



UNDERSTANDING THE MIDDLE-SKILL WORKFORCE IN THE CONNECTED & AUTOMATED VEHICLE SECTOR



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INTRODUCTION

OVERVIEW

The movement of people and goods – the mobility industry – is rapidly expanding and evolving to include new forms of package delivery;¹ mobility as a service (MaaS), the deployment of autonomous vehicles;² and more. Within this industry, the connected and automated vehicle (CAV) sector is reimagining how an automobile moves and interacts with its environment. Innovations include new technologies in Advanced Driver Assistance Systems (ADAS), such as predictive control on multi-lane roads,³ as well as the research and development of driverless vehicles.⁴ The testing and design of CAVs are concentrated within Southeast Michigan. The region strongly supports this activity through its combination of public and private automotive research & development centers, test facilities, numerous well-known research universities and community colleges, as well as hundreds of employers in the automotive industry.

Alongside the development of CAVs and their communication with each other (V2V), public infrastructure is also evolving in its ability to connect and collect data. CAVs connect to infrastructure (V2I) like street lights, crosswalks, intersections, and road markings in order to operate safely and efficiently. As the CAV industry advances,

the demands on infrastructure development and innovation will only increase.⁵

Beyond the CAV testing and infrastructure in Southeast Michigan, there is also a concentration of educational offerings and employment opportunities related to CAV.⁶ These activities provide a unique opportunity to better understand the workforce supporting the CAV sector.

This research report explores the workforce supporting CAVs in Southeast Michigan, specifically looking at the development and evolution of middle-skill jobs. While most reports on the CAV sector workforce focus primarily on highly-skilled engineer and design jobs,⁷ there is a growing need to understand middle-skill jobs, such as technicians. According to the Bureau of Labor Statistics, technicians in the automotive industry inspect, maintain, and repair cars and light trucks and work on traditional mechanical systems and increasingly advanced electronic and electrical systems. Technicians in the CAV sector have evolving duties which are rooted in technician responsibilities and are expanding into software, data systems, cybersecurity, and systems-level duties, as this report will further explore.



1 See the following article as one example of many: Keith Naughton, "Ford tests package-carrying robots for driverless delivery" Bloomberg, May 22, 2019. <https://www.autonews.com/mobility-report/ford-tests-package-carrying-robots-driverless-delivery>

2 For example: Michael Dobuski, "GM moves forward with building recently announced driverless shuttle," ABC News, January 27, 2020. <https://abcnews.go.com/Business/gm-moves-forward-building-recently-announced-driverless-shuttle/story?id=68572540>

3 Nathan Goulet and Beshah Ayalew, "Coordinated Model Predictive Control on Multi-Lane Roads," Volume 3: 21st International Conference on Advanced Vehicle Technologies; 16th International Conference on Design Education, August 18, 2019. <https://doi.org/10.1115/detc2019-98117>.

4 See the following articles for examples of recent research on autonomous and automated vehicles.

Felix Becker and Kay W. Axhausen, "Literature Review on Surveys Investigating the Acceptance of Automated Vehicles," Transportation 44, no. 6 (November 2017): p1293–1306. <https://doi.org/10.1007/s11116-017-9808-9>; Dimitris Milakis, Bart Van Arem, and Bert Van Wee, "Policy and Society Related Implications of Automated Driving: A Review of Literature and Directions for Future Research," Journal of Intelligent Transportation Systems 21, no. 4 (2017): p324–48. <https://doi.org/10.1080/15472450.2017.1291351>; Keshav Bimbraw, "Autonomous Cars: Past, Present and Future - A Review of the Developments in the Last Century, the Present Scenario and the Expected Future of Autonomous Vehicle Technology," Proceedings of the 12th International Conference on Informatics in Control, Automation and Robotics, December 2015. <https://doi.org/10.5220/0005540501910198>.

5 City officials and public servants, who the team interviewed, are currently working to proactively understand and predict what these disruptions will look like, and what role the public and private sectors will have in advancing, improving, and modifying infrastructure to meet the needs of autonomous and automated vehicles. In particular, municipalities are planning for ways to use CAV-generated data to improve public safety and mobility. At the same time, however, cities are intentionally reactive to the quickly moving innovations in the CAV field, which are driven primarily by the private sector.

6 See the completed 2018 report on the CAV industry in Southeast Michigan at the following hyperlink. <https://www.cargroup.org/publication/strategic-growth-plan-for-connected-and-automated-vehicle-assets-in-southeast-michigan/>

7 For example, "Connected Mobility: Oakland County Skills Needs Assessment Project," Oakland County, March 21, 2017, https://www.mistempartnership.com/cm/dpl/downloads/articles/34/Connected_Mobility_Skills_Needs_Assessment_-_Oakland_Cty.pdf

INTRODUCTION continued

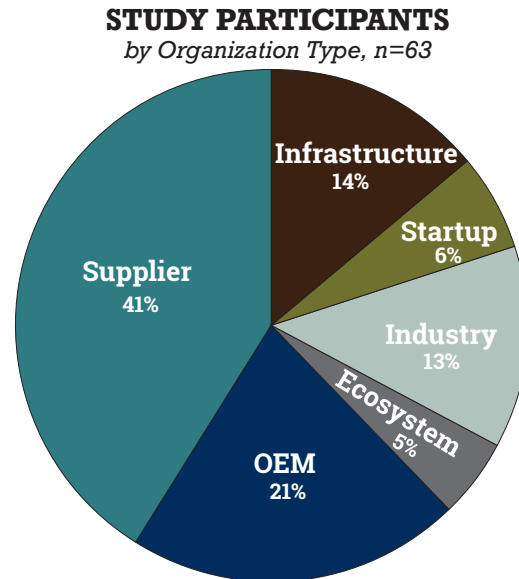
As a whole, the automotive industry is experiencing a critical shortage of qualified technicians as identified by industry trade groups.⁸ Fast-paced change in the CAV sector and its consequent demands exacerbate this problem further. This research addresses how these middle-skill jobs in the CAV sector are transitioning as it relates to testing and infrastructure.

METHODOLOGY

Through this qualitative study, the team completed 63 interviews with managers in engineering and/or human resources (HR) departments. The participants represented 30 organizations including Original Equipment Manufacturers (OEMs), suppliers, other businesses related to the CAV industry, ecosystem organizations and public organizations (such as city and state government).

The number of interviews within each organization ranged from one to seven (average: 2.1), and were not proportionally related to the organization's size but relied on voluntary participation. Some

organizations connected the research team with several engineering and HR managers, while others provided one contact.

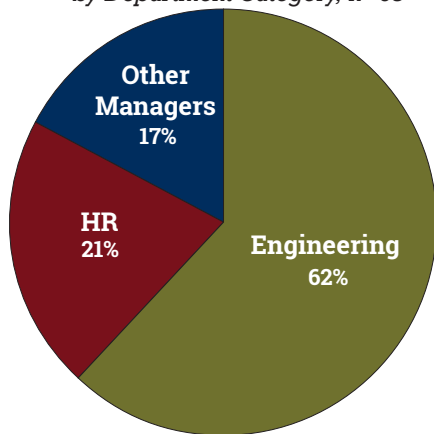


Participant Definitions and Breakdown

	Definition	Organization Count	Individual Participant Count
Connected and Automated Vehicle Sector	All companies, industries, organizations, and governmental entities involved in designing, testing, manufacturing, and selling connected and autonomous vehicles and/or the infrastructure, technology, and policy environment that supports them.	Total: 30	Total: 63
CAV-Direct Employers	OEMs, suppliers, and industry private sector companies that directly employ middle-skill, middle-wage workers to work on connected and automated vehicles, technology, and systems development.	Total: 17	Total: 47
	Industry Companies and entities that provide CAV-related services or produce products using CAV technology.	5	8
	OEMs A manufacturing company that assembles vehicles with equipment and parts produced by other companies, and sells the vehicles under its own brand name.	4	13
	Suppliers Companies that supply OEMs with equipment, parts, or other inputs to the production of CAVs.	8	26
Ecosystem	Companies and organizations involved in broader mobility and mobility workforce development.	3	3
Startup	Startup companies working on or adjacent to CAV technologies and innovations.	3	4
Infrastructure	Public and private sector entities involved in the development, provision, and maintenance of CAV-related public infrastructure.	7	9

⁸ "Mobility and Automotive Industry to Create 100,000 Jobs, Exacerbating the Talent Shortage," PR Newswire, The Boston Consulting Group, January 11, 2019. <https://www.prnewswire.com/news-releases/mobility-and-automotive-industry-to-create-100-000-jobs-exacerbating-the-talent-shortage-300776686.html>; Alan L. Adler, "The Hurdles of Fixing Automated Vehicles," Automotive News, Feb 19, 2018. <https://www.autonews.com/article/20180219/RETAIL05/180219994/the-hurdles-of-fixing-automated-vehicles>; Richard Truett, "Self-driving Vehicles will Revolutionize Service Business," Automotive News, Aug 21, 2017. <https://www.autonews.com/article/20170821/RETAIL05/170829989/self-driving-vehicles-will-revolutionize-service-business>

STUDY PARTICIPANTS
by Department Category, n=63



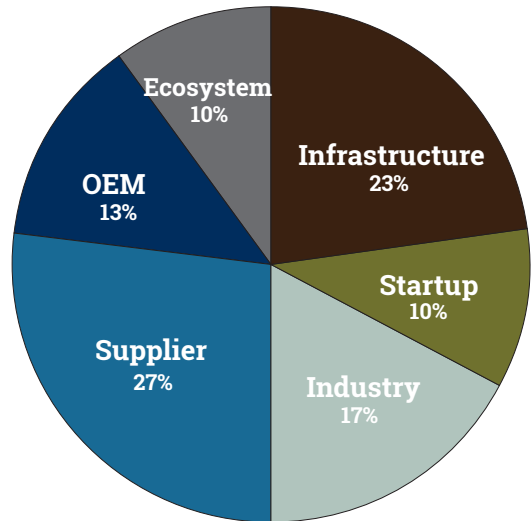
Seventy-one percent of the interviews were completed in-person, and the remaining 29 percent were conducted over the phone. Organizations included in the study possessed knowledge of the workforce within CAV testing and/or infrastructure.

MIDDLE-SKILLS JOBS

This study specifically focuses on the middle-skill jobs within the testing and infrastructure aspects of the CAV sector, which is a subset of discussions around mobility. This study narrowly focuses on testing and infrastructure, but acknowledges that changes within mobility could disrupt the entire industry. Additionally, this report was specifically focused on Southeast Michigan, the majority of which is automotive. There is also significant research on how CAVs could impact trucking and its workforce.⁹ It is critical that these findings are couched within the bigger picture of mobility as a whole.

Middle-skill jobs are classified as jobs that require more skills and experience than a high school education provides, but less than a four year degree. Within the CAV sector technicians comprise the majority of middle-skill jobs, and the bulk of these technicians are in the private sector.¹⁰ Most other

ORGANIZATION TYPE
n=30



positions in this sector, such as engineers, systems architects, managers, and IT specialists, require at least a bachelor's degree.

As an emerging sector, a majority of new positions related to CAVs are engineers or other highly-skilled positions. While some companies directly post and hire middle-skill jobs¹¹ for their CAV-related departments, others promote internally. As more CAV-related products move from the R&D space into mass production, it is expected that middle-skill jobs in the CAV sector will correspondingly grow.

9 Saeed Asadi Bagloee, Madjid Tavara, Mohsen Asadi, and Tracey Oliver, "Autonomous Vehicles: Challenges, Opportunities, and Future Implications for Transportation Policies," *Journal of Modern Transportation* 24, no. 4 (2016): 284–303, <https://doi.org/10.1007/s40534-016-0117-3>; Peter Fox-Penner, Will Gorman, and Jennifer Hatch, "Long-Term U.S Transportation Electricity Use Considering the Effect of Autonomous-Vehicles: Estimates & Policy Observations," *Energy Policy* 122 (2018): 203–13, <https://doi.org/10.1016/j.enpol.2018.07.033>; Jason Monios and Rickard Bergqvist, "The Transport Geography of Electric and Autonomous Vehicles in Road Freight Networks," *Journal of Transport Geography* 80 (2019), <https://doi.org/10.1016/j.jtrangeo.2019.102500>.

10 Technicians involved in installing and maintaining CAV infrastructure are often employed in the private sector. While the public sector employs traditional technicians that perform maintenance and repairs on public infrastructure, the demands of a quickly advancing field make it challenging for public sector technicians to become heavily involved in the installation, maintenance, troubleshooting, and repair of CAV infrastructure. That said, current municipal technicians have responded to some degree to CAV technology changes, and are involved in the initial installation and basic maintenance of certain types of CAV infrastructure. This shift has created an increased demand for infrastructure technicians with electrical and network experience, and has necessitated greater levels of coordination between municipal technicians and IT departments. It is unclear what the public-private breakdown of CAV infrastructure responsibility will be in the future, but it appears likely that the private sector will absorb much of the installation, maintenance, and repair of these systems and equipment.

11 A January 2020 review of open CAV sector positions posted on Indeed.com in Southeast Michigan serves as an illustration of the current CAV employment landscape. Job titles of open positions include: Senior Failure Analysis Technician, Autonomous Vehicle Fleet Systems Operator, Durability Test Driver, Field Service Technician, Prototype Vehicle Technician, EMC Validation Technician, Autonomous Vehicle Operator, Autonomous Vehicle Remote Supervision Technician, and Test Technician.

HISTORY AND CONTEXT

The skillsets required to work on a vehicle have drastically changed over the last 30 years. Before the 21st century, cars were mostly mechanical and simple maintenance and troubleshooting could often be completed by hobby mechanics. As vehicle technology developed, however, the number of electronic, electrical and software components increased, as well as the associated skillsets required for those working on them (see Figure 1). For example, the electronic modules within a vehicle have exponentially increased from just one or two to now around 70 modules¹² in most cars. Additionally,

the software and connectivity of vehicles are quickly evolving and changing, especially with the continued push towards automation, driven by demands for both convenience and increased safety.

The demanded skillsets of technicians are evolving as quickly as the vehicle itself. The first two sections of this report outline the job duties and related technical and soft skills of the CAV technician workforce. This is followed by how skillsets are forecast to evolve based on the research.

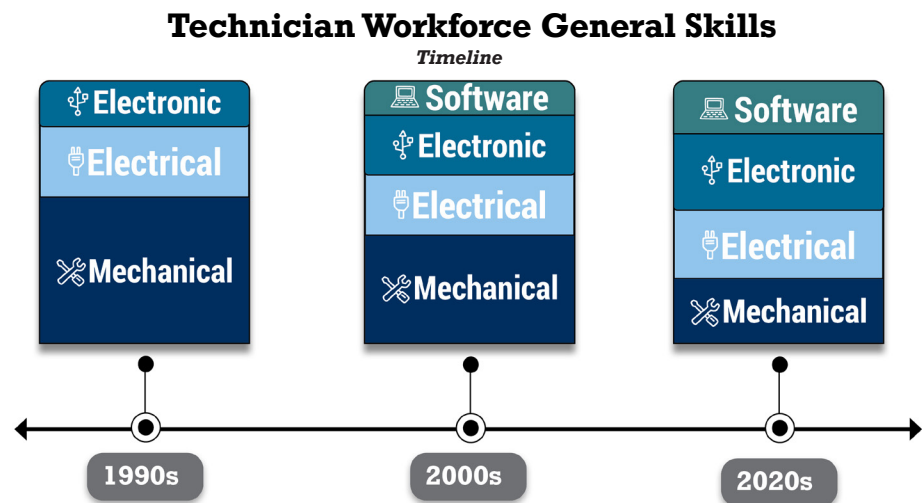


Figure 1. The skillsets required to work on today's vehicles are more diverse and complex than 30 years ago

JOB DUTIES AND SKILLSETS

Analyzing the current middle-skill CAV workforce in testing and infrastructure requires an understanding of two interdependent categories: job duties and skillsets. Job duties are

defined as the tasks employees are expected to successfully complete within their role. Skillsets are the technical and soft skills that equip employees to accomplished their duties.

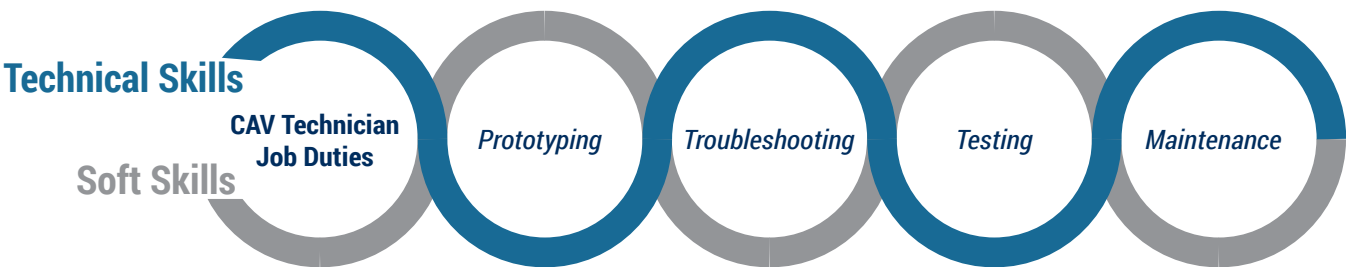


Figure 2. The job duties of CAV technicians are accomplished through a combination of technical skills and soft skills. These areas are interwoven and dependent upon each other. More details on skillsets are provided in subsequent sections.

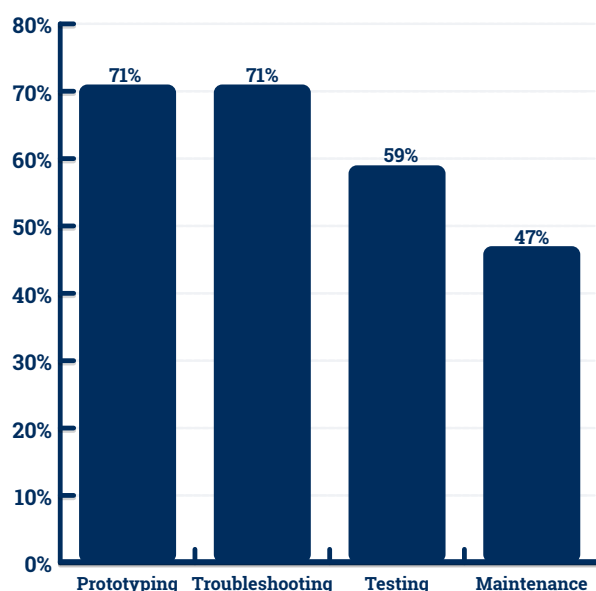
¹² An estimate from participant interviews.

JOB DUTIES

While CAV technician job duties are broad, four thematic areas emerged from participant interviews with CAV-direct employers:¹³ **prototyping, troubleshooting, testing, and maintenance.** These areas all overlap and reinforce themselves, but the distinction here facilitates further analysis. Participants most often discussed job duties for CAV technicians related to prototyping and troubleshooting, followed by testing and maintenance.

JOB DUTIES OF CAV TECHNICIANS

Reported by CAV-Direct Employers, n=17



PROTOTYPING

Prototyping encompasses fabrication of mechanical components and electronic and electrical assemblies as well as assembly and troubleshooting of a complete test vehicle. Of the CAV-direct employers, 71 percent of participants discussed various prototyping duties for CAV technicians. Basic skills like soldering, welding, and wire routing are part of the necessary competencies, but companies stressed more complex skills like data acquisition, Control Area Network (CAN) bus application, and assembly, and problem solving of complicated systems. Additionally, participants emphasized that modifying electronic and electrical components is more critical in the industry today as compared to the past emphasis on mechanical modifications. Examples of prototype fabrication and assembly tasks include:

- Custom modifications of vehicle – mechanical, electronic, and electrical
 - Drive-by-wire conversion,
 - Change the roof, etc.
- Equip vehicles or major subsystems on test rigs with monitoring systems
 - Build custom harnesses, route and secure, tap signals
 - Fabricate bracketry and attach sensors in order to get data out of vehicle (wheels, prop shaft, side shaft, power transfer units, etc.)
 - Cutting, drilling, and assembling metal
 - Hand tools
 - Machines
 - Welding
 - Assembly based on prints, 2D & 1D prints
- Upload programs into the equipment
- Read and understand CAN and test data
- Troubleshoot and problem solve complicated digitally controlled electromechanical systems



TROUBLESHOOTING

Troubleshooting, as a duty, requires soft skills in problem solving combined with expert technical knowledge in areas such as mechanical, electrical, or electronic components. These skillsets provide the foundation for technicians to perform necessary troubleshooting related to CAV infrastructure. Seventy one percent of companies discussed troubleshooting as a key responsibility required among technicians in the CAV sector. Interviewees noted that strong troubleshooting skills require a full systems understanding of the vehicle that encompasses both mechanical and electronic systems. However, knowledge of electronic systems has become increasingly important over the past 15 years and electrical power systems knowledge has become equally important as hybrid and full electric powered drivetrains continue to replace pure internal combustion. Several companies noted that this systems level of troubleshooting requires the soft skills of creativity and problem solving on the part of technicians.

“In [CAV], if you’re thinking you’re just going to receive a manual and execute oil change or

¹³ See “Participant Definitions and Breakdowns” on page 2 for the definition of this group.

JOB DUTIES: continued

execute a tire change... it's not that. You need to be able to troubleshoot." – Engineering Manager at an OEM

Troubleshooting was often discussed in the context of testing. Technicians in the CAV space work closely with engineers during testing to combine their specific technical skills and soft skills in problem solving (detailed more below) to diagnose issues in the system and propose solutions. Employers want technicians to conduct the first line of troubleshooting for the engineers during the testing process. In practice, this is not always possible since data interpretation and more complex technical analysis is often required even in this first stage of troubleshooting. These skills are still emerging and employers often need to train technicians in these areas. Generally, technicians and engineers work closely together to troubleshoot during testing. Employers stressed that technicians need to be able to clearly communicate their troubleshooting efforts to engineers and justify engineer involvement.

**TESTING**

Testing is a core job duty identified by 59 percent of CAV-direct employers. Testing requires a significant amount of troubleshooting. Employers noted that technicians need strong mechanical, electronic, and electrical understanding to carry out testing duties, with electronics and software becoming more important. Beyond these areas of expertise, employers look for a technician that has broader systems knowledge of the vehicles, devices, and parts that undergo testing. In particular, testing requires some basic computer skills and increasingly software and programming knowledge.

"You get somebody that's really strong in the electronics software side, [but] they have no mechanical aptitude. It's a balance you've got to find because, [while] it's great that he'll program a test stand, he doesn't know the difference between a 1.25 thread and a 1.5 thread. It makes a big difference. It's nice to find a balance for both the software program capability along with mechanical aptitude and understanding basically fundamental code and mechanicals." – Engineering Manager at a supplier

Moreover, employers at non-union organizations shared that technicians working on testing



vehicles and parts have begun to take on introductory engineering tasks, particularly when it comes to software and control algorithms. While engineers are still responsible for writing algorithms, technicians need to have a solid understanding of the software and algorithms so that they can set them up and use them in testing. Thus, a blurred line between engineers and technicians is pushing testing technicians to acquire more advanced computer and software skills.

Along these lines, employers anticipate that technicians will assume increasing levels of responsibility within the testing space. Currently, a less-experienced technician might simply monitor a test screen and report what they see to the engineers, while a more skilled technician uses discretion and some data interpretation skills to do first-line problem solving and flag testing issues for engineers. Some employers added that they envision technicians taking even more responsibility for the testing process in the future.

"The technicians, we hope, could do...an initial Level 1 analysis of those logs to say, 'That was a good run,' or, 'That was a bad run,' rather than having to say, 'I captured something,' and throwing it over the wall to somebody. That is the expectation we have today and I think that expectation just will grow." – Engineering Manager at an OEM

JOB DUTIES: continued**MAINTENANCE**

Maintenance is a key job function that was discussed by 47 percent of participant organizations. Broadly, technicians involved in maintenance are expected to do both hardware and software maintenance. Hardware maintenance requires extensive electrical and mechanical skills, and some computer skills. Software maintenance requires advanced computer skills, and is often carried out by a “technician with an engineering profile.” There is a sense, however, that as CAV technology advances maintenance will continue to be important but will require more data analysis and software skills.

“We’re going to need people in the workforce that can provide maintenance, that can do software updates, that can, you know, maintain these vehicles over their life cycle, whether that’s 10, 15, 20 years, however long they’re on the road. And the way we maintain them will look different in 20 years than it does today, obviously, just because of the amount of data and coding that is harbored in these vehicle networks.” – Manager at an industry organization

Municipal technicians are involved to a degree in the maintenance of CAV-related infrastructure. For example, these public sector technicians may maintain sensors, Lidar, and cameras in connected intersections. These maintenance duties require more electrical and network/IT skills than has often been expected of traditional municipal technicians. As a result, municipal IT departments have begun to work more closely with these technicians.

EXAMPLE MAINTENANCE RESPONSIBILITIES IN INDUSTRY OPENINGS*EMC Validation Technician*

- Provide support in the use and maintenance of various database applications used by the validation EMC group during the performance of daily operations
- Verify, use, and maintain test equipment

Autonomous Vehicle Operator

- Maintain and perform daily inspections of autonomous equipment

Test Technician

- Establish new preventative maintenance procedures and periodic audit/update existing procedures

EXAMPLE MAINTENANCE RESPONSIBILITIES IN CAV INFRASTRUCTURE

Municipal technicians perform basic maintenance on infrastructure that supports connected and automated vehicles. For example:

- Repair and maintain road side units that connect to CAVs and intersections
- Maintain the fiber optic system in a city
- Maintain some sensors, Lidar, and cameras at intersections

SKILLSETS

OEMs, suppliers and others in the industry outlined broad skillsets necessary to successfully complete the above job duties. Larger organizations built teams to ensure diverse skillsets, while smaller firms expressed the need to find a jack-of-all-trades.

TECHNICAL SKILLSETS

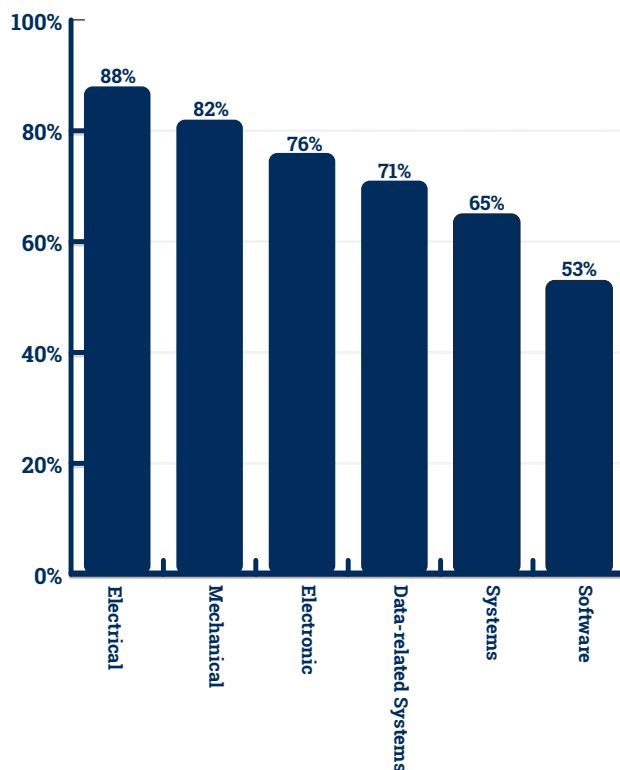
Cross-cutting skillsets are required to fulfill the four job duties of a CAV technician. The Knowledge, Skills and Abilities (KSAs) within the CAV technician workforce today include the following:

- Electrical
- Electronic
- Mechanical
- Data-related systems analysis
- Systems knowledge
- Software

The most common skillsets mentioned by CAV-direct employers of CAV technicians were related to electrical, electronic, and mechanical KSAs. This was followed by systems understanding and data-related systems knowledge. Emerging skillsets included software knowledge, as well as an understanding of cybersecurity or growing middle-skill jobs in cybersecurity. While specializations in each of these areas was unique to each OEM, supplier, or industry organization, there were general foundational KSAs that emerged, outlined in Table 1 on page 9. Although organizations expressed a desire for a technician to possess skills in most all of these areas, the

SKILLSETS OF CAV TECHNICIANS

Reported by CAV-Direct Employers, n=17



current reality is that most organizations either build a technician team or still rely on engineers.

As the CAV industry continues to develop and move out of the research realm into broader production, the market may push for efficiencies and demand more diverse skillsets in one person.



SKILLSETS: continued

MECHANICAL • Comprehensive understanding of vehicle • Wrenches and other tools to assemble and disassemble vehicle • Fabrication skills	ELECTRICAL • Electrification ◦ Batteries ◦ Inverters ◦ Boosters ◦ High-voltage • Electromechanical • Hybrid motors	ELECTRONIC • Sensors, extrinsic calibration • Power control electronics • Vision/Video systems • EMC electromagnetic understanding
DATA-RELATED SYSTEMS • Data acquisition • A to D converters • CAN • Wireless, V2X, V2V, V2I • Telematics	SOFTWARE • Understanding coding languages • Ability to run and alter programs for testing, as needed • Upload and download new software into the vehicle or component	SYSTEMS • Linkages between the systems • Collaborative Components • Inputs & Outputs • Feedback loops • Problem solving (soft skill)

Table 1: KSAs by specialty. CAV technicians are multidisciplinary in their ability to apply electrical, mechanical, electronic, data-related systems knowledge and more. Larger organizations currently find all these skillsets through teams and rarely find one employee with all the above skills.

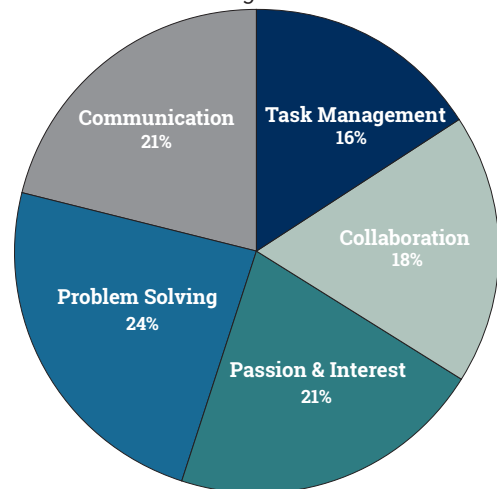
SOFT SKILLS

Several studies have emphasized the necessity of soft skills in an ever-changing economy. These skills provide employees and employers the flexibility to move within a fluid work environment.¹⁴ For example, manufacturing in the United States experienced a skills gap starting in the early 2000s, which continues today. Reports encouraged the industry to focus on developing soft skills alongside technical skills in order to better fill the skills gap.¹⁵ In this study, five types of soft skills emerged from the interviews. The following soft skills emerged from the data: problem solving (24 percent), communication (21 percent), passion and interest (21 percent), collaboration (18 percent), and task management (16 percent).

“Back in the day, it used to be 80% technical skill and 20% soft skills. It's almost completely flip flop now...People skills and the right fit with our culture is pretty important nowadays.” – Engineering Manager at a supplier

BREAKDOWN OF SOFT SKILLS

n=16 organizations



¹⁴ Linda Barrington, Mary Wright, and Jill Casner-Lotto, 2006, Are They Really Ready to Work, Employers' Perspectives on the Basic Knowledge and Applied Skills of New Entrants to the 21st Century US Workforce, <https://www.conference-board.org/publications/publicationdetail.cfm?publicationid=1218> ; Manpower Inc., 2018, Solving the Talent Shortage, Build, Buy, Borrow and Bridge, <https://go.manpowergroup.com/talent-shortage-2018>

¹⁵ National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007, Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, Washington, DC: The National Academies Press, <https://doi.org/10.17226/11463> ; National Association of Manufacturers, 2005, 2005 Skills Gap Report – A Survey of the American Manufacturing Workforce, <http://www.themanufacturinginstitute.org/Research/Skills-Gap-in-Manufacturing/Skills-Gap-in-Manufacturing.aspx>

SKILLSETS: continued



Problem Solving

Also mentioned as: root cause analysis, logical reasoning, analysis, improvisation, investigation

Problem solving was the most often mentioned soft skill across companies and organizations. As a soft skill it is a critical component of the above job duties, and is particularly essential in troubleshooting. There is a general sense that technicians should be able to do the first level of analysis and problem solving, before the issue goes to engineers.

"If they have issues, the expectation is that they problem solve themselves first versus... just raising a hand and saying I'm stuck." – Engineering Manager at a supplier

While problem solving is a clearly needed skill at every level, several participants indicated that real investigative and logical reasoning skills can be a skill gap in some cases. Some companies said that they look for people that can take apart their iPhone or fix their home gaming system: people that have naturally "curious minds" and are inclined towards finding ways to fix problems. These types of technicians are highlighted as valued members of the team and employers expressed desire for more of these individuals.

Examples of problem solving:

- Figuring out how to find data or information
- Working with engineers and on teams to solve problems and bounce ideas off each other, solve interpersonal conflicts
- Identifying problems or inefficiencies in processes and continually working to solve or improve these problems



Communication

Communication was identified as a necessary soft skill for technicians at every level. In particular, technicians need to be able to communicate with other technicians, engineers, and customers. Technicians must articulate what they have assessed in testing or prototyping, what they still need from engineers or other team members, and have the assertiveness and skill to initiate critical conversations. For direct-to-consumer companies, customer service is important for technicians on the front-line of troubleshooting. These managers emphasized the ability of technicians to communicate with customers in a professional and technical manner.

A common theme that also emerged was communication between engineers and technicians. Participants noted that both groups need to be able to talk to each other and resolve conflicts respectfully and thoughtfully. In fact, several managers indicated that this may be a bigger problem on the engineer side.

"Our technicians have pretty good communication skills and collaborate. We need help on the engineering side of the house - you have to understand that a lot of our [technicians] have been here for 30 or so years, and as a new engineer just graduating, coming out of school, you just can't go and tell a technician this needs to be done and not listen to their concerns and their expertise." – HR Manager at a supplier

Additionally, several companies highlighted their desire for good written communication skills.



SKILLSETS: continued

This skill is concentrated among higher level technicians, who need to write technical and test reports, fill out report templates, review reports, and occasionally communicate in written form with engineers.

Examples of Communication:

- Customer service
- Solving problems with team members, talking through issues
- Interfacing and communicating with engineers on technical and interpersonal issues

**Passion and Interest**

Also mentioned as: initiative, attitude, energy, enthusiasm, eagerness

Participants discussed that a good technician has a certain level of drive, initiative, and interest in the work, which fuels them to want to learn more, employ their skills, and be creative. Several interviewees noted that this is exemplified in the contrast between a technician that comes to work just to put in their hours and a technician that takes personal ownership of tasks.

"What makes one person stand out over another person? It's just enthusiasm – trying to be upbeat and wanting to do your job well. And then if you're not given the proper equipment to go out and ask for it. [Also], that they're up front, honest, and hardworking and that's not learned in the classroom but just inherent to good technicians." – Engineering Manager at an OEM

Employers are looking for technicians with some level of self-interest in the CAV sector that predisposes them to take ownership of their tasks, do more than the minimum, have a positive attitude, and bring energy and enthusiasm to the workplace.

"I really think that's a fundamental concern that [technicians] have passion for what [they] are doing. Not just 'it's a job'. A person [should have] a passion for wanting to figure it out and do it without being asked." – Engineering Manager at a supplier

Moreover, companies are looking for technicians that are trainable and have a high capacity and willingness to learn new technologies. The participants noted that this skill seems to arise primarily from attitude and personality



rather than age or some other characteristic. The desire for this skill may fuel some of the push for technicians with an associate's degree: companies believe that an individual with an associate's shows an ability to learn and grow, a capacity to develop new skills, and a certain level of trainability.

"I want somebody that embraces change; somebody that's got the drive and initiative and the interest to learn and grow. That's really what it comes down to. Right?" – Engineering Manager at a supplier

Examples of Passion and Drive:

- Strong work ethic and positive attitude
- Personal interest in the field, in newer technologies and emerging skills
- Curiosity and enthusiasm
- Doing more than what is asked
- Taking classes to improve their skills
- Open to change

**Task Management and Organization**

Task management is a skill that advanced and lead technicians are expected to develop as they advance in their careers. A lead technician needs to be able to manage small projects, plan and organize steps, manage time and targets, give guidance to the team, and deliver results. These technicians must have organization and leadership skills to augment their task management responsibilities. Within the organizational skill set, however, all levels of technicians need some time management skills

SKILLSETS: continued

because CAV is an emerging area and it is not always clear how long tasks will take and what problems may arise that need addressing.

"Technicians take full ownership of these complex, important tasks and [are] responsible ultimately for the delivery, the results and the documentation." – Engineering Manager at a supplier

Examples of Project Management and Organization:

- Review reports from other technicians
- In charge of building a vehicle component, a front end, a complete wire harness
- Schedule trainings
- Maintain records of equipment maintenance
- Assist engineers in planning programs



Collaboration

Collaboration and teamwork are seen as important soft skills for technicians. Participants discussed that technicians need to work with other technicians, managers, and engineers to complete tasks, troubleshoot problems, and learn from each other. Many technicians work on teams and have to use collaboration skills daily. Respect for one another and each other's skills and expertise was mentioned as a key

component of collaboration.

"So it could go that the engineer is asking for help from the technician to figure out what's wrong with their device, or that the technician has found the issue and giving advice back to the engineer on how to solve it and how to do it better." – Engineering Manager at an OEM

Examples of Collaboration:

- Working on a team of technicians and engineers daily
- Collaborating with engineers to solve problems

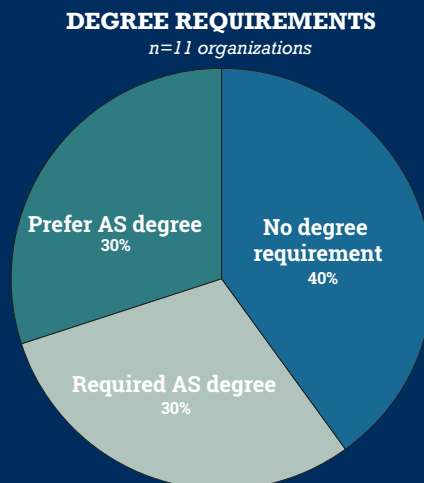


CURRENT CAV WORKFORCE CHARACTERISTICS

The current CAV technician workforce is highly-skilled, with much of its expertise developed on-the-job. As an emerging field, CAV engineering managers shared that finding new technicians with specialized skills is difficult, therefore they emphasize base technical skills plus soft skills like a passion for the field and a willingness to learn.

Education Level

Successful CAV technicians have a diversity of educational backgrounds and participant organizations were split on the requirement for a two-year degree to successfully fulfill these roles (see chart). Some organizations emphasized requiring an associate's degree because it demonstrates an ability and willingness to learn. Others stated that while they did like to see a two-year degree, they emphasized past experience and intrinsic motivation to learn as more important.



Similarly, in a January 2020 review of listed CAV positions on Indeed.com, 22 percent of the nine open CAV technician jobs in Southeast Michigan required an associate's degree. Unlike the participant data, however, the job postings indicated that 67 percent prefer one. Four of the positions, or 44 percent, mentioned that an associate's or bachelor's would be preferred, an indication that companies are seeking very highly skilled CAV technicians.

Training Priorities

Many employers noted the high degree of specialization and skills required for these positions; thus, training was common. Training current employees was a strong emphasis, with 60 percent of the CAV-direct employers prioritizing investment in their employees' skills. Three types of training were discussed by

participant organizations: on-the-job training, vendor training, and classroom training. While all discussed on-the-job training, the formality and depth of training varied by organization and capacity of senior technicians. A common tension shared was prioritizing training alongside the constraints of deadlines and a growing business model. However, 94 percent of employers mentioned their desire for more training for their technicians if and when time and budget allowed.

Employee Retention

Generally companies noted that retention is high in the private sector. In particular, if a technician stays with a company for 3-5 years, they will probably remain with that company for the long term. Across both the private and public sector, participants noted that younger employees, mainly people in their 20s, tend to have higher turnover rates and may be more inclined to jump from job to job. However, retention is lower in the public sector and in some private sector companies that cannot compete in terms of salary with larger companies. One public sector employer noted that technicians come and go like a "revolving door" because they cannot compete with private sector wages, hours, and benefits packages. For example, a technician could be easily enticed to move from the public to the private sector if they have more advanced skills.

Age and Retirement

The age of the CAV technician workforce varied by organization, with no clear trends emerging from the participant interviews. Some companies reported a large number of mid-to-late career technicians with more than 20 years of experience, while others have larger mid-career cohorts. A few companies raised concerns about a "missing middle" of the workforce that could create workforce challenges in the future.

However, 56 percent of all companies that discussed age and retirement shared that a large number of their technicians – 20 to 50 percent – will retire within the next three to five years. These companies noted that they are already preparing for this shift in their workforce by planning or backfilling positions. They are also planning to capture the knowledge and experience that will be lost.

EMERGING SKILLS IN THE WORKFORCE

The skillsets of the CAV technician workforce are diverse, and will only continue to grow based on our research. This section provides an overview of the growing skills that will be required by the CAV industry in the next several years.



1 - 12 MONTH FORECAST

The required skillsets in the next year are not expected to change, according to participant interviews, especially as most of the new positions are backfilling current roles vacated by retirees. Therefore, the forecast of needed skillsets for the next 1-12 months (Figure 2) is based on the current requested skillsets as outlined by participant organizations.

Mechanical, electrical and electronic skills form the foundation of the CAV skillset. These base skills are also the basis of “mechatronics,” which is further defined on page 15.

According to participants, 60 percent of the current workforce needs these base skills of mechanical, electrical and electronic competencies. Built on top of these base skills are enhanced skills in software and data-related systems. Twenty-seven percent of current and future workforce needs focused on this second tier. Finally, systems is an emerging skillset in CAV technicians, with 13 percent of organizations mentioning this as a workforce demand.

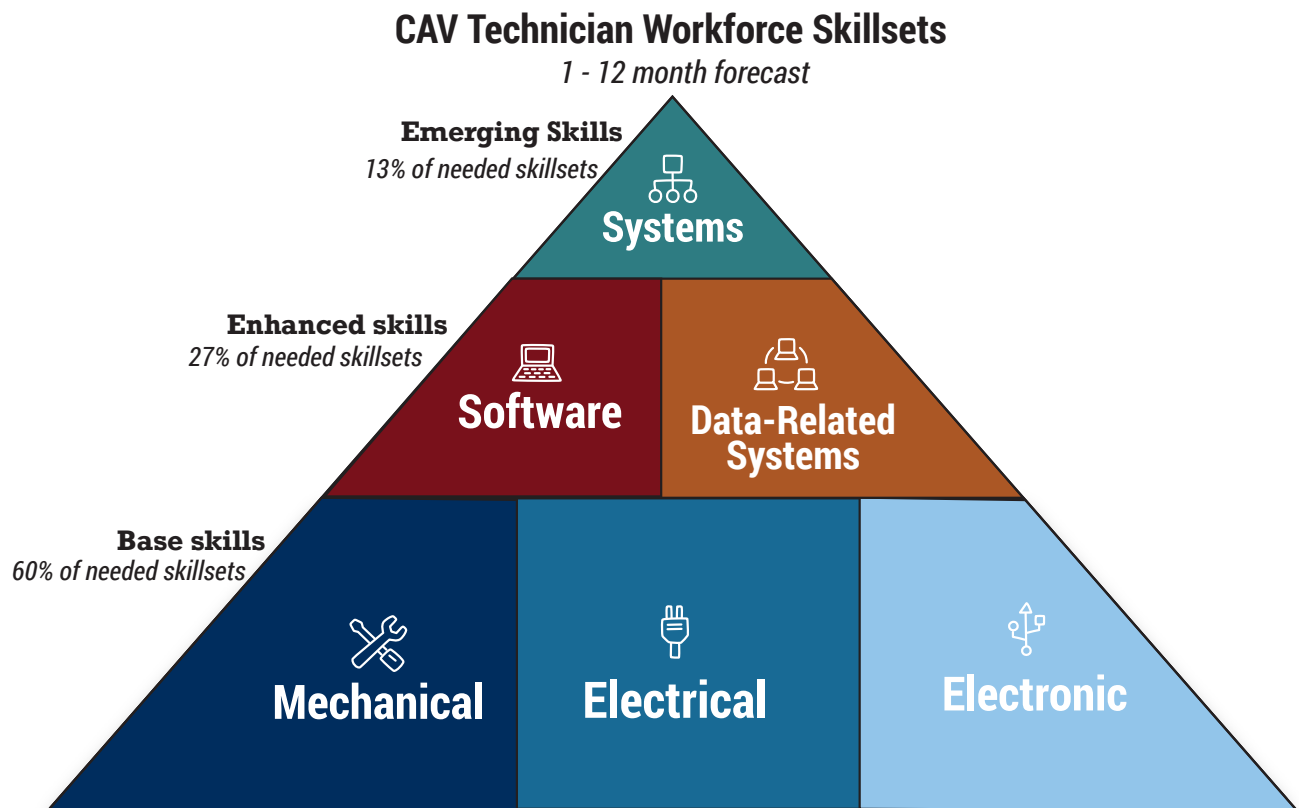


Figure 2. CAV technician skillsets needed in the sector during the next 1 - 12 months; see Table 1 and “Skillsets” section for definitions and examples of these technical skills.

DEFINING MECHATRONICS

The word “mechatronics” was coined at the end of the 1960s in Japan, by Yaskawa Electric Company.¹ At the time, mechatronics was understood to be a blend of electronics and mechanics, and products included automatic doors and vending machines. In the 1980s and 1990s, the advance of information technology, microprocessors, and communication technology expanded the definition of mechatronics to include intelligent computer control, system integration, and networks. A 1996 IEEE/ASME publication defined mechatronics as “The synergistic integration of mechanical engineering with electronic and intelligent computer control in the design and manufacturing of industrial products and processes.”²

Since the 1960s, the term has continued to evolve and there is no consensus on a static definition of mechatronics. In the book “Mechatronics: An Introduction,” Robert H. Bishop of the University of Texas defines mechatronics as the synergistic integration of mechanical, electrical, and computer systems, which comprises the following areas: physical and systems modeling, sensors and actuators,

signals and systems, computers and logic systems, and software and data acquisition.³

Some scholars understand mechatronics as more than just the integration of discrete disciplines, but as a “systems oriented approach to the design, development and implementation of complex systems,” and question whether efforts to concretely define mechatronics have confused the content and direction of the field.⁴

The 2014 book “Automotive Mechatronics” notes that mechatronics aims to “achieve a synergistic optimization of mechanical engineering, electronic hardware and software...” and notes that mechatronic systems and components are now present through nearly the entire vehicle.⁵

The evolving and varied definitions of mechatronics are reflected in the mechatronics program offerings of community colleges in Southeast Michigan. At Washtenaw Community College, mechatronics is focused on troubleshooting and maintaining robotic and automated equipment in three areas: fluid power, industrial electronics, and numerical control.⁶ Similarly, Macomb Community College and Henry Ford College define the term as the integration of mechanical, electronic, fluid power and computer robotics.⁷ At Monroe Community College, systems-level analysis, assembly, and troubleshooting are stressed as critical to the discipline, which involves the operation and maintenance of electro-mechanical-computer controlled systems.⁸



1 Auslander, David M. “What is mechatronics?” IEEE/ASME Transactions On Mechatronics 1.1 (1996): 5-9.

2 Ibid.

3 Robert, Bishop. “Mechatronics An Introduction.” (2006)

4 Bradley, David. “Mechatronics—More questions than answers.” Mechatronics 20.8 (2010): 827-841.

5 Reif, Konrad. Automotive Mechatronics. Germany: Springer Fachmedien Wiesbaden, 2014.

6 For more information please see: <https://www.wccnet.edu/learn/departments/amtd/programs/apmetr/>

7 For more information please see: <https://www.macomb.edu/future-students/programs/automated-systems-technology-mechatronics.html>, <https://catalog.hfcc.edu/programs/multi-skilled-manufacturing-maintenance-mechatronic-manufacturing-maintenance-associate>

8 For more information, please visit: <https://www.monroecc.edu/etsdbs/MCCatPub.nsf/Web+Certificate+Programs/Mechatronics-CERTIFICATE-PROGRAM?OpenDocument>



1 - 3 YEAR FORECAST

Skill needs in the CAV industry during the next one to three years are forecast in Figure 3 based on combining organizational mentions of current skill needs with future skill needs. During this time period, the relative demand for base skillsets decreases to 55 percent while the demand for enhanced and emerging skills increases to 30 percent and 15 percent, respectively.

Within the decrease of base skillsets, there is also a shift in prioritized KSAs with an increased emphasis on electrical and electronic skills, as well as the combination of all three base skills.

Participants often discussed the need for mechanical skills that are integrated with electrical and electronic competencies.

The increase in the enhanced skills is strongly focused on software skills. Finally, knowledge and understanding of cybersecurity begins to enter into the technician realm in the emerging skillsets.

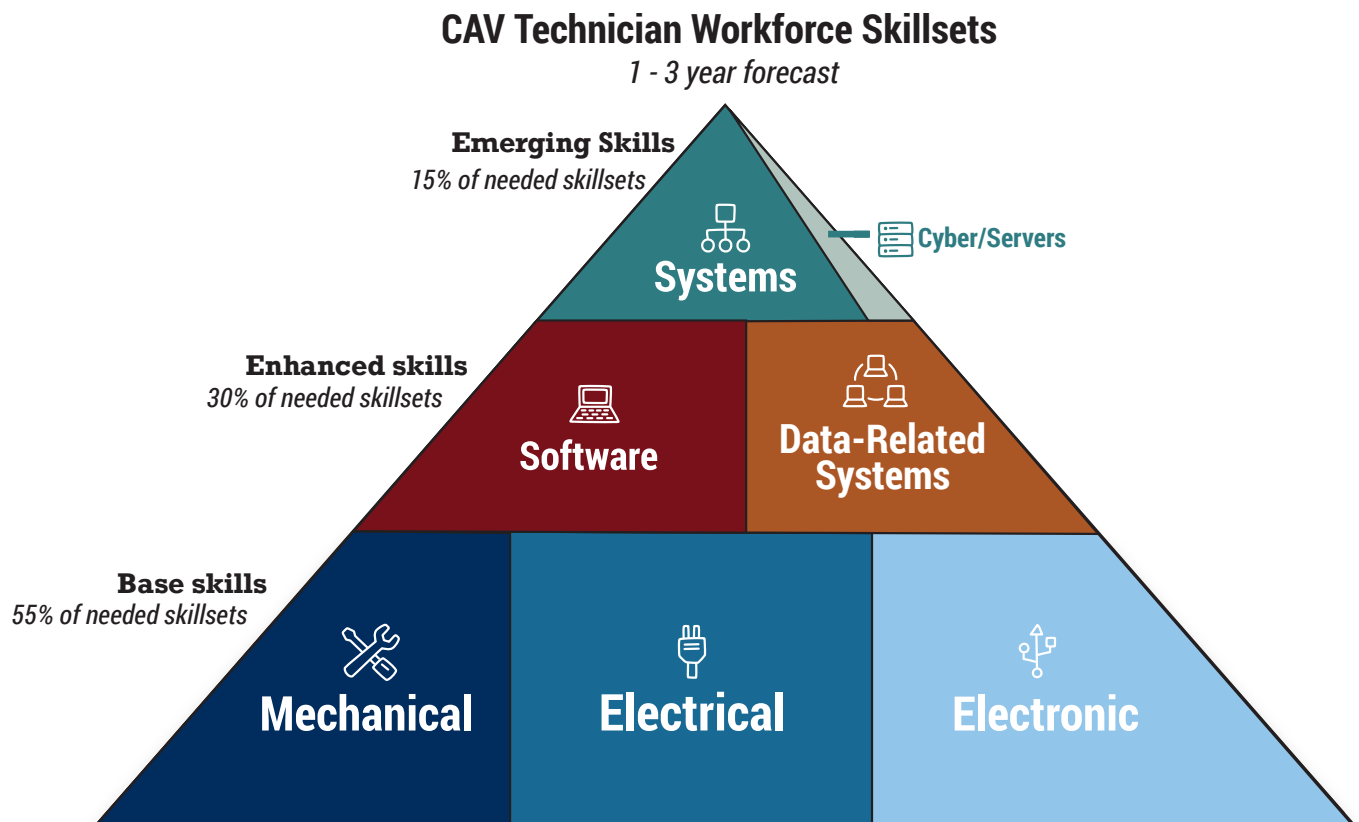


Figure 3. CAV technician skillsets needed in the sector during the next 1 - 3 years; see Table 1 and “Skillsets” section for definitions and examples of these technical skills.

Workforce skills versus industry needs

Currently (and in the near future), large employers develop this pyramid of skillsets through teams of technicians. When the market pushes for efficiencies, it is expected that technicians with a multitude of skills will be those who remain competitive within the job market. However, this also will require an increase in the number of people selecting this field as a career path. There are efforts within the ecosystem to increase interest in middle-skill jobs in CAV. For example, some large companies are leading efforts to increase interest in STEM activities through middle and high school robotics teams.

 3+ YEAR FORECAST

The workforce skills in three or more years will continue to evolve with increased demand for enhanced and emerging skills. Based on the future workforce mentions by organization, electronic skills and software skills were discussed most often, followed by mechatronics, data-related systems and electrical skills.

Emerging skillsets around systems and cyber will continue to develop as both vehicles and infrastructure connectivity advance. As participants reported, the increase in the number of CAV vehicles, both owner/operator and fleet vehicles, will continue to create new jobs requiring a strong, diverse skillset. The evolving jobs are outlined in Figure 5.

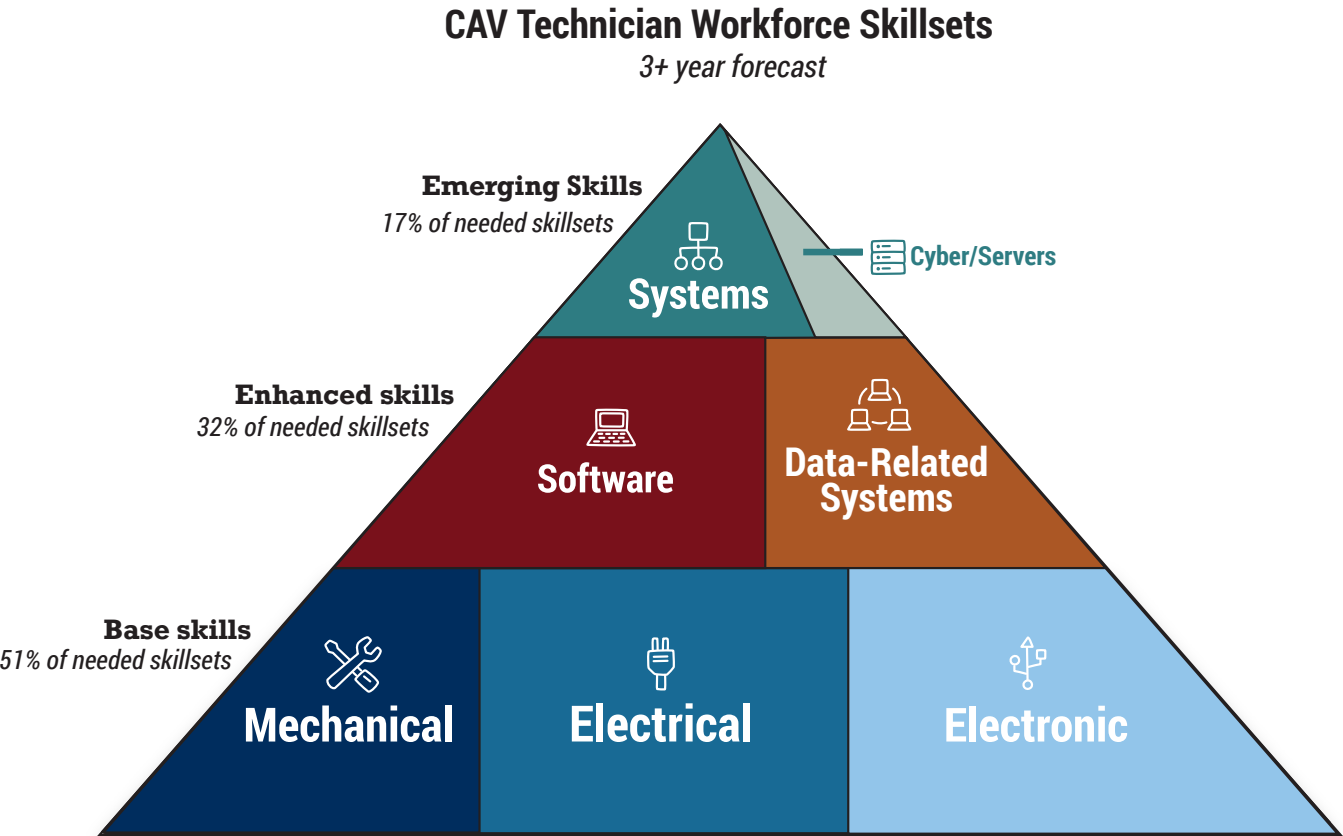


Figure 4. CAV technician skillsets needed in the sector during the next 3+ years; see Table 1 and “Skillsets” section for definitions and examples of these technical skills.

CAV INDUSTRY MIDDLE-SKILLS JOB ROADMAP



Figure 5. CAV middle-skill jobs roadmap for the next three years.



MIDDLE-SKILLS JOB ROADMAP

Jobs within the CAV industry related to testing and infrastructure are not significantly changing in the short term, according to participants, but the skillsets are becoming more advanced. As outlined in the emerging skills above, demand is growing for specialized skills, such as software and electronics, but embedded within demand for the base skills related to mechatronics.

Based on participant feedback, it is anticipated that most job openings for CAV technicians in testing departments over the next one to three years are replacements of retirees, not net new positions. It is important to note that the growing need for emerging and advanced skills should not be mistaken as a growing market or demand for technicians. Instead participants shared that while they continue to need technicians in the CAV sector, the skillsets in these positions are rapidly expanding to keep pace with technological innovations.

Figure 5 outlines the evolution of CAV sector jobs. These jobs are defined as the following:

- **CAV Technician** – a technician (or team of technicians) demonstrating mechatronics, software/data-related systems, and systems skillsets. Along the roadmap, the skillsets of technicians will need to increase in

depth and breadth to address the expanding capabilities of the vehicle. Example titles include: Prototype Technician, Calibration Technician, Validation Technician.

- **Safety Drivers** – employees who test “drive” ADAS or CAV-equipped vehicles. Troubleshoot as necessary. (In some organizations these job duties are added to a CAV technician’s role.)
- **Fleet/CAV Maintenance Technician** – skilled individuals to assist with remote troubleshooting and on-site maintenance of automated or autonomous vehicles in controlled environments with a fleet of vehicles.
- **Cybersecurity Technician** – a technician who understands the connected networks within the vehicle and can run various tests. Additionally, the technician can update the connected networks based on direction from a cybersecurity manager. Aspects of this work may be contracted out, especially within the public sector. Additionally, skillsets in cybersecurity are in such high demand that while this job requires mid-level skills, the pay level is significantly higher.
- **Customer Service Representative** – as CAVs serve the public (either on a university campus or in a city), a company representative will need to be present, either in-person or virtually. These employees will

EMERGING SKILLS: continued

need to interact with the public to assist with troubleshooting and ensure a safe customer experience.

- **IT Technician** (Infrastructure) – a public sector technician that can perform state of health monitoring and maintenance on CAV infrastructure networks and road side units.
- **Configuration Technician** (Infrastructure) – a public sector technician that configures and installs road side units. Currently, engineers configure the units using software and firmware. When this process is somewhat more automated, a technician could both configure and then go into the field to install the units. A configuration technician would need to have basic software skills in addition to the mechanical, electrical, and electronic skills required for installation.

The development of CAV-related infrastructure will increase the demand for technicians with greater network and IT experience, including cybersecurity and software skills. However, it is unclear at this point whether or not traditional public sector technicians will need to fully develop these new skillsets. To some extent these responsibilities will fall on other municipal departments and staff, like the IT department.

Additionally, it is likely that the private sector, including CAV vendors, will increasingly enter this space and contract with municipalities to provide cybersecurity and network maintenance. In a similar vein, participants expressed a general sentiment that the municipal technicians involved in maintenance and installation of CAV infrastructure will not face significant changes to their job duties and responsibilities in the next three to five years. Although it is unclear how much the skillset changes will affect traditional municipal technicians, the importance of systems, networks, software and IT will impact them to some extent.

**BLURRING OF DUTIES**

According to several participants, another aspect of the changing nature of the middle-skill jobs was the blurring of the duties between engineers and technicians, specifically in the design and testing space. While this was dependent upon the organization, several participants shared that technicians needed more analytical skills.

Conversely, engineers were needing to dig into more hands-on work.

“[At times,] I cannot tell who is a technician and who is an engineer. As a group manager, I don’t have a categorization, really. Our technicians are pushing the edge of engineering.” – Engineering Manager at a CAV-direct employer

“Based on our size, some of our engineers have to do technician-type work. Whereas if we had technicians do their work, the engineers could spend their time doing the analysis, or the counter-measures, or the development.” – Engineering Manager at the same a CAV-direct employer

Three different types of “blurring” emerged from this unexpected finding:

- Technicians and engineers work closely together to advance their projects. Given the emerging nature of CAV technologies, common boundaries between technicians and engineers grow indistinct as each individual learns new technologies and systems. This is beneficial for experimentation. Work practices and tasks are still evolving. In addition, skillsets ranging from basic skills to advanced skills are being redefined with each project. Experimentation will allow for redefined roles that most efficiently utilize skills and maximize team performance.
- Technicians are increasingly completing some entry-level engineering tasks. At times this was mentioned as a stop-gap as engineering positions were difficult to fill. Additionally, engineers are doing some technician-level tasks because of the emerging nature of the work and the lack of trained technicians in the area.
- Some technicians – one interviewer called them “hungry technicians” – want to become engineers, so they work hard to gain skills and push themselves to near-engineer level. Companies applauded the valuable skills of employees that start as technicians and then go back to school to become an engineer because of their ability to connect engineering concepts with hands-on practicality.

It should be noted that this blurred line dynamic is different with unions: when a company is unionized, the blurring of tasks and responsibilities is not feasible. However, a large portion of the CAV sector is currently operating outside of the traditional unionized space.

GAPS IN THE MIDDLE-SKILL CAV WORKFORCE

The gaps within the current CAV technician workforce emerge around the skillsets. As previously discussed, many employers are filling gaps through hiring technicians with a diversity of skillsets, but needs in the future articulated a much more streamlined team.

GAP 1

Based on participant interviews, **40 percent of the workforce gap is within the base skillsets, of which participants prioritized electronic and electrical skills, followed by mechatronic skillsets** (the combination of all three). When participants mentioned mechanical skills gaps, it was not as a stand-alone skill, but as an addition to other knowledge, such as electrical, electronic or software. Thus, mechanical expertise will need to fully evolve into mechatronic knowledge to address the demands of the CAV sector.

GAP 2

Thirty-seven percent of the workforce gaps are within the enhanced skillsets tier, with a lack of software skills accounting for 73 percent of that gap. The gaps in the enhanced skills are expected to grow more acute, especially as demand for this skillset grows during the next several years (see Figures 4 and 5). In some companies, the software gap is more acute when including resistance to (or lack of experience with) general computer skills by senior technicians. Participants reported some technicians either lacked the desire to learn new ways to include technology into their job duties or just struggled to adapt to new systems. These struggles were less evident in younger employees.

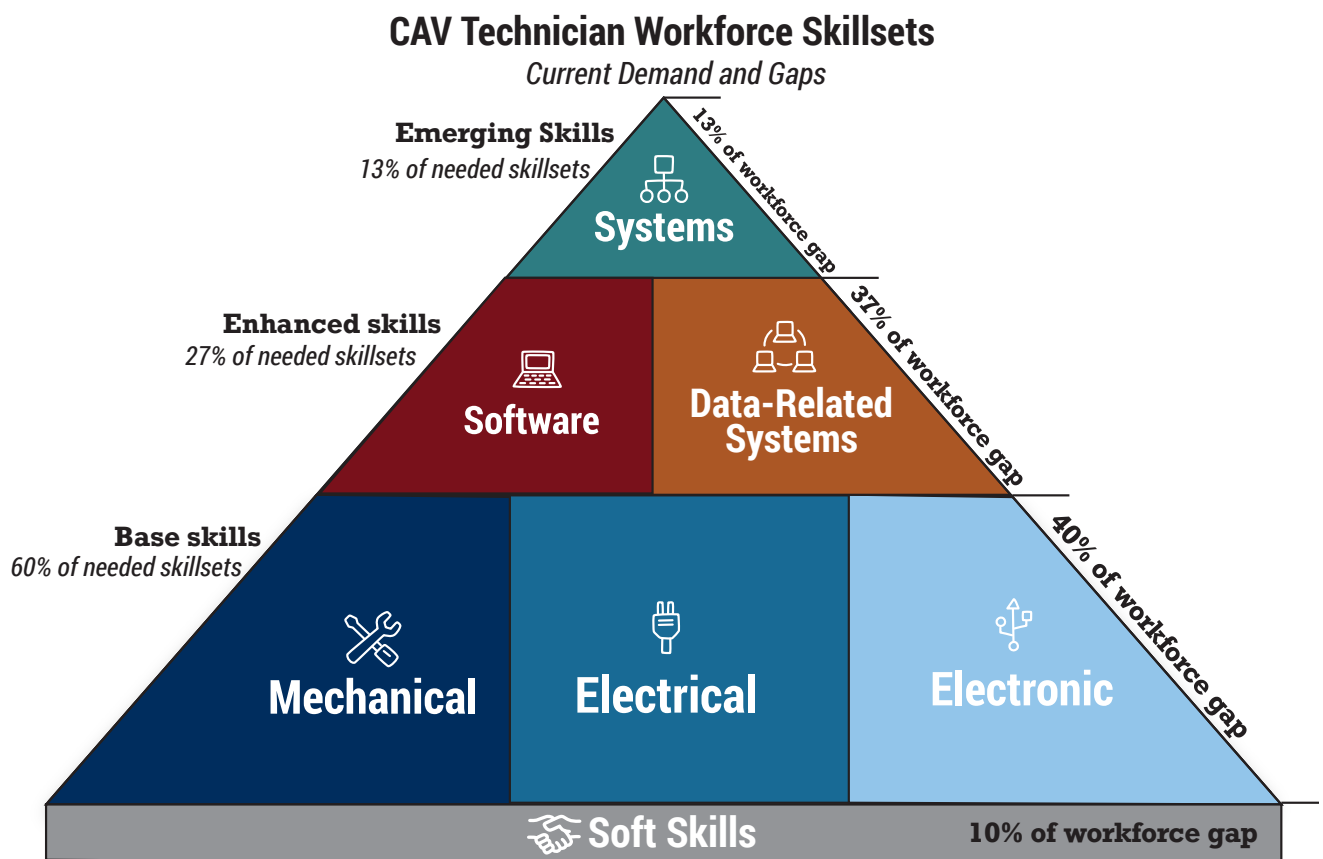


Figure 6. CAV technician skill demands and gaps

GAP 3

The **emerging skillset of systems knowledge represents 13 percent of the current gap**. While cyber is mentioned as a needed skillset in future years, no one reported that technicians currently have this skill. This role is currently filled by engineers or staff in IT settings. Thus, **cybersecurity skills will begin to form a gap in the near future**.

GAP 4

Crossing-cutting soft skills, especially a willingness and desire to learn new things, represent 10 percent of the current gap. Soft skills were increasingly emphasized by engineering and HR managers due to the rapidly evolving technology. For example, some technicians are innovating alongside engineers in prototyping, troubleshooting, and testing. The ability of these technicians to continue to develop their technical skills was based on soft skills such as passion for the field as well as a desire to learn, according to participants.

GAP 5

An additional gap implied by the skillset figures is the need for **highly-skilled, multi-disciplinary technicians**. As outlined above, the line between engineering duties and technician duties is starting to blur in the CAV space and 63 percent of the organizations mentioned employing or needing high-level technicians. The need for this blended role is two-fold: 1) shortages of engineers; 2) cost cutting measures as companies look for more efficient means to accomplish tasks. The increasing complexity of the vehicle is translating into a higher demand for multi-skilled individuals at all levels.



CONCLUSION

Innovations in mobility are transforming the movement of people and goods, leading to the emergence of new technologies and frameworks including mobility as a service (MaaS) and the ever increasing 'smart' components within a vehicle. These disruptions reverberate into the automotive workforce at all skill levels. Through this research study, the evolution of the skillsets of middle-skill jobs in the CAV sector have been identified for today's workforce as well as the future workforce.

The base skillsets of mechanical, electrical and electronic knowledge— or combined mechatronics – form the critical foundation for the CAV technician workforce. However, the proportion of these skills demanded is shrinking in comparison to the growing demand for emerging and advanced skills. Emerging skills in software and data-related systems are continuing to expand as more components on the vehicle are connected and linked together and to infrastructure. Advanced skills in systems and cybersecurity will also need to grow alongside the expanding complexity and connectivity of the vehicle. Woven through all these technical skills is also the binding nature of soft skills like problem solving and communication.

The diverse skillset pyramid might appear daunting to address in an associate's degree or certificate program. In fact, a degree may not be the sole solution. Instead focus could also be placed on course offerings to upskill or re-skill this developing workforce in these enhanced and emerging skills with hands-on, real-world experience that will be critical to the success of

this workforce. Individual experiential learning courses focused on developing particular skills can be developed and implemented in an agile manner to continuously evolve as the skills of the workforce and technology of the future advance. Complementary and compounding skillsets such as these develop over time and are best supported through life-long learning initiatives at companies.

Additionally, soft skill training and development must be integrated throughout all types of learning. These skills increase the effectiveness, productivity, and capacity of both technicians and the team. While soft skills are generally more challenging and abstract to impart, weaving these throughout all educational offerings, from primary to advanced-levels of education, will greatly benefit both students and future employers.

Successfully training and equipping middle-skill workers in the CAV sector is a critical part of its continued growth and development. Technicians offer unique perspectives and experiences in testing and can help streamline advancements when appropriately equipped and trained. The success of this sector in Southeast Michigan will depend not only on the engineering designers and innovators, but also the technicians who assist in bringing an idea from design into reality through prototyping, testing, troubleshooting and maintaining new products.

GLOSSARY

Connected and Automated Vehicles (CAVs)

Automated vehicles have varying levels of automated (i.e. non-manual) control systems. The National Highway Traffic Safety Administration defines automated vehicles on a scale from 0 (no automation) to 4 (full self-driving vehicles that do not require the driver to operate or control the vehicle at any time). Connected vehicles have some level of connection with other vehicles (V2V), infrastructure (V2I), and their other surroundings (V2X).

Connected and Automated Vehicle Sector

All companies, industries, organizations, and governmental entities involved in designing, testing, and operating connected and automated vehicles and the infrastructure, technology, and policy environment that supports them.

Mechatronics

The combination of mechanical, electrical, and electronic skillsets, as well as emerging skillsets in software and data-related systems, and system understanding. CAV systems that involve sensors or advanced driver assistance systems (ADAS) are examples of mechatronics systems. A complete discussion of mechatronics can be found on page 15.

Middle-Skill Jobs

Jobs that require more skills and experience than a high school education provides, but less than a four-year degree. Often these jobs require an associate's degree, vocational certificates, previous work experience and on-the-job training, or some college experience.

Mobility

Broadly, the mobility sector encompasses the products, services, technology, and infrastructure needed to facilitate the free movement of people and goods across physical spaces. The mobility sector includes traditional transportation industries, but also encompasses urban and environmental planning, public policy and government regulation, technological advances in connectivity and the sharing economy, cybersecurity and network architecture, and non-traditional modes of transportation.

Original Equipment Manufacturers (OEMs)

Manufacturing companies that assemble vehicles with equipment and parts produced by other companies, and sell these vehicles under their own brand name.

Technician

According to the Bureau of Labor Statistics, automotive technicians inspect, maintain, and repair cars and light trucks and work on traditional mechanical systems and increasingly advanced electronic and electrical systems. Technicians in the CAV sector have evolving duties which are rooted in basic technician responsibilities but are expanding into software, data systems, cyber-security, and systems-level duties.

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