accessed August 20, 2009. <http://www.netrino.com/Embedded-Systems/How-To/Controller-Area-Network-CAN-Robustness>.

[17] IHS Global Insight. (2009). "Resistance Is Futile – Electronics Are on the Rise: Electronic Control Units and Communication Protocols." IHS Global Insight, Inc. April 2009.

[18] Murphy, Niall. (2009). "Introduction to Controller Area Network (CAN)." Netrino. Accessed August 20, 2009. <http://www.netrino.com/Embedded-Systems/How-To/Controller-Area-Network-CAN-Robustness>.

open to them and will likely see more engagement in the definition and specification of future electronic control units, communication protocols and automotive architectures.[19] Now, rather than developing and producing just one printed circuit board with a few semiconductor components, suppliers will be expected to produce complex mechatronic systems that will include more complex hardware, software and materials. In addition, these systems will be networked together with other systems in the automobile, so network considerations will need to be considered in design.[20]

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[19] IHS Global Insight. (2009). "Resistance Is Futile – Electronics Are on the Rise: Electronic Control Units and Communication Protocols." IHS Global Insight, Inc. April 2009.

[20] Hansen Report. (2009). "The Hansen Report on Automotive Electronics." Vol. 22, No. 7. September 2009. <www.hansenreport.com>.

3. Key Vehicle Electronic System Descriptions

As described earlier, modern vehicles contain electronic components in nearly all vehicle systems, including those pertaining to powertrain, passenger safety and more. While all of these systems are important, several merit closer inspection, because they represent growth areas or because they are critical to current and future vehicles. One of these systems is the powertrain, which is both absolutely essential for the vehicle to operate and a likely growth area for electronics due to stricter fuel economy and emissions standards and the evolving mix of powertrain types (e.g., hybrids, electric, etc.). Another is vehicle communication systems; these can involve both technologies within vehicles and technology installed on the roadside. These technologies enable information sharing within a vehicle, between a vehicle and other vehicles, in mobile devices and in roadside infrastructure. These communication systems contribute to greater capabilities in the areas of mobility, infotainment and safety, where "mobility" refers to the ease and efficiency of travel and can include navigational assistance and traffic coordination. (Infotainment systems include features such as navigation and entertainment.[21]) Safety systems go beyond communications, of course, and include a wide variety of features—from those that are now standard in vehicles (e.g., air bags) to those that are currently found only in high-end automobiles (e.g., lane departure warning systems).

3.1 Powertrain and Transmission Controls

The use of electronics in vehicle powertrains is not new. Computers began to play a role in vehicle engines in the 1970s in response to fuel economy and emissions regulations, and their role has expanded.[22] Known as the powertrain control module (PCM), the engine computer has several functions in traditional internal combustion engines, including fuel management, idling speed control, ignition timing, and emissions control.[23] Today's PCMs offer 500 times more memory than the first PCMs and can perform 2,000 operations per second.[24] This progression in increased processing power is demonstrated in Table 1, which shows the changes in General Motors's PCMs over a 26-year span.

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[21] National Semiconductor. (2008). "Automotive Infotainment Applications." National Semiconductor. <http://www.national.com/vcm/NSC_Content/Files/en_US/Automotive/Automotive_Infotainment_Applications.pdf>.

[22] Hatch, Steve V. Computerized Engine Controls. Delmar, Cengage Learning. 2009.

[23] Ibid.

[24] Bogden, Dennis. "Electronic Controls for the 21st Century Powertrain." Auto Electronics. 1 October 2004.

Table 1: Changes in PCM Hardware and Software[25]

Component	1979	2005
Microprocessor	Custom Motorola 6800 (8 bit)	Motorola Power PC (32 bit)
Microprocessor Clock Speed	1 MHz	56 MHz
Memory	4 kBytes	2000 kBytes
Programming Language	Assembly Code	C Code
Calibration	0.256 kBytes	256 kBytes
Sensors and Actuators	5 each	20 each
ECM Pins	Fewer than 50	More than 200

Source: Frank, Randy. "The Newest Care Models – Software." Auto Electronics. 1 September 2005.

In addition to developments within the engine proper, vehicle electronics have also proliferated within transmissions. In 1980, electronics controlled one function, whereas they controlled 60 functions by 2005.[26]

Looking forward, as powertrain technology evolves to include gas-electric hybrids, clean diesel, pure electric, and someday perhaps even fuel cells, more electronic components will be introduced. From some estimates, the electrical and electronics content in hybrid vehicles will double what it is now.[27] Power electronics currently comprise as much as 20 percent of a hybrid vehicle's material costs, which is almost on par with the cost of the battery itself.[28] It is conceivable that electronic content and cost will be similarly high for plug-in hybrid electric and pure electric vehicles. Given the increased focus on development and deployment of these cleaner, more

advanced powertrains, the amount of electronic content will continue to increase.

3.2 Vehicle Communications

Telematics is a growing form of communications system and refers to applications that utilize wireless information sent to or from a vehicle. The use of telematics technology is not new; it has existed for many years in the form of AM, FM and CB radios as well as GPS units and in-car cellular phones.[29] Current telematics systems, however, attempt to integrate a greater variety of services into vehicles, focusing on place-based services. The global market for in-vehicle intelligent transportation systems was around $1 billion in 1999,[30] grew to $4 billion by 2001

[25] Frank, Randy. "The Newest Care Models – Software." Auto Electronics. 1 September 2005.

[26] Ibid.

[27] Frank, Randy. "Hybrid Vehicles Propel Increased Electronics Content." Auto Electronics. 1 October 2004.

[28] Frank, Randy. "Power Electronics Challenges for Hybrids." Auto Electronics. 1 November 2008.

[29] Ealey, Lance and Miller, Glenn. (1999). "Telematics: Where the radio meets the road." The McKinsey Quarterly. Spring 1999 i2 p6(1).

[30] R.G., R., Konish, N., & Gawel, R. (1999). "Buckle up! In-vehicle ITS market is on the go." Electronic Design, 47(1), 48E. January 11, 1999.

and is projected to be $47 billion by 2010.[31] General Motors has made OnStar, its embedded telematics system, a standard feature on all its cars.[32] By 2015, 40 to 50 percent of vehicles produced in North America, and 30 percent produced in Europe will have automaker embedded telematics.[33]

Sales of automotive telematics systems are forecast to be 84.4 million units in 2016, an increase from 19.3 million units in 2008. Of the 84.4 million units sold in 2016, 68.4 million (81 percent) will be installed by automakers as compared to 14.3 million (74 percent) in 2008. Aftermarket sales of telematics systems are projected to rise to just under 16 million (19 percent) in 2016, up from slightly less than 5 million (26 percent) in 2008. In 2009, the United States accounted for about half of the automaker telematics market, but by 2016, the United States will account for only about one-third of the worldwide market as telematics penetration increases in other parts of the world.[34]

There are two major types of telematics systems offered in the market currently: embedded systems (integrated into the dashboards of cars) and mobile device-oriented systems (a wireless device like a cell phone used to communicate information). Both systems are rapidly growing with embedded telematics units projected to increase from 4.8 million (34 percent) in 2008 to over 26.8 million (39 percent) in 2016 and mobile device telematics units increasing from 9.5 million (66 percent) in 2008 to more than 41.5 million (61 percent) in 2016.[35]

As the penetration of telematics in vehicles increases, these systems may serve as trigger technologies, allowing other technologies to be more readily taken up. For instance, with the adoption of telematics systems that network automobiles to each other, to mobile devices, and to roadside infrastructure, additional technologies can be enabled such as improved theft prevention, automatic toll collection, automatic vehicle registration and drivers license renewal, improved traffic control, driver monitoring for insurance purposes, and automatic driving, among others.[36]

The vehicle communication concept (formerly known as IntelliDrive[37] and before that, Vehicle Infrastructure Integration) uses advanced in-vehicle telematics systems along with

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[31] Starry, C. (2001). "The Emerging In Vehicle Intelligent Transportation Systems Market." Business Economics. April 2001.

[32] Buettner, Anna (2009). "Global Automotive Telematics Shipments to Expand by Factor of Four by 2016." iSuppli. December 2, 2009. <http://www.isuppli.com/Automotive-Infotainment-and-Telematics/News/Pages/Global-Automotive-Telematics-Shipments-to-Expand-by-Factor-of-Four-by-2016.aspx>.

[33] Blight, Joanne. (2009). "Automotive Telematics Market Forecast 2007-2015." January 8, 2009. <http://www.strategyanalytics.com/default.aspx?mod=ReportAbstractViewer&a0=4429>.

[34] Buettner, Anna (2009). "Global Automotive Telematics Shipments to Expand by Factor of Four by 2016." iSuppli. December 2, 2009. <http://www.isuppli.com/Automotive-Infotainment-and-Telematics/News/Pages/Global-Automotive-Telematics-Shipments-to-Expand-by-Factor-of-Four-by-2016.aspx>.

[35] Ibid.

[36] Ealey, Lance and Miller, Glenn. (1999). "Telematics: Where the radio meets the road." The McKinsey Quarterly. Spring 1999 i2 p6(1).

[37] Due to copyright issues, the US Department of Transportation ceased use of the term *IntelliDrive*[SM] in January 2011. As of the date this report was published, a new term had yet to be determined.

infrastructure upgrades with the overall goal of promoting networked wireless communications among vehicles, infrastructure, and personal communications devices. Wireless technologies, offer the potential to make vehicles safer, smarter and greener.[38] Vehicle communication applications enable crash prevention, travel optimization, road condition warnings and environmental benefits by taking advantage of continuous real-time connectivity to vehicles, infrastructure and wireless devices.

3.3 Vehicle Safety Systems

Electronic safety features include antilock brakes, air bags, electronic stability control and traction control, along with even more advanced tools like lane change/blind spot assist and collision warning. With the increasing electrification of safety features, it may be possible for reductions in more physical safety considerations, allowing for cost, weight and fuel savings. Safety considerations are one of the largest drivers for increasing the electronic content of the vehicle, and the market for automotive safety electronics will continue to grow over the next few years. In particular, air bags and rollover protection will see an increase in penetration.[39]

The integration of electronic sensors has allowed for significant improvements in the safety and security of automobiles. Theft prevention, air bag deployment, automatic seat belt adjustment, tire pressure monitoring, occupant detection and pedestrian detection[40] as well as vehicle stability control and traction condition monitoring are all functions that use sensors.[41]

By coordinating already existing systems and sensors and introducing new hardware, safety features can be improved. In 2002, Mercedes-Benz introduced a safety system called PreSafe®, which integrated passive (hazard-detection technology) and active (seatbelt tensioners and automatically adjusting seats and windows) safety features. The Mercedes system monitors vehicle behavior and sends warning signals to the driver if conditions become hazardous. When situations become critical, active safety systems like electronic stability control are deployed. If a crash is likely, other safety systems are engaged: front and rear seats move to position occupants upright, belts are tensioned, knee bolsters are extended and windows are automatically closed.[42] Automotive suppliers are now marketing similar systems. Continental has devised a system called "Active Passive Integration Approach" and Denso has created the "Pre-Collision System."[43]

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[38] US Department of Transportation. (2010). "IntelliDrive℠: Safer. Smarter. Greener." Accessed May 7, 2010. <http://www.intellidriveusa.org/about/overview.php>.

[39] Fischer, Kirsten. (2006). "Auto Electronics Market to Exceed US$50 Billion by 2010." Reed Electronics Research. September 19, 2006.

[40] Prosser, S. J. (2007). "Automotive Sensors: Past, Present, and Future." *Journal of Physics*: Conference Series 76 012001

[41] Ealey, Lance and Miller, Glenn. (1999). "Telematics: Where the radio meets the road." The McKinsey Quarterly. Spring 1999 i2 p6(1).

[42] SRS. (2009). "Vehicle and Product Safety: Crash Prevention." Safety Research & Strategies, Inc. 2009. <http://www.safetyresearch.net/safety-issues/crash-prevention/>.

[43] Ibid.

Connected vehicle applications can further promote safety by enabling vehicles to have 360-degree awareness, informing drivers of hazards and situations they cannot see and reducing crashes through advisories and warnings. These warnings might include advisories for entering a school zone, approaching a sharp ramp curve, nearing an area with slippery roads or other hazardous conditions. This warning system also allows users to take into account the timing of traffic signals to know whether it is safe to cross an intersection or whether they should stop at the light. Drivers could also be advised of the presence of bicycles and pedestrians equipped with vehicle communication devices, enhancing safety for all users.[44]

3.4 Mobility Enhancement

The information created by vehicle communication applications could be used to improve mobility. Using information gathered through the communications network, transportation managers can monitor and manage transportation system performance (adjusting traffic signals, transit operations, or dispatching maintenance/emergency personnel). Emergency vehicles will be able to send signals to traffic lights at intersections en route to calls, stopping cross traffic and ensuring a clear path to the emergency site. Commercial and municipal fleet operators will be able to use vehicle communications to manage resources more efficiently: reducing travel times, lowering costs and improving the environmental impact. Similarly, individuals in personal vehicles will be able to use real-time information about traffic congestion and other conditions to make more informed route decisions. By optimizing travel routes, users can save time, fuel and money. By using personal communication devices, travelers can optimize their transportation strategies, avoiding congestion by taking alternate routes or using alternate modes of transportation (e.g., public transit).[45]

3.5 Infotainment Systems

Infotainment systems are predominantly audio and video components with versatile displays that may be used for controlling an array of systems from audio to HVAC and navigation to wireless Internet. The current availability of many infotainment systems products is relatively limited to high-end vehicles and the aftermarket.[46] Increasingly, vehicle manufacturers are attempting to include vehicle solutions that can readily integrate consumer electronics such as the use of media-oriented systems transport (MOST) and Firewire architectures and the inclusion of USB ports and Bluetooth® connectivity. It is likely that by making these “plug and play architectures” more common in new vehicles, there will be fewer barriers to producing

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[44] US Department of Transportation. (2010). “IntelliDrive: Safer. Smarter. Greener.” Accessed May 7, 2010. <http://www.intellidriveusa.org/about/overview.php>.

[45] US Department of Transportation. (2010). “IntelliDrive: Safer. Smarter. Greener.” Accessed May 7, 2010. <http://www.intellidriveusa.org/about/overview.php>.

[46] IHS Global Insight. (2009). “Resistance Is Futile – Electronics Are on the Rise: Electronic Control Units and Communication Protocols.” IHS Global Insight, Inc. April 2009.

infotainment systems for vehicles—increasing competition among suppliers to gain and maintain market share.[47]

The interfaces included in dashboards are shifting from electromechanical displays to LCDs as the cost differential between the two options disappears.[48] As time passes, these displays are becoming more complex, controlling dozens of functions. Careful consideration of the ergonomics of displays and controls is becoming a more central issue, as the proper deployment of touch screens, buttons and surfaces can be used to enhance the driver experience while reducing distraction.[49] Speech interfaces, currently available in high-end models, could play an increasingly common role in improving safety as the legal rules governing the use of devices requiring hand controls change.

There are increasingly more options for entertainment systems within vehicles. Sound systems have evolved from simple head units through CD players to include MP3 players and adaptors for consumer music electronics. Subwoofers and amplifiers from aftermarket suppliers may be added to improve sound quality. Infotainment options are opening: applications like integrated navigation systems, mobile video and wireless Internet are already available in some models. Single platform integrated systems such as UConnect™ and SYNC® have been developed with support from partners like AT&T and Microsoft and include options like integration of cell phones, PDAs and MP3 players as well as options for voice command, traffic information, directions, and other telematics features.

3.6 Risks to Development of Mobility and Infotainment Applications

Though growing in popularity among consumers and increasing competition among manufacturers, mobility and infotainment applications pose various risks that threaten their development. Concerns about driver distraction and infringement on user privacy could result in consumer disapproval, regulatory prohibition, or legal battles. Cyber-security concerns also could pose risks and result in legislation hindering system development.

3.6.1 Distracted Driving

The National Highway Traffic Safety Administration (NHTSA) defines distracted driving as engagement in any of a number of activities, including eating, drinking, talking with passengers, texting, phone use and in-vehicle use of electronic devices while driving. Studies show that driver involvement in secondary tasks contributes to more than 22 percent of all crash and near-crash events.[50] According to NHTSA, distracted driving caused 5,870 fatalities (16 percent of all

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[47] Ibid.

[48] Hansen Report. (2009). "The Hansen Report on Automotive Electronics." Vol. 22, No. 7. September 2009. <www.hansenreport.com>.

[49] Ibid.

[50] US Department of Transportation. (2010). "Distracted Driving Stats and Facts." Accessed June 9, 2010 <http://www.distraction.gov/stats-and-facts/>.

fatal crashes) and 515,000 injuries in 2008.[51] With functions such as Internet browsing and dictated text-messaging being integrated, infotainment systems can both decrease and increase driver distractions.

Data from NHTSA and the Virginia Tech Transportation Institute show that use of mobile devices (texting, talking, dialing, Internet browsing, etc.) is the driver distraction associated with the highest risk of crash or near-crash events.[52]

Federal and state governments have responded to such studies by restricting use of mobile devices by drivers. The Federal Motor Carrier Safety Administration (FMCSA) prohibits commercial truck and bus drivers from texting with any handheld cell phone or other device that takes a driver's attention off the road.[53] Seven states (California, Connecticut, Maryland, New York, New Jersey, Oregon and Washington), the District of Columbia and the Virgin Islands prohibit all drivers from using handheld cell phones while driving. Twenty-six states, the District of Columbia and Guam ban text messaging for all drivers, and some states such as Maine, New Hampshire and Utah treat cell phone use and texting as part of a larger distracted driving issue.[54]

Infotainment and mobility applications that take drivers' eyes off the road pose similar risks to driver safety. Unless developers work to reduce driver distractions resulting from infotainment applications, state and federal regulators will likely institute restrictions on use of infotainment applications similar to those enforced on mobile phone use. Ray LaHood, U.S. Secretary of Transportation, has vowed to speak out against infotainment applications that increase driver distraction and is engaged in a nationwide campaign to increase laws against distracted driving.[55] In addition to regulatory concerns, infotainment developers and automotive companies must also be aware of legal risks. Companies could be legally liable if a person's vehicle crashes and the cause is determined to be the vehicle's infotainment system.[56]

To mitigate these concerns, several infotainment manufacturers have begun developing ways to reduce driver distraction caused by infotainment applications. Some infotainment developers are considering ways to manage the content available to drivers based on what maneuvers the driver is performing at a given time. Volkswagen, for example, is developing ways to limit access to e-mail and other types of content when a driver is making a lane change or driving on a curvy

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[51] US Department of Transportation. (2010). "Distracted Driving Stats and Facts." Accessed June 9, 2010 <http://www.distraction.gov/stats-and-facts/>.

[52] Box, Sherry. "New data from Virginia Tech Transportation Institute provides insight into cell phone use and driving distraction." *Virginia Tech News*. July 29, 2009. <http://www.vtnews.vt.edu/story.php?relyear=2009&itemno=571>.

[53] US Department of Transportation. (2010). "New distracted driving restrictions on commercial truck and bus drivers." January 26, 2010. <http://fastlane.dot.gov/2010/01/commercial-truck-and-bus-drivers-prohibited-from-texting-while-driving.html>.

[54] Governors Highway Safety Association "Cell Phone and Texting Laws." June 2010. <http://www.ghsa.org/html/stateinfo/laws/cell phone_laws.html>.

[55] Vance, Ashlee & Matt Richtel. "Despite Risks, Internet Creeps onto Car Dashboards." *New York Times*. January 6, 2010. <http://www.nytimes.com/2010/01/07/technology/07distracted.html?pagewanted=1&em>.

[56] Ibid.

road.[57] Companies are also working on ways to reduce driver distractions that presently exist. Nuance Communications Inc. has provided speech recognition technology to Fiat and Microsoft's Blue & Me infotainment system that allows a person to control an iPod with voice commands and have text messages read while driving. Technology that allows drivers to dictate text messages while driving is projected to be available by 2012.[58] Further measures such as completely locking out use of functions while the vehicle is moving or limiting access to rear seat occupants may also be taken by manufacturers to reduce driver distraction.

3.6.2 **Privacy Concerns**

Many vehicle communication applications involve communication between vehicle and infrastructure. This type of communication raises privacy concerns because it could lead to vehicle drivers, owners and passengers being tracked while driving or being detected violating traffic laws, leading to legal penalties.[59]

The National VII Coalition—consisting of representatives from the U.S. Department of Transportation (USDOT), automakers, and state representatives—addressed privacy concerns by establishing the *VII Privacy Policies Framework* in 2007.[60] The framework outlines nine principles regarding privacy and personal information related to a national vehicle communication system. The principles begin with the Principle of Respect for Privacy and Personal Information, followed by the Information Purposes Principle, Acquisition Principle, Notice Principle, Fair Information Use Principle, Information Protection and Retention Principle, Openness Principle, Participation Principle and Accountability Principle. A major goal of these principles is to guarantee that users in these networks have anonymity.

Although the *VII Privacy Policies Framework* seeks to ensure that vehicle communication network users have anonymity, privacy concerns still persist. Stakeholders—including privacy rights groups—who attended the June 2009 *USDOT Intelligent Technology Systems Strategic Planning Workshop* identified the need for vehicle communication to improve data quality, develop metadata and interoperability standards that also address privacy and security concerns and to have those standards adopted. Furthermore, stakeholders asserted that the data collection program must be built on a solid foundation of security, privacy and ownership. A major shortcoming of the *VII Privacy Policies Framework* that stakeholders pointed out is that the framework does not address privacy when several sources of data are combined.[61]

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[57] Edmunds Auto Observer. "Automakers Grapple with New-Age Dilemma: Software or Hardware?" Accessed May 17, 2010. <http://www.autoobserver.com/2010/05/automakers-grapple-with-new-age-dilemma-software-or-hardware.html>.

[58] Bolduc, D. "Profiting from stupidity" *Automotive News Europe*. January 31, 2010. <http://www.autonews.com/article/20100131/BLOG08/100129840>.

[59] Noblis. "Anonymity and IntelliDrive[SM]." February 2009. <http://www.intellidriveusa.org/documents/Anonymity.pdf>.

[60] Jacobson, Leslie. "VII Privacy Policies Framework, Version 1.0.2." *Institutional Issues Subcommittee of the National VII Coalition.* February 16, 2007. <http://www.intellidriveusa.org/documents/privacy-policy.pdf>.

[61] Battelle Memorial Institute. "USDOT ITS Strategic Planning Workshop June 4, 2009, Synthesis Report of Findings." July 6, 2009. http://ntl.bts.gov/lib/31000/31000/31066/14487_files/synthesis.pdf

Vehicle communication technology developers continue to address privacy concerns and technical issues as the technology progresses. In May 2010, they released a draft policy roadmap that includes action steps that will be taken to address privacy concerns, and also presented a three-year timeline for development of a feasible privacy process that will be accepted by stakeholders, tested, and become available for implementation.[62]

3.6.3 Cyber Security Concerns

Cyber security concerns run the gamut from electromagnetic interference between the growing multitude of electronic systems on board the vehicle to malicious attempts to hack the vehicle bus and harm the vehicle or its passengers. While such concerns clearly have had no discernable effect on the development the Internet or wireless networks, these systems lack the critical life-and-death passenger safety issues associated with motor vehicles. With the findings from NASA and NHTSA that electronic problems did not cause acceleration problems reported by some Toyota owners, public and legislative concerns related to faulty electronics may be alleviated for the time being.[63]

[62] US Department of Transportation. "Policy Roadmap for IntelliDriveSM Safety: Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) DRAFT: 05/19/2010" <http://www.intellidriveusa.org/documents/DRAFT%20Safety%20Program%20Policy%20Roadmap%205%2019%2010.pdf>.

[63] National Highway Traffic Safety Administration. (2011). Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems.

4. Electronic Components Overview

As described above, the electronics content of vehicles is spread across several vehicle systems and subsystems. Wherever these systems exist, however, they are composed of a myriad of electronic controllers, sensors, actuators, instrument panels, displays and data buses, as well as the software that allows it all to run properly. These components are the building blocks of vehicle electronics.

4.1 Microcontrollers

Currently, microcontrollers or electronic control units (ECUs) are used to run the electronics within the car, often with one microcontroller for each individual function. Engines, transmissions and brakes all have their own controllers; air bags, navigation, stability control systems and peripherals (window lift motors, seat motors, anti-theft alarms, door locks, power motors, lights, remote keyless entry, HVAC systems, radios, CD players, back-seat videos, several displays) also use microcontrollers.[64] The average car already uses between 30 and 45 ECUs; luxury cars use more than 70.[65] For the average vehicle, the number of ECUs per vehicle could exceed 70 by 2020,[66] with the cost for each additional ECU ranging from $10 to $15.[67]

4.2 Automotive Sensors

Sensors serve a myriad of roles within the automobile (see Figure 2) and were initially included in automobiles in the late 1980s with the adoption of air bag sensors. In 2003, the overall sensor market was around $42.2 billion, and the automotive sensor market was around $10.5 billion, making it the largest of the market segments for sensors. (Other segments include machinery manufacturers and suppliers, processing industries, aircraft and ship building, construction sector, consumer and other electronics.)[68] Because the types of sensors used in the automotive industry tend to be cheaper than those used in other sectors, automotive would have an even greater share were the market divided by production volume. The average annual growth rate of the sensor market is estimated at 4 to 5 percent, while the average annual growth rate for the automotive sensor market ranges from 5 to 7.5 percent.[69] Despite the global

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[64] Murray, Charles J. (2009). "Automakers Aim to Simplify Electrical Architectures." *Design News*. July 29, 2009. <http://www.designnews.com/article/316784-Automakers_Aim_to_Simplify_Electrical_Architectures.php>.

[65] IHS Global Insight. (2009). "Resistance Is Futile – Electronics Are on the Rise: Electronic Control Units and Communication Protocols." IHS Global Insight, Inc. April 2009.

[66] Murray, Charles J. (2009). "Automakers Aim to Simplify Electrical Architectures." *Design News*. July 29, 2009. <http://www.designnews.com/article/316784-Automakers_Aim_to_Simplify_Electrical_Architectures.php>.

[67] Hansen Report. (2009). "The Hansen Report on Automotive Electronics." Vol. 22, No. 7. September 2009. <www.hansenreport.com>.

[68] Reinhart, Karl-Franz and Illing, Matthias. (2003). "Automotive Sensor Market." Sensors Update. Volume 12, Issue 1 pp. 213-230. February 25, 2003. <http://www3.interscience.wiley.com/cgi-bin/fulltext/103519894/PDFSTART>.

[69] Ibid.

economic crisis, Strategy Analytics forecasts that the average annual growth rate for automotive sensors will be 5.4 percent between 2008 and 2013. The forecast suggests that the market will grow from $11.7 billion in 2008 to $15.2 billion in 2013.[70]

A major sector of the sensor market is the Micro Electro-Mechanical Systems (MEMS) market, which was worth $7.6 billion in 2008 (includes non-automotive applications), $8 billion in 2009 and is predicted to grow to $16.7 billion by 2012.[71] The MEMS accelerometer market (the type of sensor used for air bag deployment is a MEMS accelerometer) was worth $876 million in 2008, down to $846 million in 2009, but potentially growing to $1.6 billion by 2012[72] (or $1.7 billion in 2013 up from $947.7 million in 2007).[73] Automotive applications drive this market, accounting for 40 percent of revenues in 2008 (down from 78 percent in 2006),[74] or by another estimate, 45 to 50 percent share (in 2009).[75] Although automotive applications have been the main driver for MEMS sensor applications to date, the future market will likely be driven by consumer electronics products with a focus on information technology and communications.[76]

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[70] Fitzgerald, Mark. (2009). "Automotive Sensor Demand Forecast 2007-2016: Main Data Tables. August 28, 2009. <http://www.strategyanalytics.com/default.aspx?mod=ReportAbstractViewer&a0=4972>.

[71] Knivett, Vanessa. (2009). "MEMS Accelerometers: A Fast-Track to Design Success?" *EE Times*. February 11, 2009. < http://www.eetimes.com/showArticle.jhtml?articleID=213403733>.

[72] Ibid.

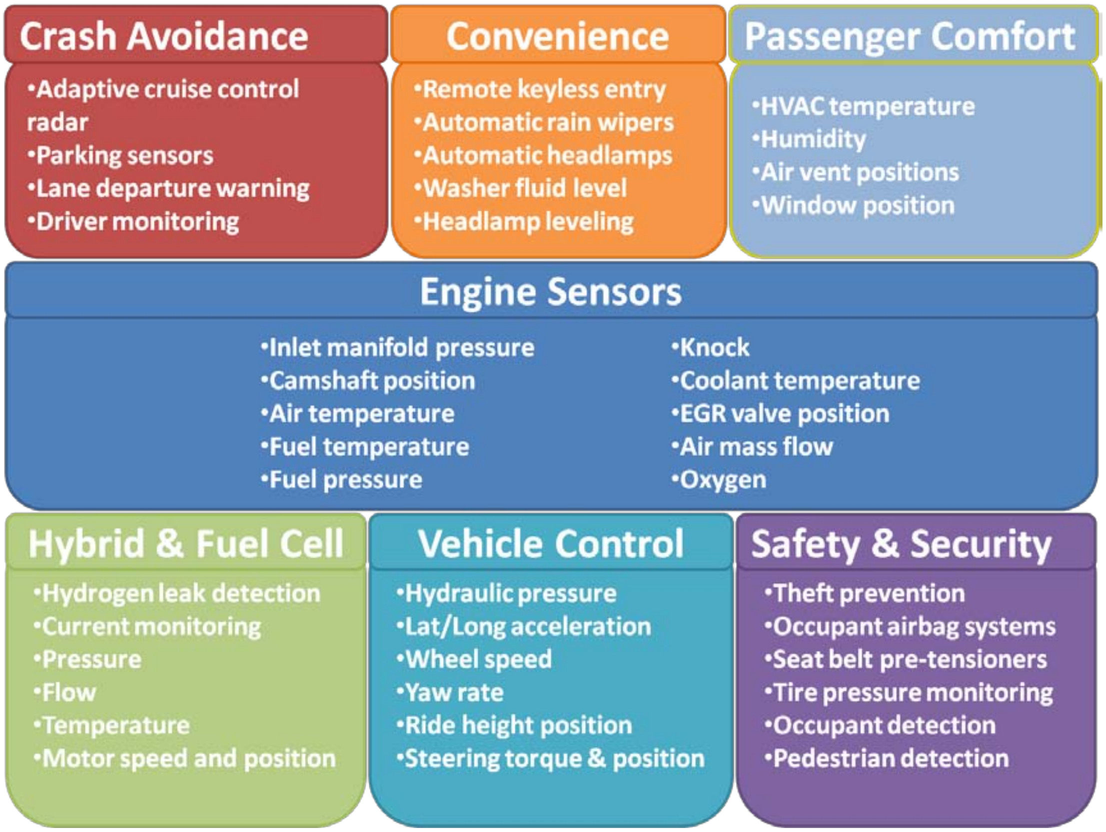
[73] Bouchaud, Jérémie. (2009). "Accelerometers set to become leading MEMS device in 2013." iSuppli. May 28, 2009. <http://www.isuppli.com/MEMS-and-Sensors/News/Pages/Accelerometers-Set-to-Become-Leading-MEMS-Device-in-2013.aspx>.

[74] Ibid.

[75] Knivett, Vanessa. (2009). "MEMS Accelerometers: A Fast-Track to Design Success?"

[76] Ernst, Peter. "MEMS @ BOSCH: Automotive Applications and Beyond." Robert Bosch GmbH Automotive Electronics. <http://www.mstbw.de/imperia/md/content/mstbw/bestpractice/bosch_mems_12_micromachine_symposium_ernst.pdf>.

Figure 2: Types of Automotive Sensors



Source: Prosser, S. J. (2007).

4.3 Actuators

An actuator is a mechanism used to initiate valves required to stop or start a function. Actuators can use fluid, air, or electric current to facilitate motion and can be divided between two categories: acoustic system or haptic system. Acoustic system actuators are used to create high frequency vibrations and require electric current or magnetic presence to function. They are most commonly used in audio equipment. Haptic system actuators produce vibrations at lower frequencies and can be initiated by coming in contact with a pressurized force. Haptic system actuators include manual, hydraulic and electric actuators.

Electric actuators are usually powered by a motor that provides torque required to run the actuator. The motor is connected to a gear or thread that creates thrust to move the valve. Electric actuators are used to operate the valves in mechanical equipment and require a battery backup to ensure safe operation should electric current somehow be prohibited. Electric actuators can be divided into linear, multi-turn and part-turn actuators.

- **Linear:** A linear actuator is a device that applies force in a linear manner, as opposed to rotationally, like an electric motor. Various methods are used for achieving this linear motion. Some actually convert rotational motion into linear motion.

- **Multi-turn:** A multi-turn actuator transmits torque to a valve for at least one full revolution. Depending on the valve, a few or several hundred rotations may be required to fully open or close the valve.
- **Part-turn/Quarter-turn:** Part-turn actuators are similar to multi-turn actuators, but only transmit a torque to a valve for less than one full revolution and are used for the automation of part-turn valves (butterfly valves, ball valves, plug valves and quarter-turn dampers). The amount of revolution usually means a turn of 90° (hence the name quarter-turn), but some valve types require a different swing angle.

4.4 Automotive Data Buses

The parameters that are used to determine which type of bus to use in an automotive electric system include the data rate, complexity and costs involved in the associated physical layer and protocol, robustness, safety level, ability to work in harsh environments and immunity grade from external noise.[77]

4.4.1 Types of Automotive Buses

Some of the most common automotive buses include controller area network (CAN), local interconnect network (LIN), MOST, SAE J1850 and FlexRay™.[78] CAN is the standard architecture for automotive communications and will likely dominate for many years to come due to investments that have already been made in it.[79] It has been widely used in Europe for years and has more recently become popular in the United States, gradually replacing SAE J1850.[80] LIN is a network system, used as a sub-network of a CAN bus to integrate sensors. MOST is a high-speed network used for devices which require multimedia capabilities.[81] IDb 1394, a high-speed version of Firewire that has been designed specifically for automotive applications, will likely replace MOST in the long-run.[82] FlexRay™ is designed to be faster and more reliable than CAN, but it is also more expensive. It will likely replace CAN in many instances as time passes and the complexity of automotive networks surpass CAN's ability to meet manufacturers' and customers' needs.[83]

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[77] Lovati, Stefano. (2009). "An Overview of Automotive Buses." April 3, 2009. <http://dev.emcelettronica.com/overview-automotive-buses>.

[78] Ibid.

[79] Murphy, Niall. (2009). "Introduction to Controller Area Network (CAN)." Netrino. Accessed August 20, 2009. <http://www.netrino.com/Embedded-Systems/How-To/Controller-Area-Network-CAN-Robustness>.

[80] Turley, Jim. (2008). "Motoring with Microprocessors." Embedded Systems Design. August 11, 2003. <http://www.embedded.com/columns/significantbits/13000166?_requestid=265679>.

[81] Murphy, Niall. (2009). "Introduction to Controller Area Network (CAN)." Netrino. Accessed August 20, 2009. <http://www.netrino.com/Embedded-Systems/How-To/Controller-Area-Network-CAN-Robustness>.

[82] Ibid. IHS Global Insight. (2009).

[83] Murphy, Niall. (2009). "Introduction to Controller Area Network (CAN)." Netrino. Accessed August 20, 2009. <http://www.netrino.com/Embedded-Systems/How-To/Controller-Area-Network-CAN-Robustness>.

5. Future Activity

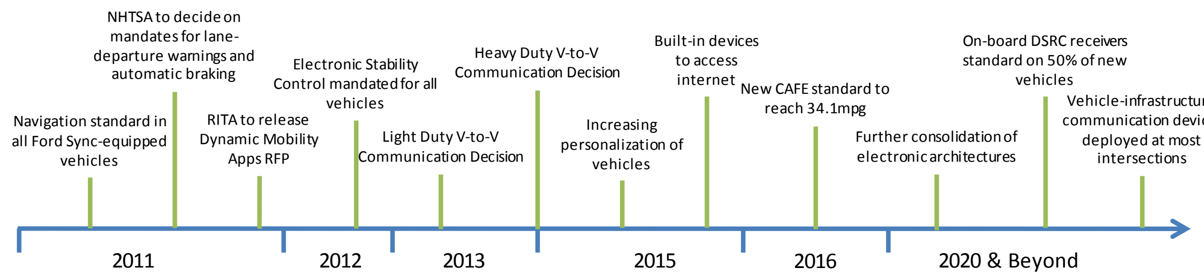
In the next five to 10 years, the electronic content of vehicles will continue to increase, and new functional systems will emerge that rely on electronics. These are likely to include active safety systems, which will rely on sensors (electro-optical or RADAR or both) and control units; vehicle communication systems for vehicle-to-vehicle and vehicle-to-infrastructure communications (for both safety and other applications); instrument panels and displays that integrate with consumer electronics (such as smart phones, digital music players); and more. In addition, we expect to see advances in chip technology on-board vehicles (such as the proliferation of dual-core processors) and greater attention to cyber security.

5.1 Vehicle Electronic Trends

All respondents believe that the electronic content in vehicles will continue to increase in upcoming years, likely at an increasing rate. This increase will include more electronic applications (such as navigation and infotainment); in addition, items that were formerly mechanical will continue to become more electronic. Within the next five years, personalization of the driver's experience will also increase, mirroring the popularity of social networking applications and the ability to get information and entertainment instantaneously. Vehicles will see greater integration of electronic systems to support more applications. Electronic control units (ECUs) are expensive; therefore, vehicle manufacturers will try to reduce the number of ECUs by integrating them. Also, components like the CAN bus will facilitate more communication within the vehicle itself. Stemming from this, the "head unit" of a vehicle, or the main unit housing radio, music, temperature controls, navigation, etc., will continue to evolve, achieving greater significance as more technological functionality is added. The vehicle aftermarket will play an important role in helping more cars become equipped with vehicle communication and other technology that is electronic in nature. Numerous vehicles (such as those equipped with Ford SYNC®) already allow external devices, such as smartphones and digital music players, to interface with electronic systems built into the vehicle.

In the next 10 years, the electronic architecture of vehicles will become more consolidated; if electronic content continues to increase, the vehicle's present electronic organization would not be able to sustain the increase. Electronic data transmission will get faster and possibly use more FlexRay™ than CAN; currently, FlexRay™ is much faster (higher data transmission rates) but more expensive. Wireless data transmission is also on the horizon, most likely through ultra-wide band (UWB).

Figure 3: Timeline for Selected and Notable Projected Milestones in Vehicle Electronics



Source: Center for Automotive Research

5.1.1 Illustrative Case Study: Keyless Entry Systems

Because the fundamental nature of vehicle electronics is not expected to change radically in the next five to 10 years, looking at a case study of a particular technology might offer a better picture of the growing and evolving developments in this area. Vehicle entry systems are one good example of changing technologies within the automobile that have resulted in and will continue to drive increased electronics content and functionality. For the better part of the last century, vehicle entry systems were largely mechanical. In the early 1980s, the remote key hit the market and steadily gained market share. The remote keyless entry (RKE) system uses a key fob that has buttons used for locking and unlocking vehicle doors. The passive keyless entry (PKE) system is another remote system which does not require the user to press buttons; rather, this system automatically locks and unlocks vehicle doors as the key fob approaches or moves away from the vehicle.

The RKE system is considered to be mature and is factory installed on nearly 80 percent of the vehicles produced each year. In 1999, the PKE system was introduced and is currently factory installed in about 10 percent of new vehicles, up from less than 5 percent just three years ago.[84] By 2015, PKE systems are forecast to be found factory installed in around 20 percent of new vehicles (see Figure 4). Growth in the production of keyless entry systems is expected to speed up between 2010 and 2012 as the North American economy recovers and the price of PKE systems decreases. (In 2007, the price of hardware for a PKE system was over $90; by 2015, it is expected that the price will drop to $50.)

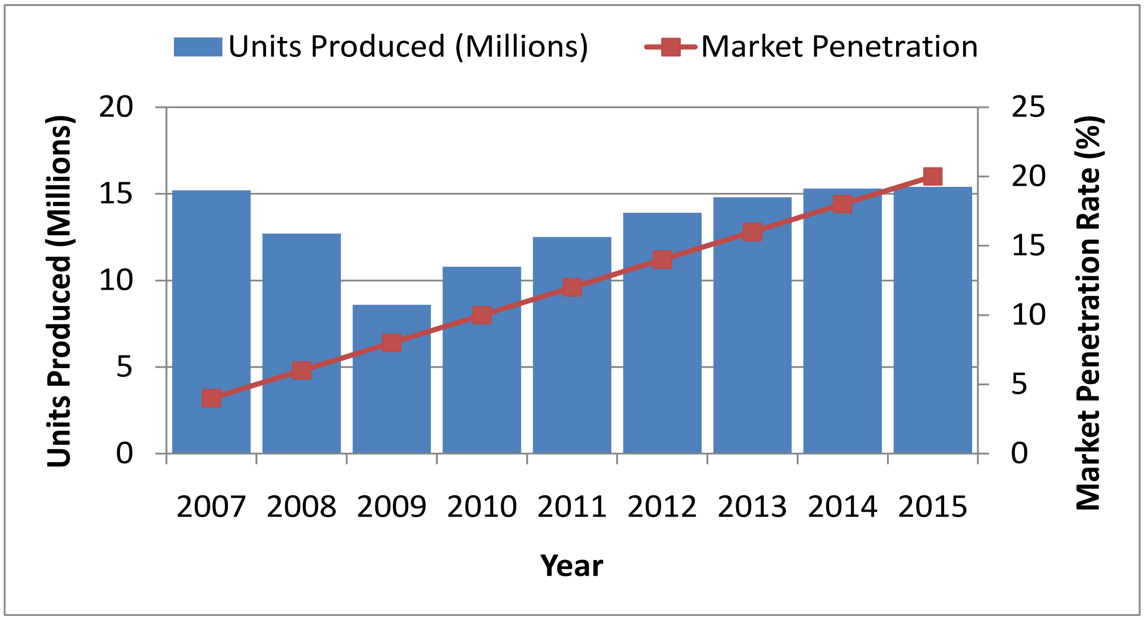
Although the demand for PKE systems is expected to increase significantly over the next five years, RKE will still be used in over 75 percent of new vehicles because the technology is cheaper (less than $20 for the hardware). A small percentage (2 to 3 percent) will continue to use mechanical keys.[85] As entry systems become more complex, they will be able to integrate more functionality, displaying vehicle information such as tire pressure, fuel level and live video feed; adding security features such as fingerprint recognition; and adjusting settings to take into

[84] Frost & Sullivan. (2009). "Keyless Vehicle Entry Systems Market in North America." Frost & Sullivan. August 2009.

[85] Ibid.

account personal preferences (seat position, mirror adjustment and radio station presets). In the not-too-distant future, key fobs could be replaced by mobile phones, adding even more functionality while simplifying controls and reducing the number of devices used by consumers.

Figure 4: Passive Keyless Entry Systems Market Forecast for North America



Source: Frost & Sullivan. (2009)

This case study demonstrates two critical dimensions of the growing market penetration of vehicle electronics. First, the amount of electronics in use grows by replacing functions previously performed by mechanical systems. Second, the electronic systems themselves evolve over time to incorporate additional functionality. Ultimately, this results in fewer distinct components—each with more and/or additional capabilities.

5.2 Electronic and Technological Applications

Not surprisingly, technological applications will continue to evolve as well. In the next five years, respondents expect to see an increase in connected vehicle applications, including safety, infotainment and mobility. Safety applications include forward collision warning, blind spot detection and other cooperative safety technologies. Infotainment applications include those allowing drivers and passengers to be productive in the vehicle, perhaps having the vehicle be a kind of mobile office. People want information to be instantly and easily accessible. Along similar lines, mobility applications on the five-year horizon include improved navigational capabilities and location-based services. There is need for data coverage to be improved, making navigational updates and finding restaurants or other locations near a vehicle an easier prospect. There will also likely be limited corridor deployment of roadside communication equipment that allows computers to monitor how quickly vehicles are moving and indicate where there are backups. That info can be sent to vehicles with navigation software and alert drivers to avoid those areas.

Distraction is an issue brought up around the mobility and infotainment aspects of vehicle electronics technology. To combat that, one representative mentioned the use of electronic technologies, such as speech recognition and workload management systems, to reduce the possibility of distraction.

A final application mentioned in the five-year horizon is the ability to monitor vehicle diagnostics. This will permit automakers to know how their vehicles are being used, as well as allow owners to download software updates wirelessly to enhance customer convenience. Mobile devices and computers are already updated this way; the capability will similarly be brought to vehicles.

Within the next 10 years, respondents expect a continuation and evolution of the above-mentioned applications, in addition to some new ones. Potential new safety features include fatigue detection and real-time parking information. From the roadside perspective, new applications include signal change warnings, road condition alerts and more widespread corridor deployment of roadside communication equipment units. In addition, the U.S. Department of Transportation can be expected to encourage greater use of autonomous (or semi-autonomous) vehicle safety applications to help eliminate driver error. These systems will use varying combinations of electro-optical sensors, RADAR sensors and communications (for cooperative systems) linked to ECUs and actuators.

6. Impact on Workforce Skills

The proliferation of electronics and electronic components in motor vehicles has been affecting employers' needs for skilled labor; these effects are expected to continue for the next five to 10 years. The changes are likely to affect the specific skill sets required, as well as the number of workers and where they are likely to be needed. Advances in vehicle communications (as represented by the USDOT's vehicle communication program) and efforts within the industry (such as the Crash Avoidance Metrics Partnership) also indicate that electronics skills will be needed in the public sector for deploying roadside equipment and the telecommunications industry, for communications infrastructure. While much of this employment cannot be attributed directly to the motor vehicle industry, it will affect the industry in terms of skills needed to design, manufacture, maintain and repair in-vehicle communications equipment. Today, this equipment is primarily represented by GM OnStar and Ford SYNC®, but new developments are on the horizon.

6.1 Skills Needed

The increase in vehicle electronics and the applications on the horizon signal an increased need for people with electronic, software and computer network skills. The specific disciplines mentioned are:

- Electrical engineers
- Software engineers
- Systems engineers
- Radio frequency engineers
- Computer engineers (systems architecture and cyber security)
- Server/information technology engineers

In addition to these disciplinary-based skill sets, respondents also stressed skills related to specific functions, such as validation testing, system certification, hazards analysis and fault tolerance analysis. Respondents indicated that manufacturers will demand increasingly that suppliers perform the testing needed to validate and certify electronic systems and subsystems, with specific mention made of the emerging ISO standard 26262, which addresses the functional safety of road vehicles.

Although public sector departments of transportation likely will contract out much of the communications work, both contract employees and the in-house hires made will have to be proficient in electronic communication, especially radio frequency technology. Transportation agency contractors, as a result, will have a growing need for staff with training in electronics and electrical engineering.

Table 2 shows the SOC codes that were identified as being relevant to motor vehicle electronics, and an assessment of whether skills will be evolving (the job is changing but there is nothing fundamentally new), additive (new roles and/or skills are being added), or new (new to the automotive sector). The table also indicates the demand for workers skilled in many of these code areas will be increasing.

The biggest theme, however, involves integration of various engineering disciplines, sometimes called "systems engineering." In the past, engineers were schooled in specific areas: chemical, mechanical, electrical, computer, etc. Now, as the technology becomes more and more integrated, the labor force must know how all the pieces of the engineering process fit together. One respondent described it as the importance of knowing the whole process, instead of specializing in individual, autonomous pieces of the process. Among the automotive manufacturers, especially, future emphasis will be on system integration, with suppliers increasingly taking the lead on the individual pieces.

Table 2: Motor Vehicle Electronics and Information Systems Skill Assessment

			Skill Impact on Workforce			Expected Trend
Job Function	**Associated SOC Codes**	**Description**	**Evolving**	**Additive**	**New**	
Production (manufacturing, assembly)	11-3051	Industrial production managers	x			Neutral
	17-3012	Electrical and electronics drafters	x			Increasing
	17-3023	Electrical and electronic engineering technicians	x			Increasing
	17-3024	Electro-mechanical technicians	x			Increasing
	17-3029	Engineering technicians, except drafters, all other	x			Increasing
	51-2022	Electrical and electronic equipment assemblers	x			Increasing
	51-2023	Electromechanical equipment assemblers	x			Increasing
	51-4012	Numerical tool and process control programmers	x			Decreasing
Installation, Maintenance, Repair, Roadside	47-2111	Electricians		x		Increasing
	49-2021	Radio mechanics		x		Increasing
	49-2022	Telecommunications equipment installers and repairers, except line installers			x	Increasing
	49-2093	Electrical and electronics installers and repairers, transportation equipment		x		Increasing

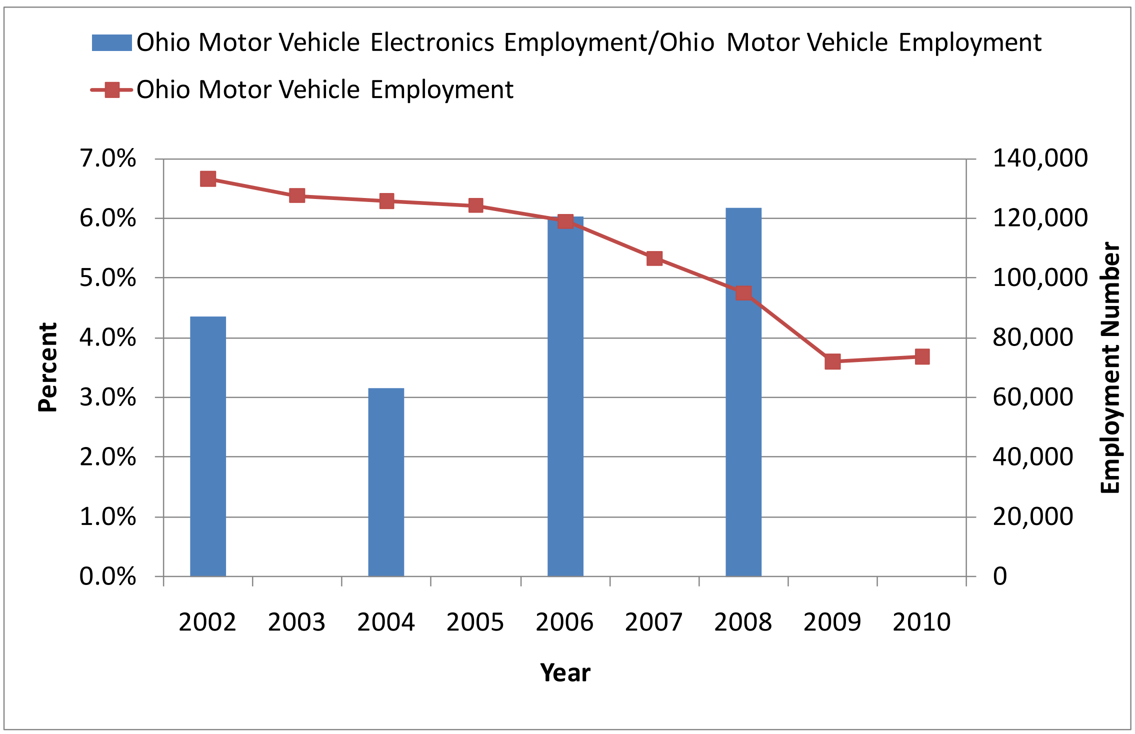
Job Function	Associated SOC Codes	Description	Skill Impact on Workforce			Expected Trend
			Evolving	Additive	New	
	49-2095	Electrical and electronics repairers, powerhouse, substation, and relay		x		Increasing
	49-2096	Electronic equipment installers and repairers, motor vehicles		x		Increasing
	49-3023	Automotive service technicians and mechanics		x		Increasing
	49-9042	Maintenance and repair workers, general		x		Neutral
	49-9051	Electrical power-line installers and repairers	x			Neutral
	49-9052	Telecommunications line installers and repairers			x	Increasing
	49-9098	Helpers--installation, maintenance, and repair workers		x		Increasing
	49-9099	Installation, maintenance, and repair workers, all other		x		Increasing
Research - Engineering	17-2071	Electrical engineers		x		Increasing
	17-2072	Electronics engineers, except computer		x		Increasing
Research - Computer	15-1031	Computer software engineers, applications	x	x		Increasing
	15-1032	Computer software engineers, systems software	x	x		Increasing
	15-1061	Database administrators		x		Increasing
	15-1071	Network and computer systems administrators		x		Increasing
	15-1081	Network systems and data communications analysts		x		Increasing
	17-2061	Computer hardware engineers	x			Increasing
Other	19-3051	Urban and regional planners			x	Neutral

6.2 Number of Workers and Locations

None of the respondents that CAR contacted foresee a net increase in the total number of employees in their organizations; some forecast a net effect of zero (losses and hires balancing each other out), while others were loath to forecast employment numbers. Nonetheless, nearly all respondents expressed the view that there will be an increase in the need for employees with the skills listed above, especially when compared to a baseline of 2008 or 2009. Thus, it will be important to train workers with these skills for the region to stay on top of advances in automotive technologies and maintain employment in the region.

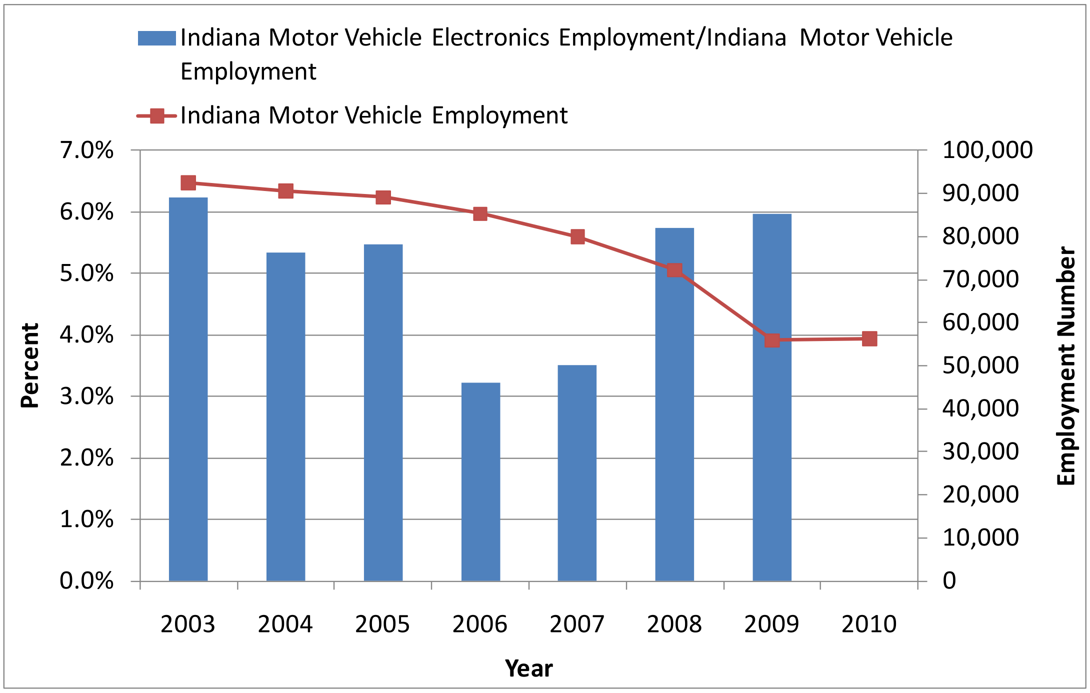
Based on analysis of motor vehicle employment and motor vehicle electronics employment in Indiana and Ohio, it appears that electronics jobs are increasing as a proportion of all motor vehicle jobs. This trend is shown in Figure 5 and Figure 6; however, as of the publication date of this report, similar data for Michigan were not available. In general, employment in motor vehicle electronics is increasing in Ohio and at least remaining more or less constant (aside from 2006 and 2007) in Indiana compared to overall motor vehicle employment in those states. Based on input from respondents, a similar trend is expected in Michigan but data are lacking. For all states, however, motor vehicle employment has declined over the same time period, though each saw an increase in 2010 as the region began emerging from the recent recession.

Figure 5: Motor Vehicle Electronics Employment in Ohio



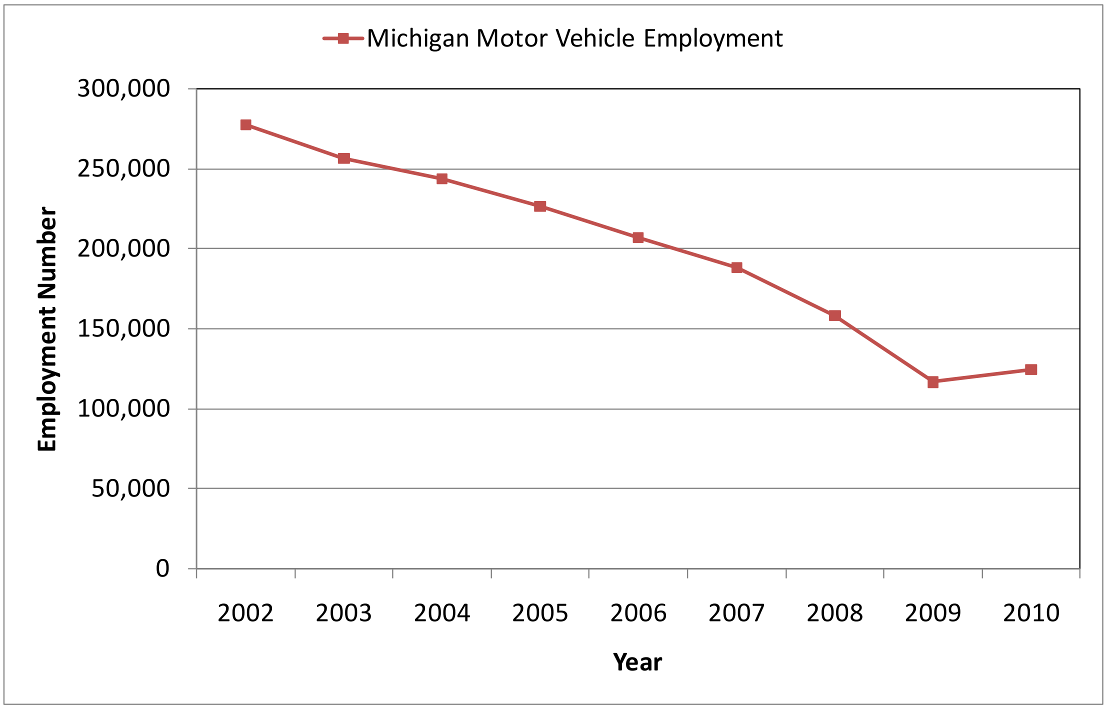
Source: BLS: May 2009, Occupational Employment and Wage Estimates, and state employment data.

Figure 6: Motor Vehicle Electronics Employment in Indiana



Source: BLS: May 2009, Occupational Employment and Wage Estimates, and state employment data.

Figure 7: Motor Vehicle Employment in Michigan



Source: BLS: May 2009, Occupational Employment and Wage Estimates, and state employment data.

Respondents expressed a mix of opinions regarding where these new jobs will be located. Some believe that development can happen anywhere, citing improvement in electronic communications negating the need to be located in proximity to other automotive resources. Others, however, indicated that electronics jobs will be located near where leaders in the field are located—specifically in Michigan and the surrounding states. With approximately 80 percent ($14 billion) of annual U.S. automotive research and development spending occurring in Michigan and a few other Great Lakes states,[86] this area already boasts a concentration of high-tech automotive activity. One respondent was adamant that electronics jobs will be located in the tri-state region because the industry will want to locate in an area with the best available people, not the best people available in another location. Another indicated that Michigan proper definitely will attract most of the systems integration positions, but that other automotive centers in Europe and Asia also would attract a fair percentage. If these viewpoints prevail, then the tri-state region is poised to see growth in vehicle electronics employment.

[86] Center for Automotive Research. (2011). "An Overview of U.S. Automotive R&D Investments." Center for Automotive Research. January 2011.

7. Conclusions

In the next five to 10 years, the amount of electrical content in vehicles will continue to increase, and even more components, systems and subsystems requiring microcontrollers will be integrated into the vehicle. Cameras, vision sensors, radar sensors, lane keeping systems, collision avoidance systems, new dashboard displays, active chassis controllers and hybrid engine sensors and controllers are likely to become more common. With the increasing penetration of hybrid and electric vehicles comes increased complexity of the electrical architectures needed to handle motor and battery controllers, as well as energy management; none of this is present in conventional gasoline-powered vehicles. Given the emphasis on improving safety features, there will be greater need for higher powered processors within vehicles, especially for features that integrate inputs from several different sensors.[87]

Without question, trends in motor vehicle electronics and their effects on employment and required skill sets interact with trends in other parts of the industry, such as in powertrain. As more complicated powertrains (e.g., plug-in hybrids) become more common, the demand for electronics is expected to increase, especially for engine control units and sensors. Indeed, one recent study of the repair and service industry in Canada revealed that hybrid technology and electronics are the top two technologies for which repair and service technicians will need additional training in the coming years.[88] Changes in materials have a less obvious interaction with electronics, though replacement of mechanical systems with electronic systems in itself has a lightweighting effect (as does simply replacing copper with fiber or wireless communications). Thus, the proliferation of electronics in the vehicle eventually can begin to affect the range of choices available in other dimensions of vehicle design.

In summary, the importance of electronics to the motor vehicle industry will continue to grow in the next decade. The electronic content of vehicles will continue to increase as measured by cost. Furthermore, electronics that are not built into vehicles will interact increasingly with vehicles. These developments bring with them an evolving set of labor needs and skills sets that differ from the current mix. There will be more demand for people with specific electronics, computer and communication technologies skills, and this demand will be broad-based across the industry—including product engineering and design, research and development, manufacturing, repair and service, validation and certification and cyber security—and eventually to the roadside. This increased demand for certain types of workers and skills, in turn, will result in increased demand for schools and programs that offer education and training in these fields. Schools and educational institutions in the tri-state region should be prepared to offer coursework in these areas to prepare their respective workforces for upcoming jobs or risk having this employment accrue to other states or nations. Special emphasis should be on

[87] Prosser, S. J. (2007). "Automotive Sensors: Past, Present, and Future." *Journal of Physics*: Conference Series 76 012001

[88] Convergence Management Consultants, Ltd. (2009). Technology Advancements and the Impact on Skills Development for the Motive Power Repair and Service Industry Workforce. Report to Canadian Automotive Repair and Service Council.

electrical (and electronics) engineering, computer science and engineering and system integration.