High-Tech Workforce Preparation for Emerging Transportation Technologies

Final Project Report

Final Report
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16. Abstract

Over the past decade, the advancement of transportation technologies has been rapid. The introduction of technologies, including mobile robotics, Advanced Traffic Management Systems, ITS, and big data analytics, has the potential to transform the way transportation agencies conduct their operations. Many state departments of transportation (DOTs) are exploring the potential applications of emerging technologies for transportation systems management. As this continues, the workforce must similarly understand how to work with these technologies.

To meet the demand for technology-enabled workforce development, MDOT has called on CAR to provide an overall strategy to prepare a high-tech construction and operations-focused workforce within the next ten years. CAR, with support from the Workforce Intelligence Network (WIN), has addressed the three primary objectives of this project:

- Conduct research on new technologies and associated implementation strategies,
- Develop a series of recommendations for MDOT units to aid decision-makers in identifying the expertise gap within MDOT's current construction and operation workforce, and
- Provide a set of recruitment strategies for acquisition and (re)training the current and future workforce. These strategies will produce a nimble model that will allow MDOT to continue to change these materials as technology emerges.

CAR researchers divided the objectives of this project into five substantive tasks. The final report presents a consolidated report of the research tasks.

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WORKFORCE INTELLIGENCE NETWORK

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Workforce Intelligence Network (WIN)

Project Final Report

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Abstract:
This document is a summary of research efforts of the MDOT-sponsored research project, "High-tech Workforce Preparation for Emerging Transportation Technologies." This project was broken into five substantial tasks. They are as follows:

Task 1: State of Practice Review for Transformative Technologies – Task 1 describes five core concepts chosen by the MDOT project management team as areas of focus to evaluate workforce development. MDOT identified these concepts based on information provided in an earlier draft and provided in the appendix sections. This section also briefly analyzes MDOT technology-related strategic plans to identify core technology concepts. Appendix B contains additional information about the core technology selection process plan.

Task 2: Recommendation for Ideal Core Competencies Needed at MDOT and MDOT's Organizational Structure – This task highlights the current state of the transportation-related infrastructure sector, provides an overview of MDOT's organization, and reviews best practices across selected state DOT's.

Task 3: Technology-enabled Workforce Strategic Plan – Task 3 is focused on the strategic planning process and provides MDOT with some strategic recommendations for preparing a technology-enabled workforce across the department. To provide a set of recommendations, the project team developed a

SWOT analysis to identify MDOT's current strengths, weaknesses, opportunities, and threats to preparing their workforce for these emerging technologies.

Task 4: Training Materials for Current and Future Workforce – Task 4 provided an in-depth analysis of five hard-to-fill occupations as determined by an internal survey of MDOT departments and discussions between the project team and MDOT RAP Committee advisors. This analysis includes an occupational snapshot of each position, an analysis of the current training landscape by occupation, and a gap analysis of how to prepare additional training to accommodate future technologies.

Task 5: Future Workforce Recruitment Planning – The last task focused on delivering recommendations for recruitment strategies for MDOT. Under this section, the team provided an overview of the current recruitment landscape, along with an analysis of challenges and opportunities MDOT could utilize in their recruiting strategy, and this section ended with a comprehensive recruitment flow by occupation for the five hard-to-fill positions identified in Task 4.

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Introduction

Over the past decade, the advancement of transportation technologies has been rapid. The introduction of technologies, including wireless communication, ITS, big data analytics, connected and automated vehicle technologies (CAV), and civil integrated management (CIM), can transform the way transportation agencies conduct their operations. Many state departments of transportation (DOTs) are exploring the potential applications of emerging technologies for transportation systems management. As this continues, the workforce must similarly understand how to work with these technologies.

MDOT has called on CAR to provide an overall strategy to prepare a high-tech construction and operations-focused workforce within the next ten years to meet the demand for technology-enabled workforce development. CAR, with support from the Workforce Intelligence Network (WIN), is addressing three primary objectives for this project:

- Conduct research on new technologies and associated implementation strategies,
- Develop a series of recommendations for MDOT units to aid decision-makers in identifying the expertise gap within MDOT's current construction and operation workforce, and
- Provide a set of recruitment strategies and training materials for acquisition and (re)training the current and future workforce. These strategies will produce an agile model that will allow MDOT to continue to change these materials as technology emerges.

CAR researchers divided the objectives of this project into five substantive tasks. The following document presents a consolidated report of the research tasks.

Main Objectives

MDOT must ensure its workforce maintains knowledge in these specialties. Providing retraining opportunities for the current workforce while simultaneously identifying emerging skills needed for workers is vital when attracting and recruiting skilled employees. Maintaining an efficient organizational structure is crucial to keep pace with the advancement of emerging technologies.

The following analysis explores the critical emerging technologies that will impact MDOT’s work considerably and the existing internal and external resources available to the department for workforce development. This guide also provides recommendations for workforce development strategies. It highlights the educational institutions and programs, skills, and occupations in southeast Michigan to analyze the current landscape of transportation-related occupations and identify emerging trends in the industry.

Methodology

In Task 1, the CAR team reviewed pre-existing MDOT documents to identify core technology concepts. The team then identified a series of basic technologies with potential implications for current or future MDOT activities, technology-based concepts that describe how disparate technologies can work together within practical applications, and finally, transportation departments adopted technology-based practices. These practices leverage the aforementioned individual technologies and concepts.

CAR broke Task 2 down into the following sections: Current State of the Industry, MDOT Organizational Analysis, and Review of Best Practices of workforce development programs within the state DOTs. Throughout this effort, researchers gathered information using various methods, including literature research, data analysis, and interviews, to assess the primary skills needed to adopt each technology. Researchers pulled data from the Bureau of Labor Statistics Occupational Employment Statistics program, which produces employment and wage estimates for nearly 800 occupations (Bureau of Labor Statistics, 2020). The analysis focuses on the following occupational categories:

- Architecture and Engineering
- Computer and Mathematical
- Construction and Extraction
- Life, Physical, and Social Science
- Management

The final part of this section provides a review of the academic programs offered across Michigan focused on the construction and operations of the transportation-related infrastructure. This analysis includes pre-professional, certificate, associate-level, undergraduate-level, and graduate-level degree programs across major academic institutions in Michigan. Using the occupational categories listed above, CAR consolidated educational programs under each of the relevant categories.

In Task 3, to provide a strategic plan for MDOT, the team conducted an extensive literature review of existing reports and journal articles on recruiting, retention, and training practices for transportation employees and performed a content analysis of MDOT strategic plans. Further, the team prepared a survey to collect MDOT leaders' insights about emerging high-tech workforce needs and the existing gaps. The team used the findings to arrange a matrix of strengths, weaknesses, opportunities, and threats and a set of recommendations on technology-enabled workforce preparation for MDOT.

To accomplish Task 4, the WIN team analyzed the data obtained through CAR research, together with WIN data, to conduct an environmental scan and asset map of educational training resources and conduct an environmental scan of Performance-Based Objectives (PBO's) for high demand occupations. WIN examined in-demand training programs, skills, certifications, and wages to provide a full landscape of the projected change in operations to the transportation industry.

During Task 5, WIN analyzed the survey results obtained through the MDOT organization-wide survey. WIN examined in-demand training programs, skills, certifications, and wages to provide the entire landscape of the projected change in operations to the transportation industry. This report includes recruitment recommendations to identify critical techniques needed to manage the changing transportation infrastructure. WIN conducted 1:1 interviews with transportation infrastructure education experts to inform additional research on recruitment and strategy. WIN also performed a literature review of various recruitment best practices in the Southeast Michigan region and the state.

Task 1: State of Practice Review for Transformative Technologies

1.1 Core Technology Focus Areas

One of the critical goals of this project was to identify a group of core technologies forecasted to become especially essential to a transportation agency's operation in the future. With that aim in mind, the CAR team researchers first identified a comprehensive list of emerging technologies, practices, and concepts in engineering, design, construction, operation, and transportation system management (please see Appendix B for more detail). The list included technologies, technology-based practices, and also technology-based concepts. Guided by creating the list of emerging technologies, methods, and concepts, the CAR team worked with the MDOT Project Manager and Research Advisory Panel to narrow down the list to five groups of highly impactful technologies to MDOT practices. This section provides detail on the top five focus areas as selected by the MDOT project management team.

1.1.1 Mobile Robotics

Recent advancements in mobile robotics offer possibilities for DOTs to provide valuable data while reducing risk to personnel. Mobile robots might be either remote-controlled or capable of autonomous operation. Autonomous on-road vehicles are one obvious and potentially long-term application of autonomous robotics. However, DOTs are currently using small robotics for practical applications and investigating other near-term uses.

FIGURE 1. A TETHERED MOBILE ROBOT USED FOR INSPECTION OF DRAINAGE SYSTEMS

Source: SR&R Environmental (accessed July 2020)

Operation

The operation of mobile robots is a learned skill. A qualified operator will be required to control the robot without undue risk to people, the environment, or the technology itself. Some mobile robots may have aspects of their operation that are automated by software. DOT staff responsible for mobile robots' operation may need to be knowledgeable in real-time remote control and programming code.

Data Collection

Adopting mobile robotics will also present opportunities and challenges in utilizing remote sensing technologies for inspection tasks that traditionally have relied on human vision and experience. Robotic platforms can accommodate an ever-expanding variety of sensors (e.g., vision, thermal vision, lidar). DOT staff utilizing such platforms will require working knowledge of the appropriate sensor types and how to interpret the sensors' data.

On-road Automated Vehicles

Automated vehicle technology has many potential applications, including use by highway work crews. One demonstrated application is to install leader-follower technology in attenuator trucks (designed to absorb the impact of wayward vehicles) (Kratos Defense & Security Solutions, n.d.). By setting an attenuator vehicle to follow a leading vehicle, work crews can avoid putting a driver in a high-risk situation and utilize that crew member for other tasks.

FIGURE 2. AUTONOMOUS ATTENUATOR TRUCKS CAN REDUCE RISKS TO ROAD CREWS

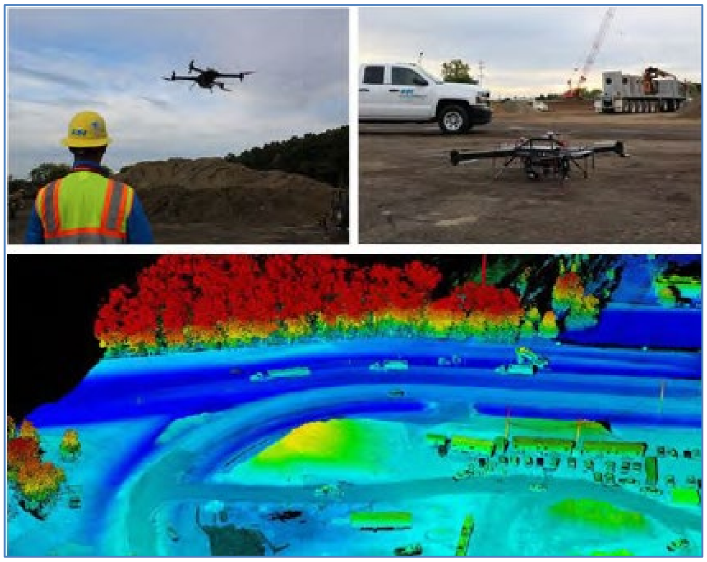
Source: Heavy Hunt (accessed July 2020)

Unoccupied Aerial Vehicles (UAVs)

Unoccupied aerial vehicles (UAVs)—more commonly referred to as *drones*—offer agencies improved infrastructure inspection practices compared to traditional methods. Also, recent FAA regulations have facilitated the use of UAVs for commercial (and government) applications such as digital mapping and bridge inspection. DOTs may find it very useful to have professional UAV operators on staff to inform other staff members on the established and potential use cases.

Inspection via UAVs has been substantially researched and shows much promise for implementation into routine operations. Recent research with the Michigan Tech Research Institute (MTRI) evaluated five UAV platforms for practical suitability for bridge inspection and traffic monitoring. The project demonstrated the ability to rapidly and accurately detect bridge deck surface and subsurface condition issues using UAV-collected imagery (Brooks, et al., 2018).

FIGURE 3. UAV-BASED LIDAR INSPECTION PLATFORM



Source: MTRI and MDOT accessed July 2020

Crawling and Climbing Robots

In the realm of mobile robotics, full-size autonomous vehicles and UAVs receive much attention. However, transportation agencies have quietly adopted ground-dwelling robots into practice. Researchers continue to improve on existing platforms and experiment with new applications. For example, roboticists have designed robots to crawl along with bridge members, tunnel through drainage culverts (Figure 4), and even climb concrete walls (Figure 5).

FIGURE 4. PIPE AND CULVERT INSPECTION ROBOT

Source: SuperdroidRobots, accessed July 2020

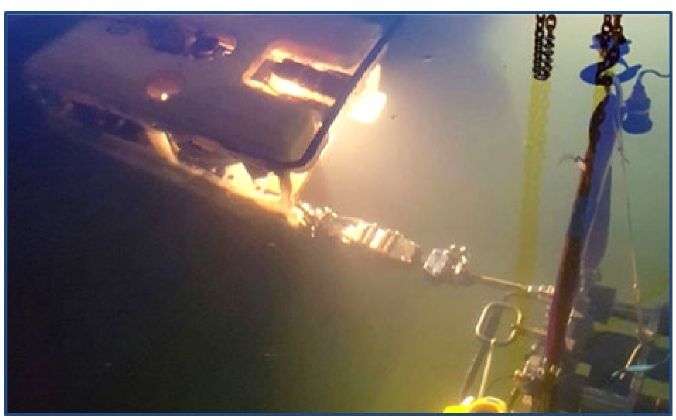
FIGURE 5. A PROTOTYPE BRIDGE INSPECTION ROBOT

Source: Swiss Federal Institute of Technology via HJ3 Composite Technologies

Aquatic Robots

Traditional underwater inspection is performed manually by a certified diver who is also appropriately trained to conduct inspections. The increasing availability of low-cost high-function aquatic robots equipped with high-quality sensors can reduce the necessity of manual inspection—decreasing risk and cost. Submarine robots have even been used in underwater construction (Figure 6 & Figure 7) (ROV Replaces Divers in Monopile Installation Work, 2017).

FIGURE 6. AN UNDERWATER ROV WITH CUSTOM-FITTED TOOLS CAN PERFORM SOME CONSTRUCTION TASKS



Source: Ocean News, accessed July 2020

FIGURE 7. MDOT'S BRIDGE INSPECTION ROBOT USES SONAR TO DETECT UNDERWATER CHANNEL SCOUR AROUND BRIDGE PILINGS

Source: AASHTO Journal, accessed July 2020

1.1.2 Advanced Traffic Management Systems

An Advanced Traffic Management System (ATMS) is a concept for leveraging information and communications technology for active traffic control interventions. Complex ATMS are often centrally operated from a traffic operations center. Traffic operations professionals monitor data feeds in real-time to detect issues such as crashes and congestion. When necessary, traffic operators can respond to traffic problems with a variety of mitigating interventions. The options available to traffic operators may include sending traveler information out to dynamic message signs, deploying first responders, and adjusting traffic control signal timing (De Schutter, et al., 1999, pp. 42-51).

FIGURE 8. SOUTHEAST MICHIGAN TRAFFIC OPERATIONS CENTER (SEMTOC)

Source: Click On Detroit, (accessed July 2020)

Intelligent Transportation Systems

ITS describes a broad conceptual approach of utilizing information and communications technology to improve traffic and the transportation system's management and operation.[1] The statewide MDOT ITS system includes the following devices and approximate device counts.

TABLE 1. MDOT ITS DEVICE COUNT AS OF SEPTEMBER 2019

Closed-circuit Television (CCTV) Camera	670
Microwave Vehicle Detection Station (MVDS)	717
Environmental Sensor	563
[DSRC] Roadside Unit (RSU)	251
Dynamic Message Sign (DMS)	235
Pavement Sensor	140
Lane Control Sign	93
Wireless Vehicle Detection Station (WVDS)	43
Dynamic Display Panel	68
Flasher Sign + Flashing Beacon	40
Travel Time Sign	12

Source: MDOT ITS Database, downloaded September 2019. CAR performed additional data cleaning.

Advanced Signals [2]

A standard traffic signal has a pre-determined cycle time no matter what the circumstances. A slightly more complicated system may allow for timing variations based on time of day; for example, extending the green phase for a corridor during rush hour or converting to a blinking-red phase during late-night hours, but these phases are still pre-determined. Changing timing schemes on traditional signals generally requires manual re-programming of the device in the field.

In recent decades, state and local transportation departments have been upgrading signal systems with advanced signals that provide various means of more efficient traffic control. Modern signals are intelligent connected devices capable of control and monitoring by remote TOCs and dynamic response to traffic conditions (Descant, 2018). Many agencies, including MDOT, have adopted extensible

[1] ATMS is sometimes considered a subset of ITS. However, ITS is a broader concept that includes individual devices. ATMS is an ITS-based system that combines a variety of devices and processes within a coherent operational architecture.

[2] Advanced signal technologies are often considered a subset of ITS. MDOT is currently in the process of merging their signals and ITS operations. For the time-being, MDOT’s Intelligent Transportation Systems (ITS) program is considered a subcomponent of MDOT’s TSMO program and the signals program is separate, but integrated into MDOTs ATMS via TOCs.

standards to integrate future signal technologies (Michigan Departments of Technology, Management and Budget and Transportation, 2019).

Figure 9. MDOT Standards For Traffic Signal Control Cabinets Require A Modular Layout To Allow For Future Technologies

Source: Econolite

1.1.3 Data Analytics

MDOT, like all DOTs and most large organizations, has access to myriad data sources. Determining what data is valuable and how it can be used is a complex task. Turning data into actionable information often requires skill and experience. The ability to understand the value of data and information is valuable across an enterprise.

The term "Big Data" became popular about a decade ago but has declined in use in the last five years or so. Big data is just data but reflects an understanding that the cost of collecting and storing data had prompted the aggregation of massive datasets that were difficult to analyze using traditional methods like spreadsheets. Often, conventional relational databases are not even up to making sense of massive datasets, prompting many large organizations to develop proprietary data analysis software. The complexity of pavement management systems and associated data have led many transportation agencies to pursue such options (Zimmerman, 2017).

Transportation agencies typically work with fairly well-structured and standardized data, implying that common database approaches are sufficient for most purposes. However, leveraging even simple databases for practical purposes often requires working knowledge of programming languages and database architectures (Brooks & Ahlborn, 2017). Data science professionals and MDOT staff with a working knowledge of database management systems, geographical information systems (GIS), and other tools could provide additional value in identifying new ways to glean insight and integrate valuable information throughout the enterprise.

Artificial Intelligence

Recent advancements in artificial intelligence (AI) allow data analysts to automate and optimize analytics processes to generate new and powerful insights. The following are specific approaches to AI.

Machine Learning

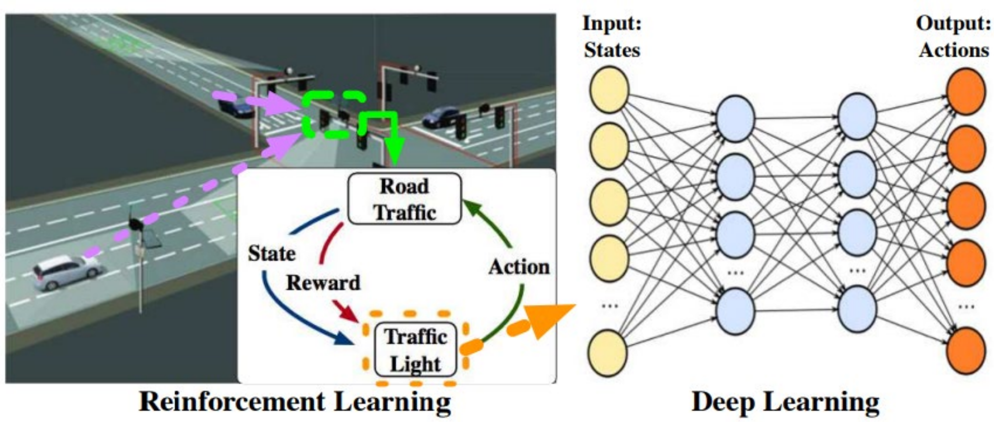
Machine learning is a process in which a specifically designed algorithm can automatically derive information from large datasets. With machine-learning techniques, programmers establish general relationships between potential inputs and outputs concerning the program's end goal. The operational details of the algorithm are initially left unresolved. Instead of specific operating rules, AI learns the relationships between inputs and outputs when presented with a set of training data. A basic machine-learning process is often similar to statistical regression. However, it may use advanced statistical methods or handle large inter-related datasets that would be difficult or impossible for humans to comprehend and manipulate with traditional regression approaches.

Neural Networks, Deep Learning, and Cognitive Computing

Many decades ago, computer scientists and artificial intelligence (AI) researchers, inspired by new neuroscience findings, designed processing architectures and software algorithms that mimic neurons' biological activity in the human brain. This approach to artificial intelligence has enjoyed a recent resurgence as evolving computer hardware, and the availability of large data sets have made it more viable. Such an approach is generally known as an *artificial neural network*. Multiple layers of artificial neurons (known as perceptrons) can be combined to process data in a process known as *deep learning*. The real-time implementation of deep learning is known as *cognitive computing* (Center for Automotive Research, 2018).

One promising application of deep learning to transportation management is to use neural networks to adjust adaptive traffic signals' timing across a grid road network (Liang, Du, Yang, & Han, 2019).

FIGURE 10. A MODEL FOR TRAFFIC SIGNAL CONTROL VIA DEEP REINFORCEMENT LEARNING

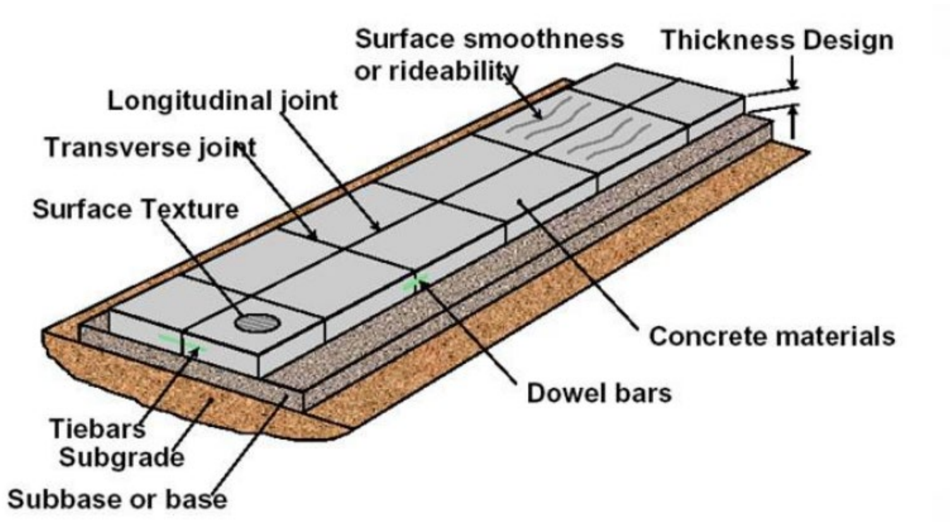


Source: Liang et al. via IEEE Transactions on Vehicular Technology

1.1.4 Mechanistic-Empirical Design and Engineering

While MDOT provides a range of transportation and mobility-related services, highway pavements construction and maintenance are core priorities. Pavements and bridges comprise the vast majority of MDOT's assets by cost. There are opportunities for MDOT to achieve substantial improvements in operational efficiency by improving the design and management of pavement assets. The state-of-the-art in pavement design is called *mechanistic-empirical (M-E) design*.

FIGURE 11. BASIC COMPONENTS OF CONCRETE PAVEMENT DESIGN



Source: Dr. B Munwar Basha, accessed July 2020

Mechanistic-empirical design and engineering is an accepted best practice intended to promote continual advancement in providing high-quality infrastructure will minimal lifecycle costs. This approach requires data collection matched to key performance metrics, efficient enterprise data management, and intelligent data analytics. The ability to use M-E pavement design to optimize pavement asset management relies on collecting specific objective pavement performance metrics across a pavement's service life (Pierce & McGovern, 2014).

MDOT Construction Field Services Division began efforts to transition to M-E design in 2012. However, because the action was not coordinated with maintenance or asset management processes, MDOT's pavement engineers are not provided with key data elements. The full adoption of M-E principles across MDOT would enable continual improvement of pavement design and asset management strategies (Dennis & Spulber, Performance-Based Planning and Programming for Pavement Management, 2016).

The *MDOT Pavement Design Guide* details how MDOT pavement engineers utilize *AASHTOWare Pavement ME Design* software. The guide also highlights aspects of the design process where historical data is missing to allow for better local calibration. A department-wide adoption of an M-E framework could collect this data to inform pavement design and management strategies, helping to maintain Michigan's highway network in better condition at a reduced cost (Michigan Department of Transportation, 2020).

1.1.5 Complete Streets Design and Context-sensitive Solutions

State DOTs historically optimized highway design for "level-of-service" (LOS)—a measure of vehicle throughput. As a result, transportation systems often prioritize traffic of privately-owned vehicles, often to the detriment of other uses of public rights-of-way. While MDOT has adopted various context-sensitive policies to obtain community buy-in and provide multimodal service (Michigan Department of Transportation, n.d.), achieving a sustainable future of transportation and mobility will require familiarity and buy-in of these policies across the organization.

Complete Streets

According to the USDOT, adopting a complete streets policy implies that "the focus of road design is no longer about auto-mobility, but creating an overall network that serves all users" (U.S. Department of Transportation, n.d.). There is no single design prescription for a complete street. Each design should be context-sensitive to the community's needs (Smart Growth America and National Complete Streets Coalition, 2016). Aspects of complete streets design that highway engineers have historically ignored include (Smart Growth America and National Complete Streets Coalition, 2016):

- Needs of bicyclists and people on foot
- Transit and multimodal infrastructure
- Links between transportation and land-use planning
- Links between transportation systems and human health metrics
- Links between transportation and sustainability (social, environmental, and economic)

FIGURE 12. WASHINGTON AVENUE IN BAY CITY FEATURES COMPLETE STREETS DESIGN ELEMENTS SUCH AS WIDE PEDESTRIAN-FRIENDLY SIDEWALKS, TRAFFIC-EXCLUDING BOLLARDS, AND STREET TREES

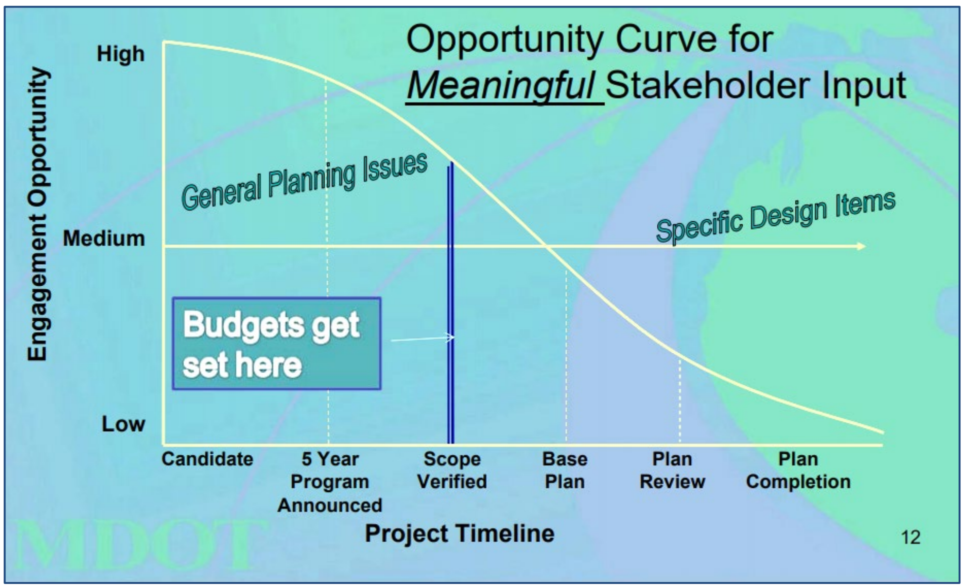
Source: MDOT, accessed July 2020

Context-Sensitive Solutions

The earnest adoption of a complete streets policy is an essential first step in transitioning a transportation agency focused on traffic to a mobility agency focused on people. However, it is critical that designers also consider the community's needs and preferences surrounding a highway project; this is a difficult task requiring new skills. Individual people have individual interests and expectations that may be conflicting or unrealistic. For a highway project to best fit a community's context, a transportation agency may need to incorporate communicative planning, consensus building, and conflict resolution processes.

The non-profit Project for Public Spaces describes context-sensitive solutions as "a collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic and environmental resources while maintaining safety and mobility" (Project for Public Spaces, 2013-2017).

FIGURE 13. COMMUNITY ENGAGEMENT SHOULD OCCUR EARLY IN THE PROJECT DEVELOPMENT TIMELINE



Source: MDOT, accessed July 2020

The subsequent sections of this document contain background information that was aggregated in selecting these core five concepts.

1.2 MDOT Technology Strategic planning

CAR has reviewed existing MDOT planning documents that guide the Department's technology integration into transportation systems management and operations. A summary of the critical aspects of each document is available in Appendix B.

A review of MDOT's most pertinent technology-related planning documents reaffirms MDOT's commitment to remaining informed of the advancements in transportation-related technology. Further, MDOT aspires to operate with sufficient flexibility and a culture of innovation to facilitate the efficient adoption and utilization of emerging technologies when appropriate. This collection of plans is often specific in describing technology innovations that MDOT has explored and adopted in the past but does not propose particular deployment plans or investment strategies for future years. MDOT not declaring specific technology initiatives for coming years may be an appropriate approach given that it is practically impossible to predict the future development and adoption of emerging technologies. Unlike forward-looking transportation planning based on broad structural and demographic trends, integrating future technologies must remain reflexive and adaptive.

A theme that runs through several of the planning documents is internal friction between MDOT business areas. Part of this is general communication and coordination issues, but there is also a frequent acknowledgment that various data streams within MDOT are redundant, underutilized, inefficient, outdated, or otherwise suboptimal. Addressing MDOT's ICT and enterprise data management architecture is likely to be a multi-year effort. This will likely never reach a state of completion but will require continual revision and improvements in response to changing technologies, regulations, and other factors. However, this issue points to an immediate need for in-house expertise in information/communications technology (ICT), including computer network architecture, database architecture, data analysis, and enterprise data management.

Task 2: Recommendation for Ideal Core Competencies Needed at MDOT and MDOT's Organizational Structure

2.1 Current State of the Industry

Providing recommendations for the ideal core competencies needed at MDOT (recommendations found under Task 3) requires starting by analyzing the industry's current state. The following section provides an overview of emerging skills required for the operation and construction workforce, employment trends in the transportation-related infrastructure industry, and Michigan's current educational and training programs for this sector.

2.2 Emerging Skills in the Operation and Construction Workforce

Much of the emerging technology in the transportation-related infrastructure sector, especially on the construction side of operations, is developed to increase productivity, safety, job satisfaction, and profitability. The following section highlights the emerging skills needed to accommodate this era of advancement in this industry (please see Task 1 for a complete analysis of emerging technologies). These skills are broken into two distinct categories: technical skills and soft skills.

Technical Skills:

- Building Information Modeling
- Circuit Knowledge
- Cloud Computing
- Cybersecurity
- Data Mining and Predictive Modeling
- Data Science
- Geographic Information Science
- Internet of Things (IoT)
- Mechatronics
- Productivity software solutions (PlanGrid)
- Project Controls (Earned Value Management (EVM))
- Programming (i.e., Python, C++, MATLAB, JavaScript)
- Robotics Engineering
- Robotic Process Automation
- Signal Processing
- Software Development
- Statistics
- Trouble-shooting

Soft Skills:

- Communication
- Creativity
- Collaboration
- Critical Thinking
- Cultural Awareness
- Decision Making
- Emotional Intelligence
- Growth Mindset
- Innovation
- Leadership
- Management
- Systems Thinking
- Task Management

2.3 Analysis of Employment Trends in Transportation-Related Infrastructure Industry

The following section provides a detailed analysis of the five major occupational groups that are employed in the transportation-related infrastructure sector (please see the methodology section for greater detail on the classification system):

- Architecture and engineering,
- Computer and mathematics,
- Construction and extraction,
- Life, physical, and social science, and
- Management

2.3.1 Architecture and Engineering

The architecture and engineering category includes three minor groups: Architects, Surveyors, and Cartographers; Engineers; and Drafters, Engineering Technicians, and Mapping Technicians. Occupations within these minor groupings include Surveyors, Civil Engineers, and Architectural and Civil Drafters.

In 2019, the largest occupations in the United States and the state of Michigan within this category were electrical and electronics engineers (314,360 US employment/14,090 MI employment), followed by civil engineers (310,850/6,640), drafters (192,760/5,330), and electrical and electronics engineering technicians (122,550/2,320) (Bureau of Labor Statistics, 2020). Michigan saw a year-over-year percent decline in two of the largest occupations in the architecture and engineering category: civil engineers (declined by 8.7 percent) and electrical and electronics engineering technicians (declined by 16.8 percent) (Bureau of Labor Statistics, 2020).

Please see Table 2 below for more details.

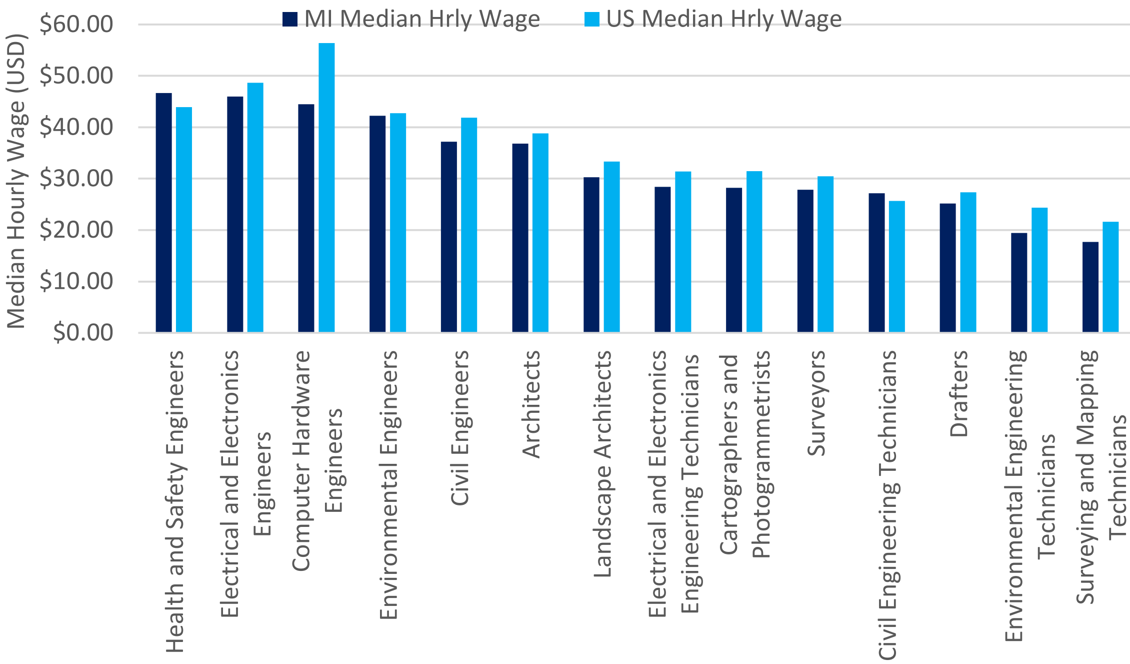
Table 2. Top Architecture and Engineering Occupations in Michigan, 2019

Top Occupations	MI Employment (2019)	YOY Percent Change
Electrical and Electronics Engineers	14,090	6.7%
Civil Engineers	6,640	-8.7%
Drafters	5,330	5.8%
Electrical and Electronics Engineering Technicians	2,320	-16.8%

Source: U.S. Department of Labor, Bureau of Labor Statistics

The highest paying architecture and engineering jobs in 2019 in the United States were computer hardware engineers (USD 56.36 median hourly wage), electrical and electronics engineers (USD 48.68), health and safety engineers (USD 43.95), and environmental engineers (USD 42.72) (Bureau of Labor Statistics, 2020). Michigan's top-earning occupations in this category in 2019 were health and safety engineers (USD 46.68 median hourly wage), electrical and electronics engineering (USD 46.00), computer hardware engineers (USD 44.49), and environmental engineers (USD 42.25) (Bureau of Labor Statistics, 2020).

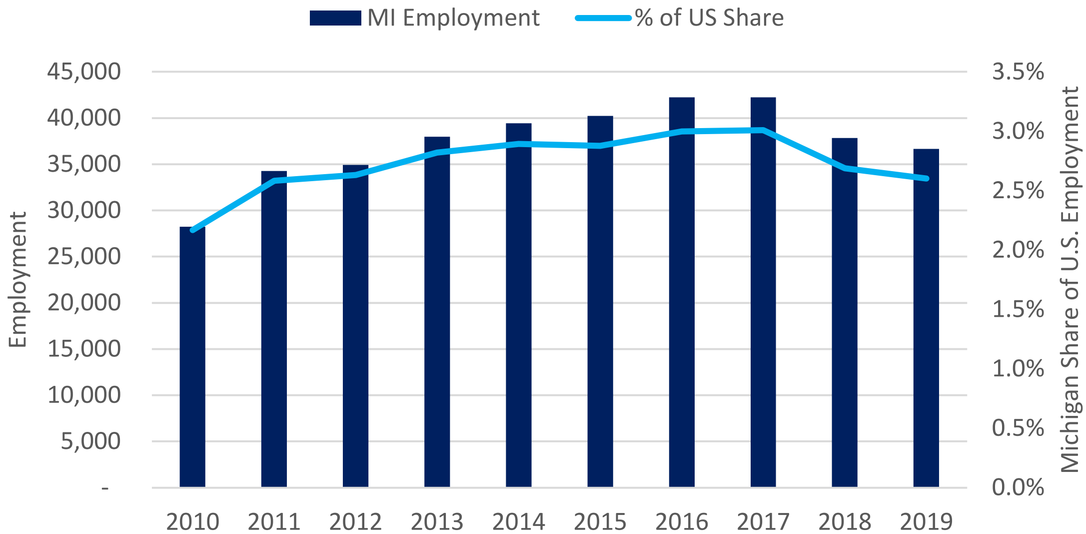
FIGURE 14. ARCHITECTURE AND ENGINEERING WAGE ANALYSIS BY OCCUPATION, 2019



Source: U.S. Department of Labor, Bureau of Labor Statistics

From 2010 to 2017, Michigan's architecture and engineering employment level increased year-over-year. However, since 2017, this occupation category has seen year-over-year declines—dropping Michigan's share of U.S. employment in this occupational group from 3 percent in 2017 down to 2.6 percent in 2019 (Bureau of Labor Statistics, 2020). Please refer to Figure 15 below for the complete historical trend of the group.

Figure 15: Architecture and Engineering Employment, 2010 to 2019



Source: U.S. Department of Labor, Bureau of Labor Statistics

2.3.2 Computer and Mathematics

The computer and mathematical category is split into two minor groups: Computer Occupations and Mathematical Science Occupations. Occupations within these subgroups include Information Security Analysts and Data Scientists.

In 2019, the largest occupations in the United States and Michigan within the computer and mathematics occupational category were software developers (1,406,870 US employment/40,190 MI employment) followed by computer support specialists (832,750/21,480), computer systems analysts (589,060/14,350), and network and computer systems administrators (354,450/6,680) (Bureau of Labor Statistics, 2020). Michigan saw a year-over-year percent decline in three of the largest occupations under the computer and mathematics category. These occupations were computer support specialists (declined by 1.8 percent), computer systems analysts (decreased by 6.9 percent), and network and computer systems administrators (declined by 7.7 percent) (Bureau of Labor Statistics, 2020). Please see Table 3 below for more details.

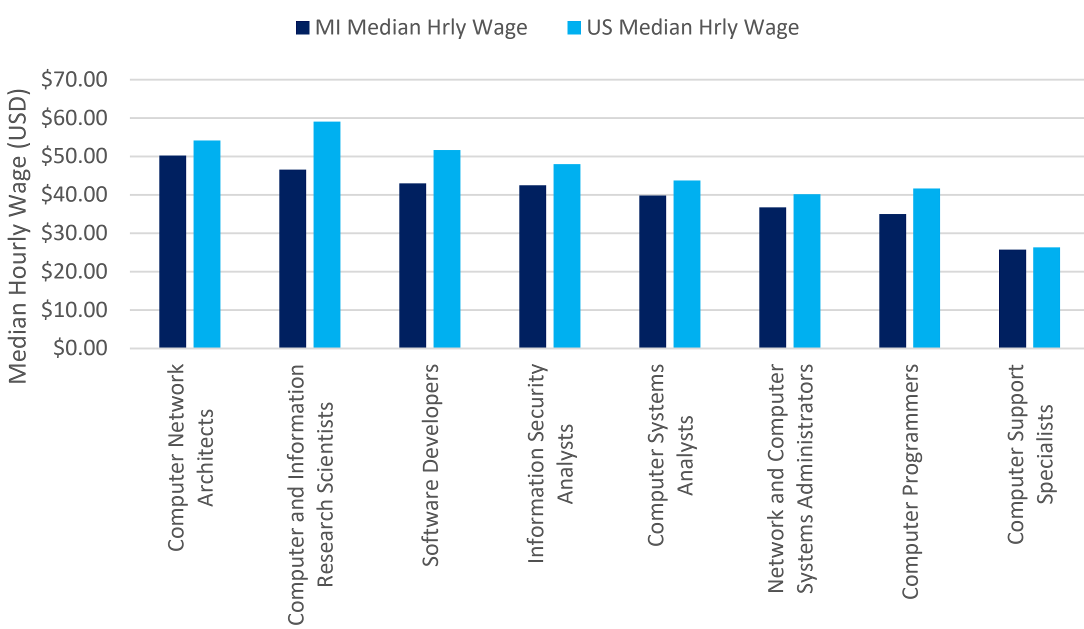
TABLE 3: TOP COMPUTER AND MATHEMATICS OCCUPATIONS IN MICHIGAN, 2019

Top Occupations	MI Employment (2019)	YOY Percent Change
Software Developers	40,190	0.8%
Computer Support Specialists	21,480	-1.8%
Computer Systems Analysts	14,350	-6.9%
Network and Computer Systems Administrators	6,680	-7.7%

Source: U.S. Department of Labor, Bureau of Labor Statistics

The highest paying computer and mathematics jobs in 2019 in the United States are computer and information research scientists (USD 59.06 median hourly wage), computer network architects (USD 54.18), software developers (USD 51.69), and information security analysts (USD 47.95). Michigan's top-earning occupations in this category are computer network architects (USD 50.25 median hourly wage), computer and information research scientists (USD 46.54), software developers (USD 43.01), and information security analysts (USD 42.45) (Bureau of Labor Statistics, 2020).

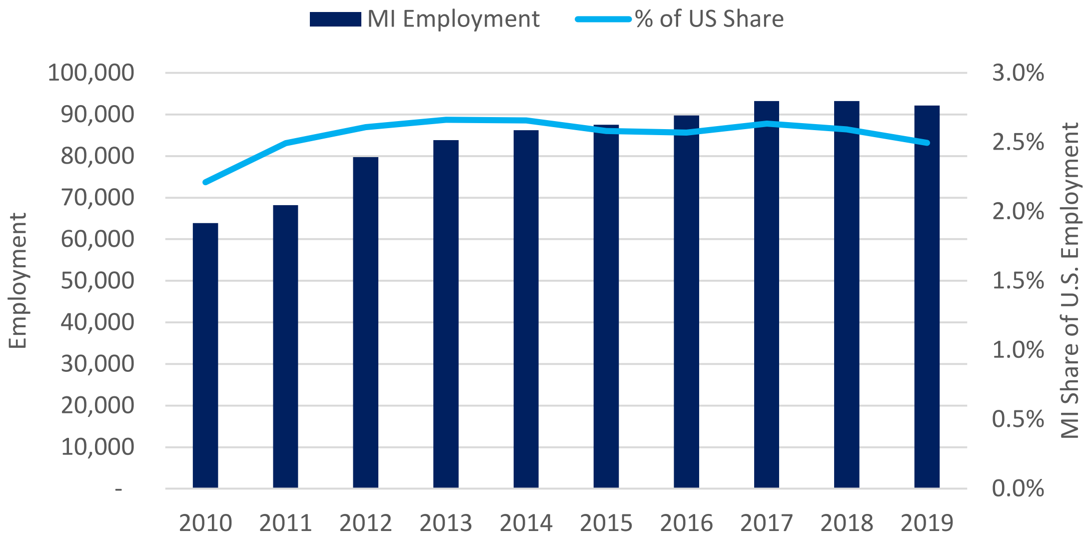
FIGURE 16: COMPUTER AND MATHEMATICS WAGE ANALYSIS BY OCCUPATION, 2019



Source: U.S. Department of Labor, Bureau of Labor Statistics

From 2010 to 2018, Michigan's computer and mathematics employment increased year-over-year. However, from 2018 to 2019, this occupational category saw a year-over-year decline of 1.2 percent (Bureau of Labor Statistics, 2020). Please refer to Figure 17 below for the complete historical trend of the group.

FIGURE 17: COMPUTER AND MATHEMATICS EMPLOYMENT, 2010 TO 2019



Source: U.S. Department of Labor, Bureau of Labor Statistics

2.3.3 Construction and Extraction

The construction and extraction category contains five minor groups, including Supervisors of Construction and Extraction Workers; Construction Trade Workers; Helpers, Construction Trades; Other Construction and Related Workers; and Extraction Workers. Occupations within these subgroups include First-Line Supervisors of Construction Trades and Extraction Workers, Construction Laborers, Helpers-Electricians, Highway Maintenance Workers, and Surface Mining Machine Operators and Earth Drillers.

In 2019, the largest construction and extraction occupations in the United States and Michigan were construction laborers and helpers (1,020,350 US employment/25,750 MI employment), followed by construction equipment operators (455,050/8,300), plumbers, pipefitters, and steamfitters (442,870/12,180), and masonry workers (299,490/8,220) (Bureau of Labor Statistics, 2020). Every top construction and extraction occupation in Michigan saw year-over-year growth. Masonry workers' year-over-year employment change was the most significant out of all the top occupations (an increase of 10.3 percent) (Bureau of Labor Statistics, 2020). Please see Table 4 below for more details.

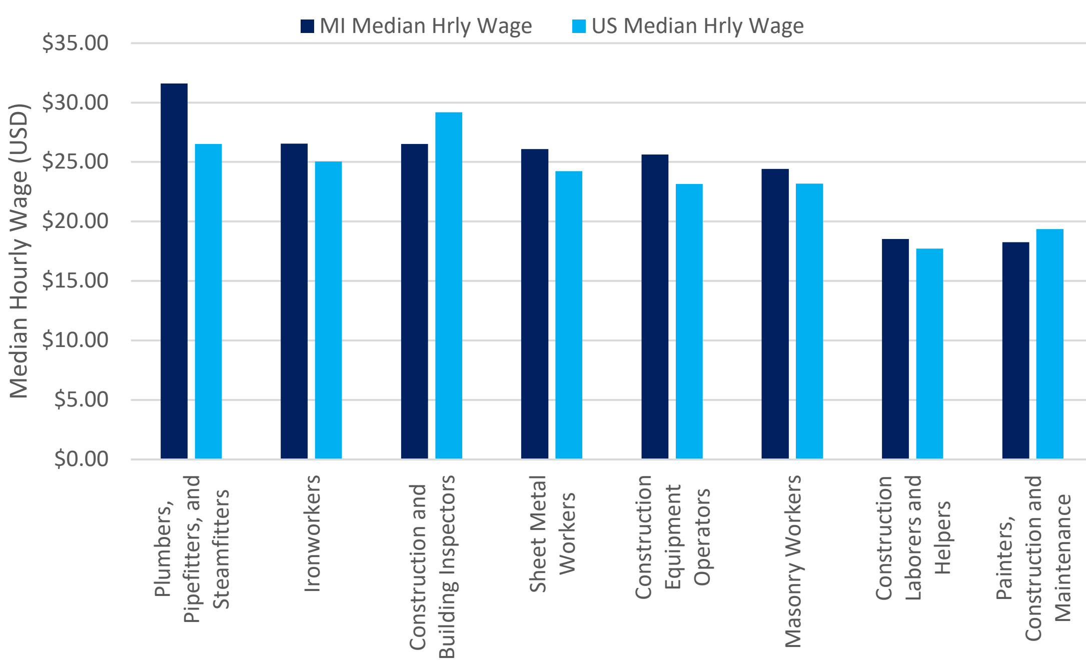
Table 4:Top Construction and Extraction Occupations In Michigan, 2019

Top Occupations	MI Employment (2019)	YOY Percent Change
Construction Laborers and Helpers	25,750	5.1%
Plumbers, Pipefitters, and Steamfitters	12,180	1.9%
Construction Equipment Operators	8,300	5.5%
Masonry Workers	8,220	10.3%

Source: U.S. Department of Labor, Bureau of Labor Statistics

The highest paying construction and extraction jobs in 2019 in the United States are construction and building inspectors (USD 29.19 median hourly wage), followed by plumbers, pipefitters, and steamfitters (USD 26.52); ironworkers (USD 25.03); and sheet metal workers (USD 24.23) (Bureau of Labor Statistics, 2020). However, Michigan's top-earning occupations in this category are plumbers, pipefitters, and steamfitters (USD 31.61 median hourly wage), which is significantly higher than the U.S. median wage for this occupation.

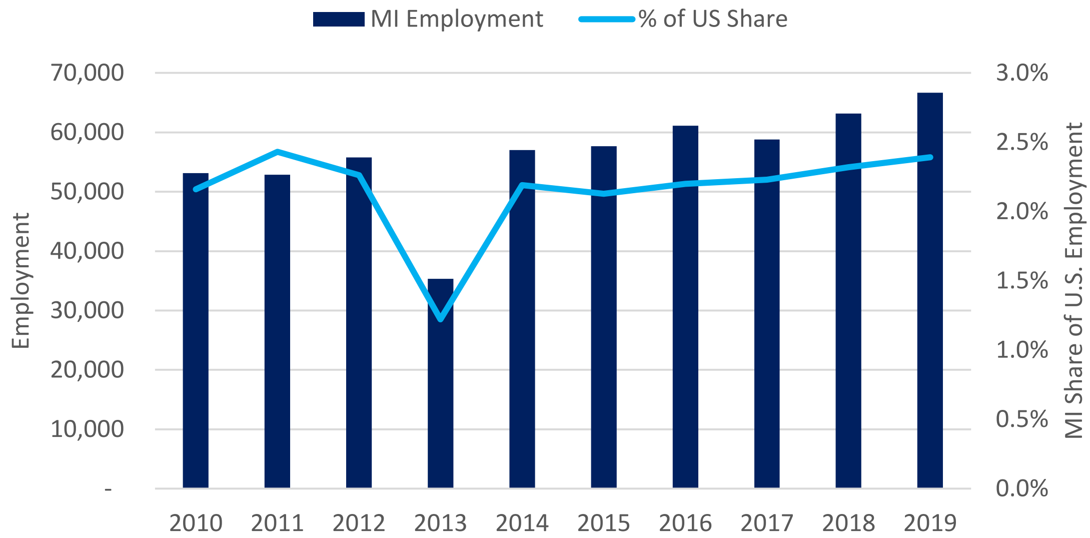
FIGURE 18: CONSTRUCTION AND EXTRACTION WAGE ANALYSIS BY OCCUPATION, 2019



Source: U.S. Department of Labor, Bureau of Labor Statistics

Michigan's construction and extraction employment peaked in 2019 at 66,650. This occupation category saw a year-over-year increase of 5.5 percent (Bureau of Labor Statistics, 2020). Please refer to Figure 19 below for the complete historical trend of the group.

FIGURE 19: CONSTRUCTION AND EXTRACTION EMPLOYMENT, 2010 TO 2019



Source: U.S. Department of Labor, Bureau of Labor Statistics

2.3.4 Life, Physical, and Social Science

The life, physical, and social science category has five subgroups, including Life Scientists; Physical Scientists; Social Scientists and Related Workers; Life, Physical, and Social Science Technicians; and Occupational Health and Safety Specialists and Technicians. Occupations within these subgroups include Material Scientists, Environmental Scientists and Geoscientists, Urban and Regional Planners, Geographers, and Chemical Technicians.

In 2019, the largest occupations in the United States and Michigan within this category were environmental scientists and specialists (84,290 US employment/3,030 MI employment), followed by urban and regional planners (38,560/870), environmental science and protection technicians (32,620/670), and survey researchers (9,930/200) (Bureau of Labor Statistics, 2020). Michigan saw a year-over-year percent decline in three out of four of the largest life, physical, and social science occupations. These occupations are urban and regional planners (declined by 9.4 percent), environmental science and protection technicians (decreased by 5.6 percent), and survey researchers (declined by 16.7 percent) (Bureau of Labor Statistics, 2020). Please see Table 5 below for more details.

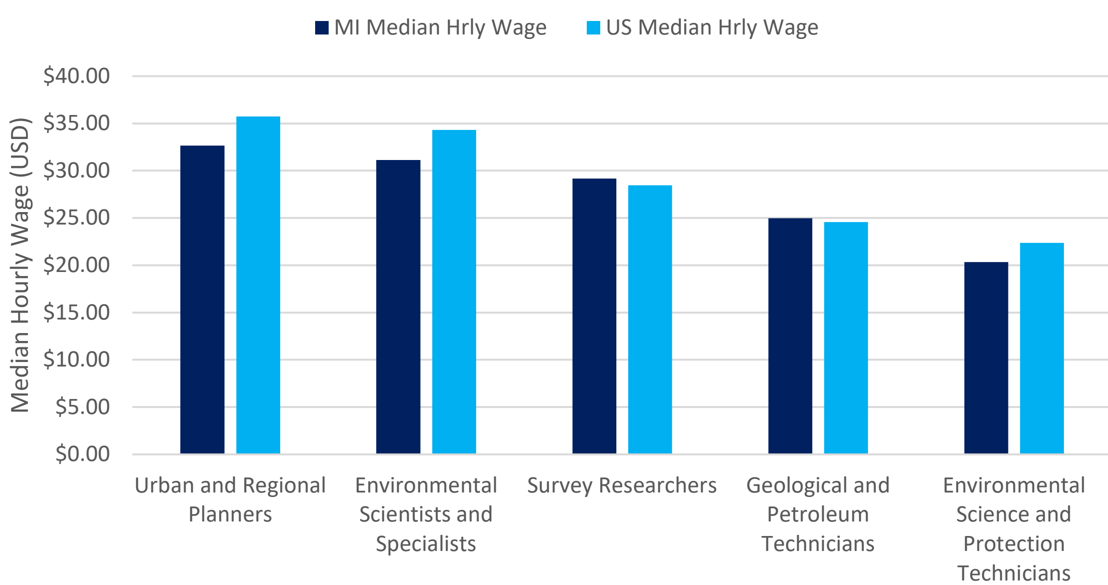
TABLE 5: TOP LIFE, PHYSICAL, AND SOCIAL SCIENCE OCCUPATIONS IN MICHIGAN, 2019

Top Occupations	MI Employment (2019)	YOY Percent Change
Environmental Scientists and Specialists	3,030	9.0%
Urban and Regional Planners	870	-9.4%
Environmental Science and Protection Technicians	670	-5.6%
Survey Researchers	200	-16.7%

Source: U.S. Department of Labor, Bureau of Labor Statistics

The highest paying life, physical, and social science jobs in 2019 in the United States were geographers (USD 39.20 median hourly wage), urban and regional planners (USD 35.75), environmental scientists and specialists (USD 34.31), and survey researchers (USD 28.45). Michigan's top-earning occupations in this category were urban and regional planners (USD 32.65 median hourly wage), environmental scientists and specialists (USD 31.14), survey researchers (USD 29.17), and geological and petroleum technicians (USD 24.97) (Bureau of Labor Statistics, 2020).

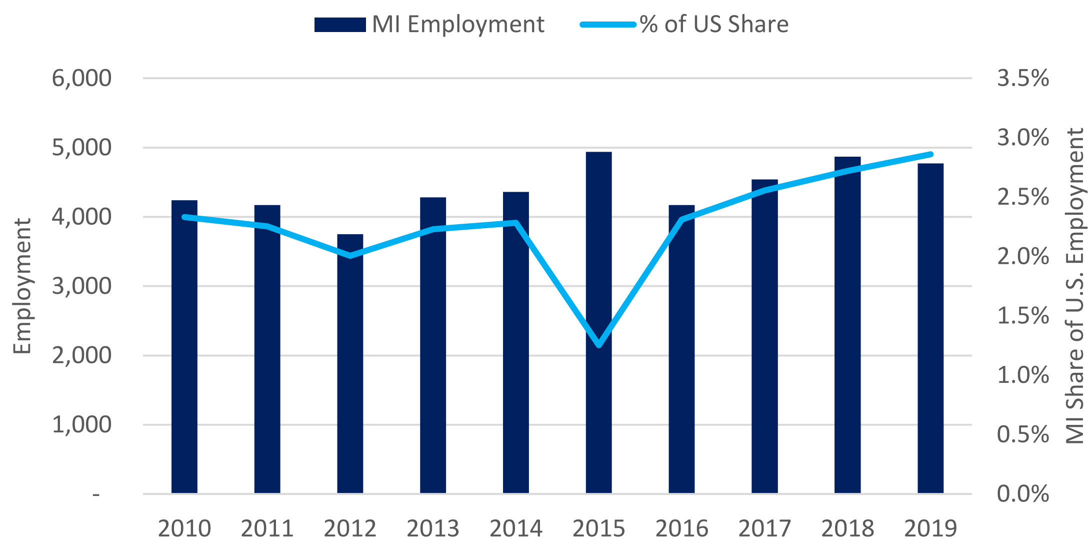
FIGURE 20: LIFE, PHYSICAL, AND SOCIAL SCIENCE WAGE ANALYSIS BY OCCUPATION, 2019



Source: U.S. Department of Labor, Bureau of Labor Statistics

Michigan's life, physical, and social science employment peaked in 2015 at 4,940. In 2019 Michigan's share of U.S. employment reached nearly 3 percent—the highest percentage share since before 2010 (Bureau of Labor Statistics, 2020). Please refer to Figure 21 below for the complete historical trend of the group.

FIGURE 21: LIFE, PHYSICAL, AND SOCIAL SCIENCE EMPLOYMENT, 2010 TO 2019



Source: U.S. Department of Labor, Bureau of Labor Statistics

2.3.5 Management

The management category has four subgroups, including Top Executives; Advertising, Marketing, Promotions, Public Relations, and Sales Managers; Operations Specialties Managers; and Other Management Occupations. Occupations within these subgroups include Chief Executives, Computer and Information Systems Managers, Construction Managers, and Architectural and Engineering Managers.

In 2019, the largest occupations in the United States and Michigan within this category were computer and information systems managers (433,960 U.S. employment/10,220 MI employment), followed by construction managers (293,380/5,090), and architectural and engineering managers (194,250/11,410) (Bureau of Labor Statistics, 2020). Michigan saw a year-over-year percent increase across all of the largest occupations under the management category. These occupations are architectural and engineering managers (increased by 9.1 percent), computer and information systems managers (increased by 7.8 percent), and construction managers (increased by 17.3 percent) (Bureau of Labor Statistics, 2020). Please see Table 6 below for more details.

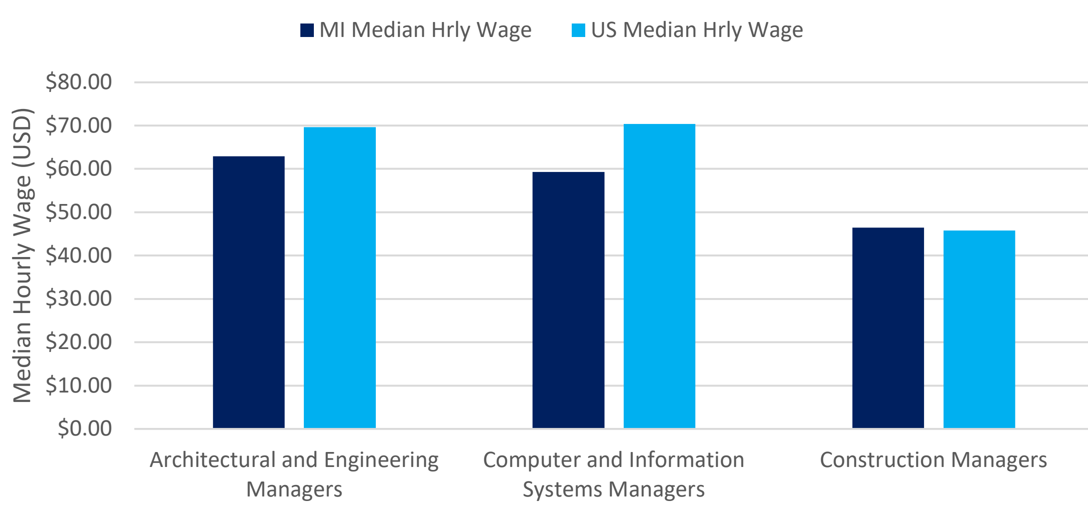
TABLE 6: TOP MANAGEMENT OCCUPATIONS IN MICHIGAN, 2019

Top Occupations	MI Employment (2019)	YOY Percent Change
Architectural and Engineering Managers	11,410	9.1%
Computer and Information Systems Managers	10,220	7.8%
Construction Managers	5,090	17.3%

Source: U.S. Department of Labor, Bureau of Labor Statistics

The highest paying management jobs in 2019 in the United States were computer and information systems managers (USD 70.37 median hourly wage), architectural and engineering managers (USD 69.63), and construction managers (USD 45.80). Michigan's top-earning occupations in this category were architectural and engineering managers (USD 62.89 median hourly wage), computer and information systems managers (USD 59.30), and construction managers (USD 46.48) (Bureau of Labor Statistics, 2020).

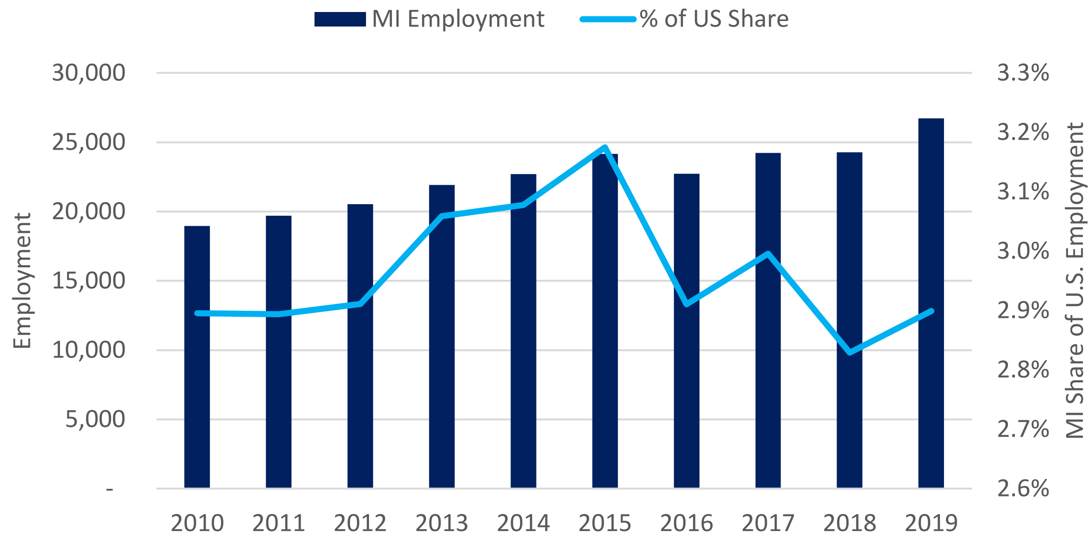
FIGURE 22: MANAGEMENT WAGE ANALYSIS BY OCCUPATION, 2019



Source: U.S. Department of Labor, Bureau of Labor Statistics

Michigan's management employment increased year-over-year from 2010 to 2019, with a slight dip in 2016. Michigan's share of U.S. employment peaked at 3.2 percent in 2015 and has declined to 2.9 percent in 2019 (Bureau of Labor Statistics, 2020). Please refer to Figure 23 below for the complete historical trend of the group.

FIGURE 23: MANAGEMENT EMPLOYMENT, 2010 TO 2019



Source: U.S. Department of Labor, Bureau of Labor Statistics

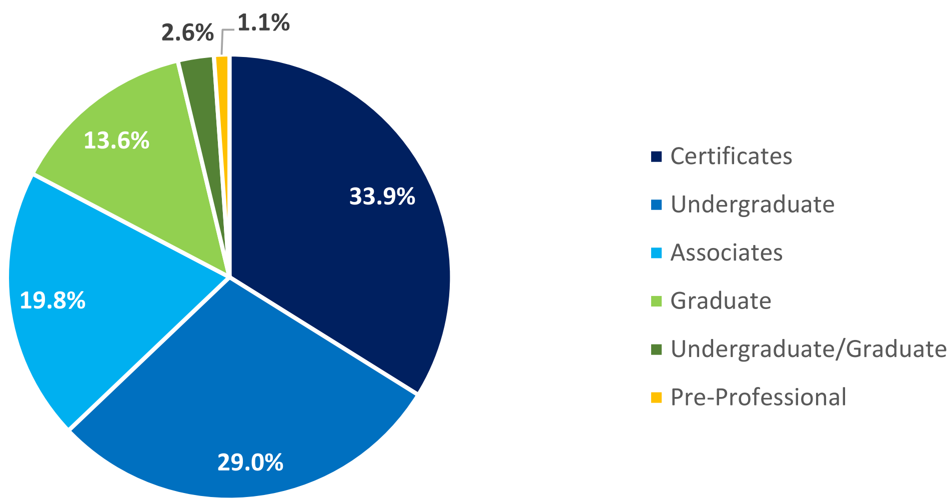
2.4 Michigan's Educational and Training Programs

2.4.1 Current Academic Programs and Resources

Michigan has over 45 academic institutions that offer educational programs that fall under the transportation-related infrastructure sector. CAR researchers organized the relevant academic programs at Michigan institutions into six different categories, including Architecture and Engineering, Computer and Mathematics, Construction and Extraction, Life, Physical, and Social Science, Management, and Robotics/Automated Technology. These classifications are based on the Bureau of Labor Statistics' 2018 version of the Standard Occupational Classification (SOC) system (Bureau of Labor Statistics, 2020).

As shown in Figure 24 below, certificates and minor programs capture the largest share (nearly 34 percent) of transportation-related infrastructure offerings at Michigan academic institutions, followed by undergraduate degrees (29 percent), associate programs (20 percent), and graduate programs (14 percent).

Figure 24: Academic Programs in the Transportation-Related Infrastructure Sector by Program Level, April 2020



Source: CAR Research drawn from numerous academic institution websites, April 2020

The following section highlights the academic institutions with the most substantial program offerings under the construction and operation of the transportation-related infrastructure sector. The three schools with the largest number of programs in the transportation-related infrastructure sector are Eastern Michigan University (56), Washtenaw Community College (45), and Ferris State University (43).

2.4.2 Certificate Programs

Eastern Michigan University (22), Washtenaw Community College (22), and Lansing Community College (21) are the three schools with the highest number of certificate programs[3] in the transportation sector.

- **Eastern Michigan University & Washtenaw Community College** both lead in the number of certificate programs offered for the transportation-related sector. Eastern Michigan University's certificate programs fall into architecture and engineering, computer and mathematics, construction and extraction, life, physical, and social science, and management disciplines. Examples of certificates offered include Transportation Planning and Modeling, Geographic Information Systems, and Sustainable Construction.
- **Washtenaw Community College's** certificate programs fall into architecture and engineering, computer and mathematics, construction and extraction, and management disciplines. The majority of the certificates at Washtenaw Community College evaluated for this study fall into the computer and mathematics category, including programs such as Automotive Cybersecurity, Applied Data Science, and Foundations of Information Systems.
- **Lansing Community College** offers 21 certificate programs in this sector, only slightly behind Eastern Michigan University and Washtenaw Community College. Lansing Community College's certificate programs fall into the following disciplines: architecture and engineering, computer

[3] Note that Minor programs at academic institutions are included in this classification of "certificates."

and mathematics, construction and extraction, life, physical, and social science, management, and robotics/automated technology. Program offerings include Geospatial Science, Construction Management, Computer Security and Controls, and Mechanical Systems.

2.4.3 Associate Degrees

Throughout Michigan, nearly 20 percent of transportation-related infrastructure educational programs offered at schools are associate-level degree programs. Washtenaw Community College (21), Muskegon Community College (14), Lansing Community College (13), and Macomb Community College (13) offer the most associate-level degree programs in this industry.

- **Washtenaw Community College** offers the highest number of associate-level degree programs (21), which lie within the following disciplines architecture and engineering, computer and mathematics, construction and extraction, life, physical, and social science, and management. Degrees include Construction Technology, Computer Systems and Networking, and Cybersecurity.
- **Muskegon Community College** offers 14 associate degree programs in the transportation-related infrastructure sector. These programs fall into the following disciplines architecture and engineering, computer and mathematics, and management. Examples of the degree programs offered include Management, Software Development, and Engineering Technology.
- **Lansing Community College & Macomb Community College** both offer 13 associate degree programs in this sector. Lansing Community College's programs fall into architecture and engineering, computer and mathematics, construction and extraction, life, physical, and social science, and management disciplines offering programs such as Civil Technology, Computer Networking, and Cybersecurity, and Building Construction.

  Macomb Community College associate-level programs fall into architecture and engineering, computer and mathematics, construction and extraction, and management, including Construction Management and Applied Technology and Apprenticeship.

2.4.4 Undergraduate Degrees

Nearly 30 percent of the total transportation-related infrastructure programs in Michigan are undergraduate degrees. The schools with the largest number of undergrad programs offered are Eastern Michigan University (21), Michigan Technological University (17), Ferris State University (14), and Lawrence Technological University (14).

- **Eastern Michigan University** is the academic institution with the most undergraduate offerings in the transportation-related infrastructure sector. This university offers over 20 undergrad programs in architecture and engineering, computer and mathematics, life, physical, and social science, and management. Examples of programs offered include Geospatial Information Science and Technology, Urban and Regional Planning, and Computer Engineering Technology.
- **Michigan Technological University** offers 17 undergraduate programs within the following disciplines: architecture and engineering, computer and mathematics, construction and extraction, and management. Examples of these degrees are Computer Network and System Administration, Computer Science, Cybersecurity, and Engineering Management.

- **Ferris State University & Lawrence Technological University** both offer 14 undergraduate degrees in this sector. Ferris State University's programs fall into architecture and engineering, computer and mathematics, construction and extraction, and management disciplines. In contrast, Lawrence Technological University's programs lie within architecture and engineering, computer and mathematics, construction and extraction, and robotics/automated technology.

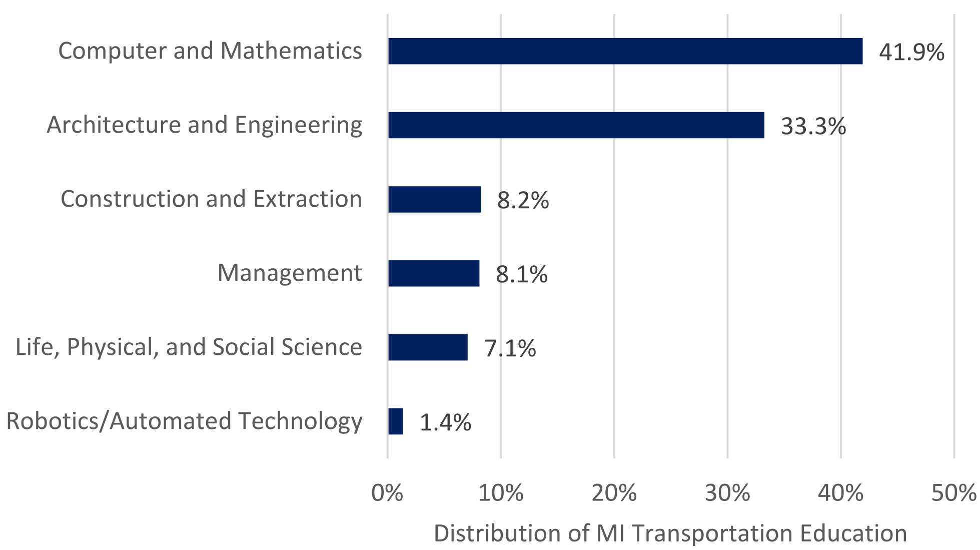
2.4.5 Graduate Degrees

The University of Michigan, University of Detroit Mercy, and Wayne State University are the three academic institutions with the highest share of graduate programs offered in this industry.

- **The University of Michigan, University of Detroit Mercy, & Wayne State University** all offer the largest share (13 degrees) of recognized graduate programs for this study. Most of the University of Michigan's graduate programs fall into the architecture, and engineering discipline programs include Computer Science and Engineering, Electrical and Computer Engineering, and Construction Engineering and Management. The majority of the University of Detroit Mercy's graduate programs fall under the computer and mathematics discipline. The school offers degrees in Intelligence Analysis, Information Assurance (Cybersecurity), and Software Engineering. Like the University of Michigan, most Wayne State University's graduate programs fall into the architecture and engineering field. Programs offered include Civil Engineering, Environmental and Sustainability Engineering, and Engineering Management.

Michigan's educational strengths in this industry focus on preparing the future workforce in the fields of computer and information technology (42 percent) and architecture and engineering (33 percent). Please see Figure 25 below for the complete breakdown of educational programs by occupational category for more detail.

FIGURE 25: MICHIGAN EDUCATIONAL PROGRAMS BY OCCUPATIONAL CATEGORY, APRIL 2020



Source: CAR Research drawn from numerous academic institution websites, April 2020

2.4.6 Challenges and Opportunities

Throughout conversations with academic institutions, several challenges and opportunities surfaced. The following section highlights some of the most salient points.

Challenges:

- **Keeping up with the pace of technology and finding qualified teachers/professors to teach courses:** Throughout several interviews, academic representatives mentioned the struggle to keep educational resources on pace with technological advancement in the industry. To aid in this gap, the industry could require senior staff to conduct community service at local universities to teach a lesson or class to students providing real-world context and expertise.
- **Prioritizing the skills/job demands of the industry:** Academic institutions struggle to prioritize the needs of the industry. To support the development of the workforce, communication to these educators on the organization's ten-year workforce development goal can provide educators with a plan to prepare the appropriate curriculum needs for students.
- **Low student interest in the construction and operation sector:** Schools would like support from the industry on branding programs and engaging young students for careers in the construction and operations sector.

Opportunities:

- **Continued education advancement:** Educational institutions can support the ITS sector's steady progress by updating courses and educating the current and future workforce. The following topics were mentioned as part of upcoming programs: information infrastructure, 5G, cellular, sensors, software development, cybersecurity, 3D printing, and virtual reality (VR).
- **Development of an advisory board or center:** Some academic institutions have developed internal centers to spur new curriculum in the transportation infrastructure industry.
- **Increased collaboration to support the growth of apprenticeship/internship programs:** Schools would like to increase apprenticeship/internship opportunities for their students and develop more focused programs between academia and industry. Such programs allow students to earn a wage while developing the necessary skills needed for employment.
- **Knowledge sharing with key stakeholders:** Respondents suggested roundtable events to discuss current research findings and provide a space to network with others in the industry to share knowledge and materials to advance the overall sector.

2.5 MDOT Organizational Analysis

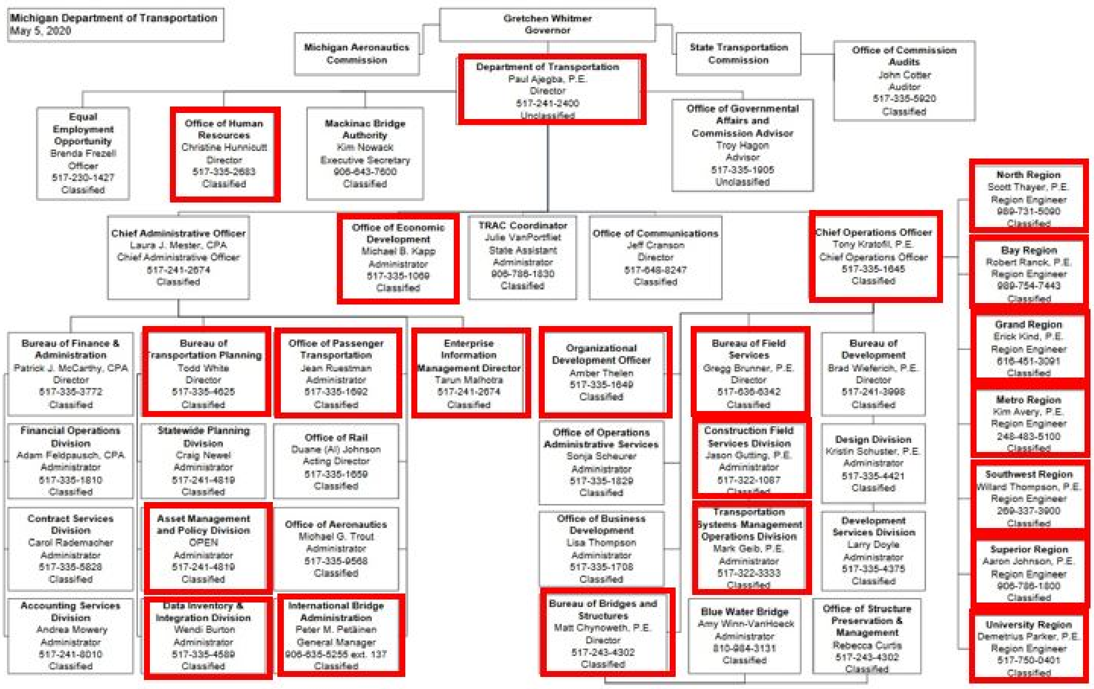
CAR analyzed MDOT's current organizational structure and reviewed the technical expertise needed to provide recommendations to MDOT regarding potential organizational changes needed to accommodate emerging technology in the operations and construction of the transportation-related infrastructure industry.

2.5.1 MDOT's Current Organizational Structure

MDOT is responsible for the state's highway system. It also administers state and federal transportation programs for aviation, intercity passenger services, rail freight, and public transit services (Michigan

Department of Transportation, 2020). The organization comprises several offices and bureaus that report to the department's Director. The offices highlighted below are the ones that can benefit the most from the findings of this study.

FIGURE 26: MDOT CURRENT ORGANIZATIONAL CHART, 2020



Source: MDOT

Organization's Overall Mission

MDOT's primary mission is to provide the highest quality of transportation services for economic benefit and improved quality of life in the state of Michigan (Michigan Department of Transportation). To accomplish its mission, MDOT has prioritized becoming a progressive and innovative agency, and the agency's values include:

- Quality – Achieving the best results within given resources
- Teamwork – The active involvement and cooperation of its people
- Customer Orientation – Knowing and understanding their customers
- Integrity – Doing the right thing
- Pride – In the organization and importance of its work

Occupation Analysis

Currently, MDOT is looking to fill nine positions across Michigan; four of these positions fall within this project's scope of work. These positions include:

- **Transportation Technician:** The transportation technician's role is to assist construction engineers with numerous duties such as administration, oversight of projects, providing data management, and project documentation (Michigan Department of Transportation, 2020).
- **Transportation Engineer:** This position serves as the traffic and safety engineer. Responsibilities include project coordination, conflict resolution, and continued customer engagement. Other duties include preparing items to address traffic maintenance on construction projects, reviewing traffic and safety items for prospective projects, reviewing information related to traffic and safety for inclusion in upcoming plans, and reviewing public concerns (Michigan Department of Transportation, 2020).
- **Project Operations Coordinator:** The project operations coordinator is responsible for utility coordination and permits for the Gordie Howe International Bridge. This position will also assist the project management team during the construction phase (Michigan Department of Transportation, 2020).
- **Engineering Manager (Construction Engineer):** This position coordinates and administers construction operations processes while maintaining alignment with other regions. Candidates are required to practice and promote accountability, collaboration, clarity, continued learning, and flexibility to perform this job effectively (Michigan Department of Transportation, 2020).

In addition to current postings at MDOT's organization, researchers also gathered a list of hard-to-fill positions from MDOT stakeholders to review what types of skills have been difficult to hire. These positions include Auditors, Electricians, Financial Analysts, Fixed Wing Pilot, Heavy Equipment Operators, Surveyors, Technicians (Civil), Transportation Engineers (Bridges), and Transportation Technicians (GIS).

2.5.2 Workforce Planning, Training Programs, and Partnerships

MDOT has a workforce and succession planning system, also known as "The House." The House supports the development of the organization's current workforce. This system has five pillars: leadership standards of excellence, role assessment model, talent review process, knowledge management system, and employee life cycle.

Workforce Planning

MDOT leaders are to respect the **leadership standards of excellence**. The standards recognized in this system are to ensure positive outcomes, put people first, maintain professional excellence, exhibit character, and integrity, and be a visionary. Leaders should maintain these standards of excellence while representing their departments.

The purpose of the **role assessment model** is to plan for future succession needs. Using this model, managers can develop strategies to recruit, train, and share knowledge across teams on an as-needed basis.

Throughout the year, leaders conduct **talent reviews** of their internal teams. During this process, leaders have the opportunity to identify ways to strengthen and develop their teams through conversation, consistency, and calibration.

The **knowledge management system** supports capturing, sharing, and applying information across multiple entities within MDOT. Ensuring intellectual capital is available to all MDOT employees.

The final pillar of this system is the **employee life cycle**. This cycle supports employees throughout each phase of their careers throughout employment, including onboarding, performance management, and learning and development.

Furthermore, MDOT leaders are developing a 5-year plan to evaluate and improve the organization's current workforce programs and recruitment strategy. This strategy will provide structure to existing programs through quality metrics and transparency on results through annual reports. The Workforce Programs and Recruitment Unit within the Office of Organizational Development will lead this effort (with assistance and coordination of others within the department) through three main tasks. First, the team will evaluate and improve current recruitment, internal communications, etc., while keeping diversity and inclusion at the forefront. Second, the team will assess and measure current talent pipeline efforts in a quantitative framework. Lastly, this unit will lead the final strategy implementation and coordinate with various departments, ensuring a smooth distribution across the organization (MDOT, 2020).

Training Programs

MDOT offers numerous educational programs for students. The following are a few applications within the organization to educate and develop the future transportation construction workforce.

- MDOT offers internship opportunities for undergraduate and graduate students interested in construction-related careers, including civil engineers and construction managers. This program allows students to gain work experience, develop a professional network, and integrate work experience with academic knowledge (Michigan Department of Transportation, 2020).
- The Youth Development and Mentoring Program's (YDMP) purpose is to prepare a diverse workforce for the future. This program educates high school students and recent high school graduates on careers in civil engineering, road construction, maintenance, planning, and other transportation career opportunities (Michigan Department of Transportation, 2020).
- The Transportation and Civil Engineering (TRAC) Program, created by the American Association of State Highway Transportation Officials, aims to generate awareness of transportation careers among middle and high school students. The TRAC program provides teachers with a free curriculum and hands-on tools for their classrooms (Michigan Department of Transportation, 2020).

Partnerships

In addition to the workforce development strategy and internal training conducted at MDOT's organization, the agency has numerous partnerships with other associations, companies, and academia. The following section highlights several examples of MDOT's current partnerships.

- Michigan Construction's mission focuses on connecting individuals with construction jobs at construction companies within Michigan. MDOT is part of Michigan Construction's partner companies. This partnership includes promoting and marketing currently available positions within MDOT's organization (Michigan Construction, 2020).

- In 2020, MDOT partnered with The Henry Ford for National Engineer Week from 16-22 February. MDOT sponsored the event and hosted an activity for students to build and test their bridges with MDOT engineers. This event supports raising awareness and educating students on future career opportunities in engineering (The Henry Ford, 2020).
- MDOT requires its technicians to conduct field density tests to obtain and maintain certification through a program conducted or approved by the MDOT Geotechnical Services Section, Density Technology unit. With support from Lawrence Technological University, MDOT staff teach students a Density Control Training and Certification program to acquire/maintain this requirement (Lawrence Technological University, 2020).
- MDOT requires its welders to be certified. The organization partners with numerous academic institutions to conduct welder certification testing through the MDOT Welder Certificate Program. Examples of schools in this partnership include Ferris State University, Lansing Community College, and Monroe Community College.

2.5.3 Technical Expertise Needed

After gathering the data for the transportation infrastructure industry in Michigan and MDOT's current organizational structure, the next step was to identify what technical expertise is needed within the organization.

Identify Expertise Gaps

MDOT needs are very similar to the skill needs of the overall industry. According to the results of this research, MDOT's expertise gaps fall into three different groupings: skilled trades, transportation needs, and financial needs.

FIGURE 27: SKILLED TRADE OCCUPATIONS IN DEMAND, 2020

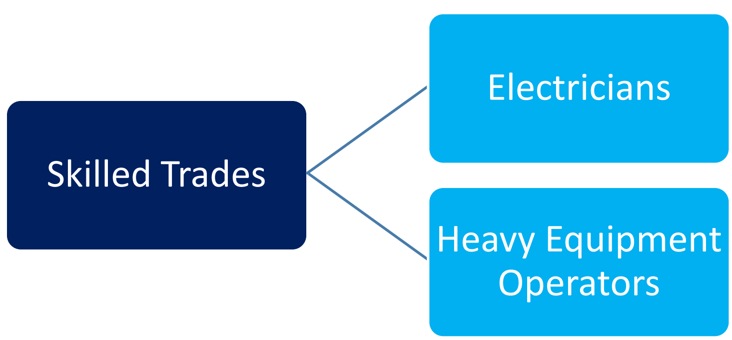


FIGURE 28: TRANSPORTATION OCCUPATIONS IN DEMAND, 2020

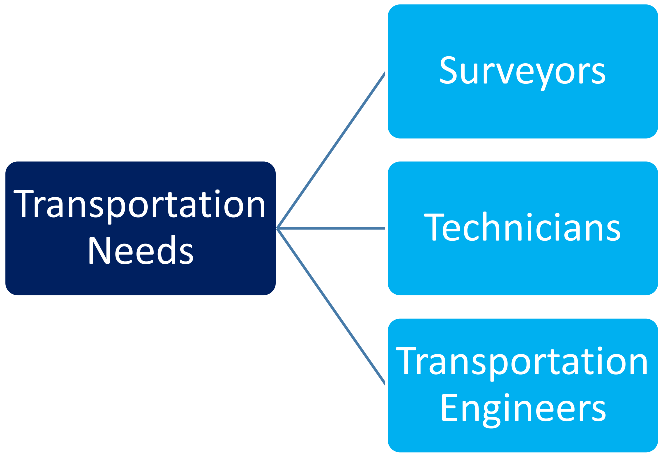
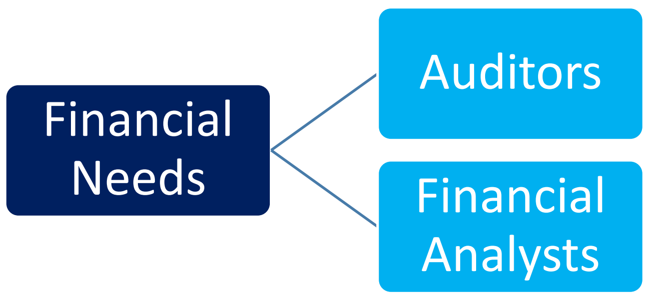


FIGURE 29: FINANCIAL OCCUPATIONS IN DEMAND, 2020



Skills Gap

According to the current job postings, the top skills needed at MDOT include data analytics and management. Similar to the overall industry, MDOT skill demands fall under both technical and soft skills.

- **Data:** The use of data across organizations in numerous industries is becoming more prevalent. Companies are exploring ways to incorporate artificial intelligence to improve current operations. According to Udemy's 2020 Workplace Learning Trends Report, data analytics and AI will continue to surface over the next decade to support workers' needs (Udemy for Business, 2020). There's been a considerable shift toward data science skillsets over the past several years. Not surprisingly, this category of skill sets was the most popular in 2020 (Pate, 2020)
- **Management:** The next identified skill need is management. This category includes everything from managing people to financial resources, products and projects, operations, and more. At MDOT, there is a need for greater project management skills for employees to coordinate multiple time schedules of different construction projects, ensuring a successful outcome. Similar to the overall industry, management is a needed soft skill.

2.6 Best Practices Review

With the current shift of the transportation industry toward intelligent transportation systems and connected and automated vehicles and the baby boomer generation's retirement from the transportation infrastructure construction and operation jobs, transportation agencies will increasingly need to plan for recruiting, developing, training, and retraining high-tech workers.

CAR's findings indicate that most state DOTs have some types of training programs such as on-the-job training, certificates, continuing education, and young professional education. However, many of these DOT's do not focus on training their workforce on the new technologies highlighted in this research effort. The main areas on which state DOTs are focused are traditional roadway engineering, safety, and technical equipment instruction (Puentes, Grossman, Eby, & Bond, 2019).

Also, CAR's research highlights that transportation agencies across the country are well aware of the necessity and value of effective workforce development programs. However, numerous challenges often slow down these programs, including limited funding, limited communication on existing and future inter-department skill needs, and difficulties in coordinating the internal and external partners' training efforts.

Given the organizational structure of state DOTs, workforce development programs vary considerably. Some DOTs, like Montana and Colorado, rely primarily on their partnerships with universities. At the same time, Michigan has an active in-house workforce development program that covers both inter-department training and partnerships with local community colleges and universities.

Here is a summary of CAR's findings on the state DOTs that have noteworthy training programs:

2.6.1 Colorado Department of Transportation

The Colorado Department of Transportation, in partnership with Montana DOT and Front Range Community College, has developed the "first-in-the-nation" Associate of Applied Science (AAS) in Highway Maintenance Management degree program. This program mainly focuses on preparing the DOT workers for leadership positions in highway maintenance management at different industry levels. During four semesters of study, students learn about various skills such as leadership, project management, highway maintenance & operations safety, traffic control, highway asset management, pavement preservation, and human relations in organizations (Front Range Community College, 2020).

2.6.2 Ohio Department of Transportation

Within the Ohio Department of Transportation (ODOT), the Office of Employee Development and Lean is responsible for ODOT's employee required training, HR, workforce planning, and union training. This office offers internal training programs to ODOT employees in the following programs (Ohio DOT, 2020):

- County Management Training
- Heavy Equipment Training
- Leadership Development Program
- Mechanics, Auto Techs, and Auto Body Workers Training
- E-learning

- Highway Technician Academy
- Management Development Program
- Personal and Professional Development Training

Using some of the resources and courses developed by FHWA and the American Association of State Highway and Transportation Officials (AASHTO), the ODOT Office of Local Programs manages a portfolio of courses and training programs offered to local governments. Some of the unique offerings include (Ohio DOT, 2020):

- GPS technology
- Introduction to GIS mapping
- Math basics
- Simplified highway forecasting toll training (SHIFT)
- Slab stabilization and slab jacking
- Unoccupied aircraft systems (UAS) awareness course

The courses and programs are being offered in in-person classes, online, and also webinars.

2.6.3 Oregon Department of Transportation

The Oregon Technology Transfer Center (T2 Center) of the Oregon Department of Transportation is responsible for offering training, technical assistance, and technology transfer to local transportation agencies. The Federal Highway Administration jointly funds this center through the Local Technical Assistance Program (LTAP), Oregon's counties and cities, and the Oregon Department of Transportation. The T2 center's activities include:

- "Provide low-cost seminars, training classes, and workshops
- Publish a newsletter
- Provide a Circuit Rider service, taking video programs and informational materials to local agencies
- Provide a video lending library on a variety of transportation topics
- Provide copies of technical bulletins or reports upon request
- Respond to inquiries from local agencies by providing technical resources or making a referral to a specialist" (Oregon DOT, 2020)

The T2 Center also administers the local agencies' staff access to the LTAP resources available online. Other DOTs and the FWHA mostly offered the online LTAP courses; thus, the T2 center does not host or sponsor these courses. Some of the LTAP's courses available through the LTAP include:

- UAS Awareness Course (offered by Ohio LTAP)
- Alternative Interchange and Intersection Design (offered by Virginia LTAP)
- Building Intelligence for Next Generation Traffic Management (offered by Iowa LTAP)
- A Local Agency Perspective on Automated Traffic Signal Performance Measures (offered by Iowa LTAP)
- Improving Work Zone Safety: Temporary Rumble Strips, Smart Arrow Boards, and Other Connected Traffic Control Device (TCD) Technologies (offered by Iowa LTAP)

- Working with Heated Pavements: Recent Technical Advances (offered by Iowa LTAP)

"*Oregon law (ORS 184.866) requires the Oregon ODOT to expend one-half of one percent, up to an amount of USD2.1 million, of the federal funds received each biennium by ODOT according to 23 U.S.C. 140(b), to increase diversity in the highway construction workforce and prepare those interested in entering the highway construction workforce*." (Oregon DOT& Oregon Bureau of Labor & Industries, 2018) To comply with ORS 184.866, Oregon DOT has developed the Highway Construction Workforce Development Program. The goal of this program is to build a skilled and diverse construction workforce for the Oregon DOT. Oregon DOT partners with the Oregon Bureau of Labor and Industries and local educational institutions to achieve this goal. Over the years, these programs have offered numerous training and apprenticeship opportunities to Oregon's students and residents who are willing to pursue a career in highway construction. Some of these programs include (Oregon DOT & Oregon Bureau of Labor & Industries, 2017)

- Construction Career Camps
    - "Building Girls" Career Camps in Portland
    - Constructing Hope and Northwest College of Construction Career Camp
    - Phoenix Charter School
    - Baker School District
- Career/Trade Fairs
- Pre-Apprenticeship Graduates Entering Apprenticeship
    - Oregon Tradeswomen Inc. and Pre-Apprenticeship Training
    - Portland Youth builders
- University of North Carolina - Supervisor Training

2.6.4 Tennessee Department of Transportation

The Human Resources Division manages many workforce training and development programs for the Tennessee Department of Transportation (TDOT). Some of these programs include:

- **TDOT Summer Internship Program**: TDOT offers 12-weeks paid summer internship to college students or recent graduates who are interested in gaining experience in areas such as aeronautics, business administration, civil engineering, construction management, environmental science, urban planning and development, and training (Tennessee Department of Transportation, 2020).
- **Graduate Transportation Associate (GTA) Program**: Through a partnership program with Lipscomb University, TDOT offers professional development training to entry-level civil engineers to get experience in different areas of transportation infrastructure operation, construction, and management. After passing the training phase, GTA grads will go into a one-year probation period. Successful candidates will get promotions, switch to higher-level jobs, and receive a salary increase. Construction, maintenance, materials and tests, right-of-way-utilities, roadway design, structures-bridge inspection, survey, traffic, environment are the main focus areas of the GTA program (Tennessee Department of Transportation, 2020).
- **TDOT Transportation and Civil Engineering (TRAC)**: provides teacher training sessions and supplies to middle and high school teachers (grades 6-12) and students across Tennessee. The

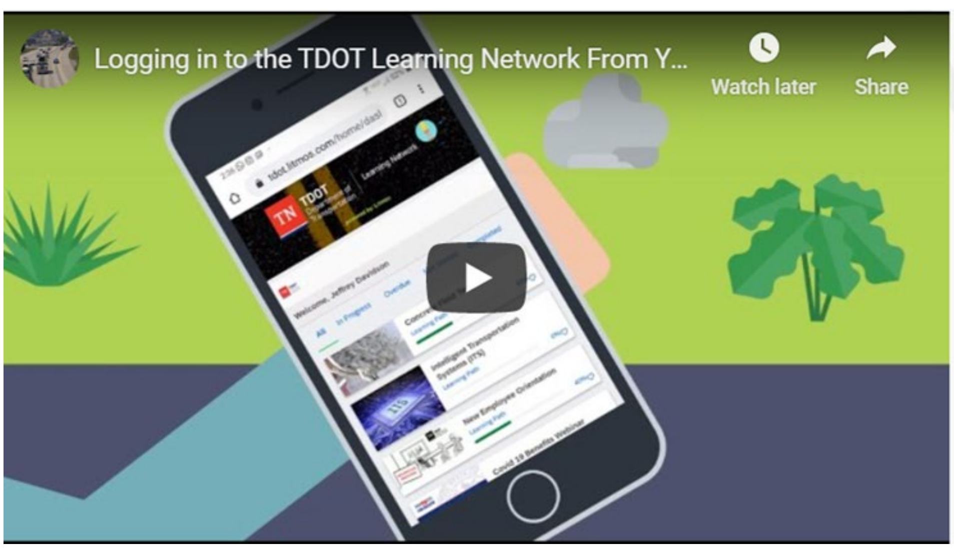
program has three modules: Design and Construction, Magnetic Levitation, Bridge Builder. TDOT provides equipment, software, and supplies needed for each module to the teachers and students. TDOT has adopted this program from AASHTO in 2016. AASHTO established the original TRAC program in 1993 to increase the career interest in civil engineering in high school students (Tennessee Department of Transportation, 2020).

- **TDOT Learning and Development**: TDOT Learning and Development hosts HR-related training in four regions in addition to the headquarter location. Training programs are focused on: employee onboarding and professional development, performance management, leadership, principles, and practice of engineering (PE) exam, fundamentals of engineering exam, employee assistance program (EAP).
- **TDOT Education**: TDOT supports employees who are willing to continue their education. Interested employees will be introduced to the Tennessee Reconnect Grant and provided with a list of programs in which tuition is either waived or discounted.

In addition to the programs mentioned above, some of the departments within TDOT offer technical training programs related to their areas of expertise. For example, the Office of Field Operations provides hot mix asphalt certification, concrete technician certification, and radiation safety/nuclear gauge technician certification.

TDOT has been transparent about the available training programs and resources. The department has made most of the relevant information available and accessible on its website. In some cases, the information is accompanied by some simple, short, and easy-to-understand videos on accessing the resources.

FIGURE 30 HOW-TO VIDEOS ON TDOT WEBSITE



Source: TDOT

2.6.5 Virginia Department of Transportation

Like the other DOTs across the country, the Virginia Department of Transportation (VDOT) is also concerned about its retiring and experienced workforce. To meet the upcoming expertise demand, the

Department has designed various programs to increase training resources and opportunities for current and future DOT workers, including:

National Summer Transportation Institute

The National Summer Transportation Institute (NSTIP) is sponsored by the Virginia Department of Transportation, Federal Highway Administration, Hampton University, and Virginia State University.

Northern Virginia Transportation Career Fair

Each year VDOT host a career fair in which high school students attend and learn about transportation-related career opportunities. Alongside VDOT, colleges and universities such as the University of Virginia, Virginia Tech, and Northern Virginia also attend the event and present students with transportation-related programs. In addition, engineering and consulting firms, agencies, and organizations also attend this event to inspire students to consider transportation-related career pathways in the future.

Veterans Internship Program

In 2006, VDOT launched the Veterans Internship Program (VIP). The VIP aims to assist veterans in enhancing their skills and applying them in transportation-related roles. VDOT was the first transportation department to create a program of this type and has served as a model for other states to follow. (VDOT, 2019)

Veterans are placed in VDOT divisions by request and feature areas including:

FIGURE 31. VDOT VETERANS INTERNSHIP CLASSROOM

- Planning program
- Finance
- Project management
- Inspection
- Security
- Procurement
- Quality control
- Information systems
- Construction
- Environmental compliance ((VDOT, 2019)

Source: VDOT (2019)

Task 3: Technology-Enabled Workforce Strategic Plan

Providing strategic recommendations for preparing MDOT’s current and future workforce for new transportation technologies requires analyzing MDOT’s existing strategies related to the new transportation technologies. The following section provides an overview of the organization's existing strategic plans, followed by results from staff engagement through a survey. Based on the previous section's findings, the research team has provided a SWOT analysis of the MDOT workforce and a set of recommendations to prepare a technology-enabled workforce.

3.1 Review of MDOT Existing Strategic Plans

In a thorough analysis, the CAR team reviewed MDOT's existing strategic plan focusing on identifying the critical strategies for workforce development.

3.1.1 MDOT Department-wide Strategic Plan

The MDOT department-wide Strategic Plan was prepared in 2017 and outlined MDOT's strategic pathway as follows:

MDOT Mission:

"Providing the highest quality integrated transportation services for economic benefit and improved quality of life."

MDOT Vision:

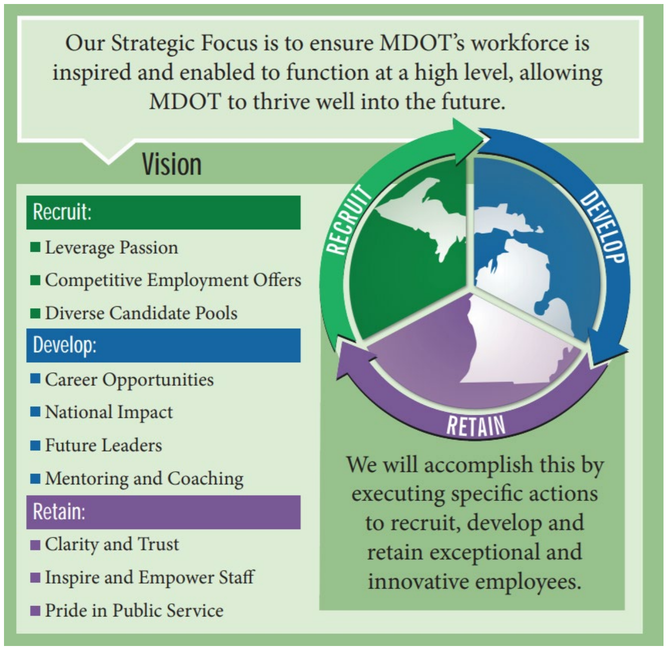
"MDOT will be recognized as a progressive and innovative agency with an exceptional workforce that inspires public confidence." (MDOT, 2017)

MDOT Values:

- Quality: Achieving our best within our resources.
- Teamwork: Effective involvement of people.
- Customer Orientation: Knowing our customers and understanding their needs.
- Integrity: Doing the right thing.
- Pride: In MDOT and the importance of our work.

Further in the document and through the big-picture strategies section, MDOT emphasizes innovations, cost-efficiency, sustainability, and workforce planning. MDOT leadership sees workforce planning as an opportunity to improve organizational performance, focusing on customer service. With a forward-looking approach, the department seeks strategies focused on valuing, engaging, and empowering MDOT employees.

FIGURE 32. MDOT WORKFORCE STRATEGIC FOCUS



Source: MDOT

3.1.2 MDOT Transportation Systems Management and Operations (TSMO) Implementation and Strategic Plan

Through the TSMO[4] program, MDOT sees an opportunity to use technology to optimize existing multimodal infrastructure performance. This document outlines the mission and vision as follows:

MDOT TSMO Program Mission

"Operate and manage an optimized, integrated transportation network by delivering high-quality services for safe and reliable mobility for all users

MDOT TSMO Program Vision

- Integrate Operations as a core MDOT program united with the execution of MDOT's overall mission.
- Inspire public confidence as a progressive and innovative national leader in the management and operations of our transportation system.
- Collaborate across program areas, leveraging technology and resources to achieve the best possible results.

4 "Transportation Systems Management and Operations (TSMO) is an integrated program to optimize the performance of existing multimodal infrastructure by implementing systems, services, and projects to maximize capacity and improve the security, safety, and reliability of the transportation system. MDOT employs TSMO strategies and solutions to provide more efficient use of existing transportation resources by implementing strategies, deploying technologies, and integrating systems to address freeway and arterial congestion, improve safety and mobility, and encourage sustainability (Cambridge Systematics, 2018)."

- Maintain a sustainable and engaged operations workforce with exceptional knowledge, skills, and abilities" (Cambridge Systematics, 2018).

As stated above, the TSMO plan envisions the TSMO program's success by developing a highly skilled and knowledgeable workforce as one of the critical areas. And later in the document, the plan outlines seven major focus areas in which the importance of emerging technologies and a resourceful workforce is highlighted.

TSMO Program Seven Focus Areas:

- Evaluate and streamline information technology processes
- Integrate operations across all business areas
- Integrate the operations of intelligent transportation systems (its) and signals
- Adapt processes, products, and training to advances in technology
- Enhance communications and outreach to external and internal stakeholders
- Prioritize resources to meet critical emerging needs
- Drive progress with meaningful performance measures

3.1.3 MDOT Connected and Automated Vehicle Strategic Plan

As the home for the home to the U.S. automotive industry, the State of Michigan and the Michigan Department of Transportation (MDOT) have put lots of effort into establishing and maintaining its position as a leader in Connected and Automated Vehicle (CAV) and Intelligent Transportation Systems (ITS) technologies. As part of that effort, in 2017, MDOT published a CAV Strategic Plan, which is aimed at "*encompassing the department's initiative to support and implement emerging transportation technologies*." (WSP U.S.A, 2017)

As a subsequent effort to the TSMO Strategic plan, the CAV Strategic Plan outlines the department's mission and vision concerning emerging CAV technologies as follows:

MDOT CAV Mission:

MDOT will work to ensure Michigan remains the national leader in the evolution of CAV technologies to deliver enhanced transportation safety and reliability, providing economic benefits and improved quality of life.

MDOT CAV Vision

MDOT's CAV Program will be recognized as a progressive and innovative leader, driving national efforts to explore and implement emerging mobility technology

To achieve and maintain the envisioned innovative leadership position, MDOT needs to invest in emerging transportation technologies and a technology-enabled workforce. To guide these investments, the CAV Strategic Plan outlines six focus areas for MDOT:

- Serve as a national model to catalyze CAV deployment
- Establish foundational systems to support wide-scale CAV deployment
- Make Michigan the go-to state for CAV research and deployment

- Accelerate CAV Benefits to users
- Exploit mutual benefit opportunities between CAV technologies and other department business processes and objectives
- Use Michigan experience to lead dialogue on national standards and best practices

The CAV Strategic Plan recommends that MDOT contribute to the state's industry development by supporting industry research, testing, and education. MDOT's contribution could be in the form of leveraging assets and human resources to support industry partners. Also, the plan highlights the importance of MDOT playing a leadership role in developing the CAV workforce in the state. To realize this goal, MDOT will need to assist its partners in developing curricula, providing direct training, or supporting third-party workforce initiatives.

3.1.4 MDOT Intelligent Transportation System Strategic Plan

Another strategic plan that outlines the MDOT approach toward new technologies is the Intelligent Transportation System (ITS) Strategic Plan[5]. According to the plan, the MDOT ITS program Mission and Vision are:

Mission:

"*ITS provides high quality, adaptive, and integrated transportation technology solutions that improve safety and mobility for all users.*

Vision:

Integrate MDOT's ITS Program into all TSMO business areas and leverage both proven and emerging transportation technologies to sustainably enhance safety, mobility, economic benefit, and support improved quality of life". (HNTB, 2018)

As a subsequent plan to the TSMO Strategic plan, the MDOT ITS Strategic Plan relates the TSMO strategic areas of focus to seven focus areas, as shown in Table 7.

TABLE 7. MDOT ITS STRATEGIC PLAN FOCUS AREAS

	TSMO STRATEGIC AREAS OF FOCUS		ITS FOCUS AREA
1	Evaluate and Streamline Information Technology Processes	→	Information Technology Processes
2	Integrate Operations across All Business Areas	→	TSMO Business Area Integration
3	Integrate the Operations of ITS and Signals	→	ITS/Signal Program Integration
4	Adapt Processes, Products, and Training to Advances in Technology	→	Emerging Technologies
5	Enhance Communications and Outreach to External and Internal Stakeholders	→	Partners and Outreach
6	Prioritize Resources to Meet Critical Emerging Needs	→	Workforce Development
7	Drive Progress with Meaningful Performance Measures	→	Performance-Based Priorities

Source: HNTB

[5] MDOT has recently released a new version of this strategic plan in September 2021.

The two focus areas that are most relevant to this research effort are Number 4 and 6, as described below:

- **#4 Emerging Technologies Goal:** "*Effectively deploy advanced transportation technologies promptly to remain a DOT leader in emerging technologies and innovation."*
- **#6 Workforce Development Goal:** *Recruit, develop, and retain an engaged workforce that is prepared for the rapidly changing nature of the ITS landscape."* (HNTB, 2018)

The ITS Strategic Plan envisions realizing these goals to happen through a set of actions focused on understanding and testing emerging technologies, establishing processes to evaluate the technology's effectiveness, and communicating the advantages of the technology to MDOT staff. Also, on the workforce development goal, the plan recommends that MDOT expand their employee's exposure to ITS technologies by engaging them in projects, sending them to industry events and conferences, and encouraging employees to develop their skill sets to work with these technologies. Another way the ITS Strategic Plan suggests preparing the organization's future workforce is to identify current, and future skill sets needed and work with academic partners to prepare students for a future career in ITS-related fields.

3.1.5 MDOT Workforce Programs and Recruitment Strategy

Through the MDOT Workforce Programs and Recruitment Strategy document, the Workforce Programs and Recruitment Unit recognizes the transportation industry's evolving nature and the rising competition for talent. The Workforce Programs and Recruitment Strategy Development Team has created workforce development strategies to align with the employee life-cycle (ELC) in response to such a need. The strategies focus on the following key areas:

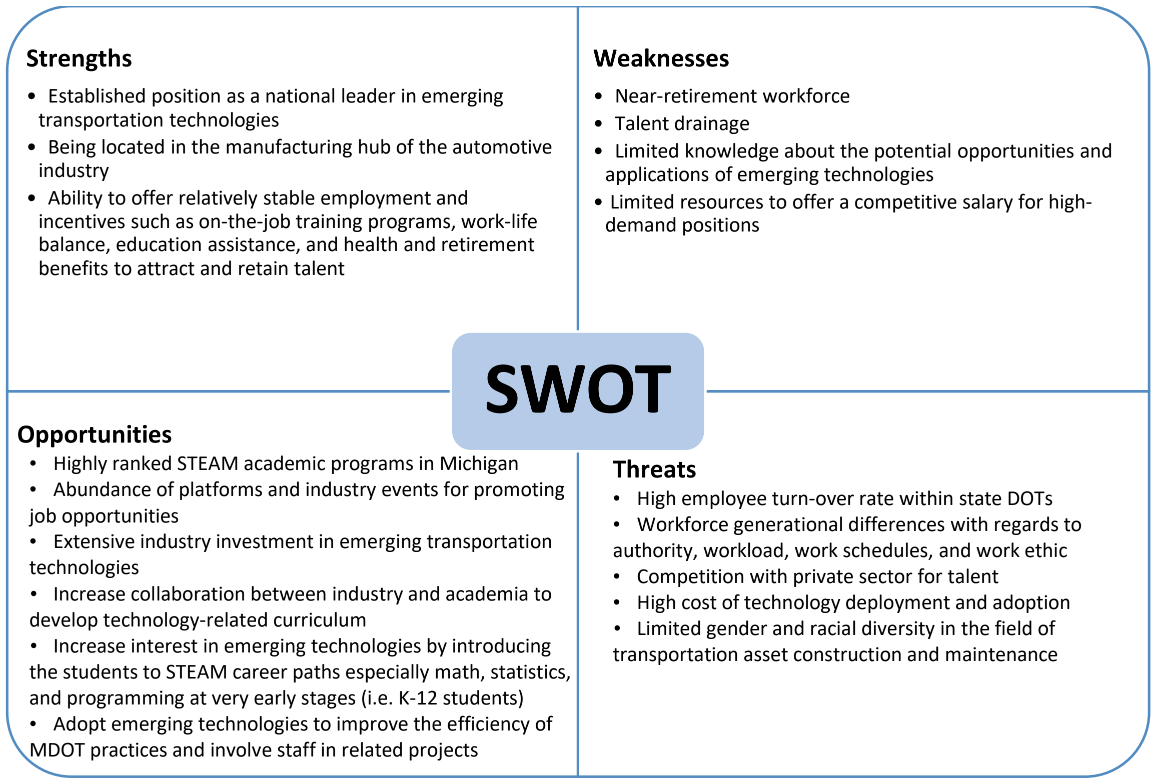
- Metrics for measuring the effectiveness of workforce programs and recruitment efforts
- Identifying challenges and barriers to employment at MDOT
- Recruitment marketing strategy
- Workforce strategies based on needs and gaps in MDOT workforce
- Mapping career pathways at MDOT
- Partnerships for enhancing recruitment at MDOT
- Importance of diversity and equal opportunities in recruitment efforts
- Importance of clear communication in defining roles and responsibilities
- Importance of industry-wide collaboration on hiring needs

The MDOT Workforce Programs and Recruitment Strategy document also highlights the department's vision of prioritizing internal hiring to fill open positions, emphasizing continuity of engagement as a pipeline for all positions (MDOT, 2020).

3.2 SWOT Analysis

For this strategic plan, CAR researchers conducted a SWOT analysis based on the survey findings and the study of MDOT resources and organizational structure. The SWOT analysis's primary goal is to help MDOT develop more robust technology-enabled workforce development strategies by considering all the department's areas of strength and weaknesses and the opportunities and threats it faces on its path. Figure 33 shows a summary of the SWOT analysis.

FIGURE 33. MDOT WORKFORCE SWOT ANALYSIS



3.3 Recommendations

Dealing with the changing dynamics of the transportation infrastructure workforce is a challenging task for state DOTS. To be able to plan and prepare for such changes, "state DOTs need robust workforce management strategies and guidance that can attract, train, retain, and promote the personnel needed to construct and maintain the U.S. highway infrastructure now and into the future." (Harper, Bogus, Kommalapati, & Choe, 2018)

Throughout this project, CAR researchers found that MDOT's organization is among the leading DOTs regarding developing its workforce for emerging technologies. Many of the skills needed throughout this organization reflect similarly to the overall trend of the transportation infrastructure industry. However, there is always room for improvement.

This section will provide MDOT with a set of recommendations to lead efforts toward high-tech workforce preparation. CAR categorized the recommendations into five major groups: ideal core competencies, organizational structure, recruitment, training and development, and retention recommendations.

3.3.1 Ideal Core Competencies

The need for technical and soft skills is a high priority for the transportation infrastructure sector. Many technical skills listed focus on data analytics, artificial intelligence, neural networks, and cybersecurity needs.

Many believe the advancement of AI across businesses will continue to dominate as AI applications are vast. Preparing the workforce for this emerging technology should be a priority. The use of AI will bring data analysts, data scientists, and others familiar with working in databases, mining data, and building out neural networks and machine learning models.

Many organizations are also prioritizing skills such as cybersecurity. As more connectivity occurs in the industry, cybersecurity expertise will continue to be crucial to ensure safety. According to a survey conducted by Udemy, cybersecurity (among other technical skills) was the essential skill area for Learning and Development leaders for training (Udemy for Business, 2020).

In addition to technical skills, many organizations highlighted the importance of workers with soft skills. Some examples of recommended soft skills include a growth mindset, communication, and emotional intelligence.

3.3.2 Organizational Structure

- **Develop a program similar to the U.S. Chamber of Commerce's Talent Pipeline Management (TPM):** TPM will help create a talent pipeline for an in-demand position. This method uses supply chain management methodology and applies the same principles to talent acquisition and development (Consumers Energy, 2017). Consumers Energy conducted one successful example of TPM's success in 2015 when the company identified the challenge to attract and retain skilled electric and gas line workers. Utilizing the TPM methodology, the company projected the occupational demands, identified competencies, expanded training partners (specifically for electrical line workers), and obtained 100 qualified hires over two years (Consumers Energy, 2017).
- **Conduct skills mapping for positions across MDOT:** Continuous skills mapping will become critical for workplace planning. For example, Amazon created career training paths for its warehouse workers to support a future role as a data technician at the organization (Udemy for Business, 2020).

3.3.3 Recruitment

- **Invest time and effort to increase workforce diversity** as transportation becomes more about inclusivity and accessibility for all. The workforce should also represent minority groups, including people who understand the unique needs and represent their communities.
- **Engage in job fairs at various universities and colleges in Michigan** to recruit potential applicants and hire underrepresented minorities to promote diversity.
- **Embrace the use of websites and social media for advertising and recruiting efforts** to reach a broad younger audience.
- **Align and strengthen partnerships with academia** to increase young students' exposure to transportation-related fields, especially engineering and construction. Working closely with

educators to identify the organization's needs for the next ten years will support clear curriculum development and provide connections between MDOT and students.

- **Communicate clearly and advertise the excellent benefits offered by state employment**, such as valuable public service, stable careers, health benefits, and retirement benefits.
- **Include a quantified value of benefits with the starting salary to be competitive with private sector firms.** In many cases, DOTs offer better benefit packages that include more incentives and options than private firms can offer.

3.3.4 Training and Development

- **Understand workforce generational differences** and revise HR processes and work conditions to reflect the younger generation's needs and preferences.
- **Diversify training programs by utilizing available online resources** such as FHWA's LTAP resources. Some of the DOTs across the country have been active in developing LTAP resources. Using the available online training resources allows MDOT to offer training programs in multiple fields and gives more flexibility to MDOT employees.
- **Invest in education assistance programs** that offer new hires and current employees skills needed to face new technologies.
- **Establish internal processes to develop talent and build additional employees' skills**, such as mentorship opportunities provided by senior staff, job rotations, and on-the-job training.
- **Establish an inter-department succession planning committee** that monitors prospect retirements and potential vacant positions and can advise the department on the possible skills and candidates who can fill the position.
- **Identify the employees nearing retirement ahead of time** and engage them in activities to mentor younger employees and retain the knowledge base before their departure.

3.3.5 Retention

- **Grow a culture within the department that encourages loyalty and improves morale among employees** by emphasizing transparency and clarity of processes and communication and feedback between staff and management.
- **Implement an employee support program** that offers work schedule flexibility, work-life balance opportunities, on-the-job training, access to commuting support, etc.
- **Promote the value of being a public servant and helping to improve society**.
- **Create a transparent system for promotions and incentives** based on employee performance to award highly effective employees.
- **Require employees to work for the DOT for a set period** after obtaining a job-related license.
- **Provide supervisors with leadership training** to lead their teams and help their associates identify the potential career path they can follow.

Task 4: Training Materials for Current and Future Workforce

Transportation technology and infrastructure developments are changing rapidly, which impacts MDOT workforce recruiting and training. This section highlights the postsecondary education and training programs to support the emerging trends and occupations in the transportation industry.

4.1 Methodology

4.1.1 Purpose, Timeframe, and Geography

To accomplish Task 4, the WIN team analyzed the results of Tasks 1-3, together with additional research to conduct an environmental scan and asset map of educational training resources and conduct an environmental scan of skills for five high demand occupations. WIN examined in-demand training programs, skills, certifications, and wages to provide a full landscape of the projected change in operations to the transportation industry.

The focus of data in this report is for the state of Michigan. The data was compiled using employer demand, ascertained from online job advertisements, employment, wage data, and education program from Economic Modeling Specialists, International (Emsi). Emsi scans multiple governmental sources (i.e. Bureau of Labor Statistics, US Census Bureau) to provide insight into major trends in jobs and wages. The occupational employment analyzed in the following was for 2019 to 2020 and projected through 2030, where applicable. While online posting data reflects January 2019 through December 2019. All data is focused on occupations identified by MDOT. In addition, researchers conducted an internal survey of Michigan Department of Transportation department heads. The survey provided critical content to assess the current needs and barriers departments face. This data shed light on future skills that are needed in response to emerging technological advancements which aided in the development of Tasks 4 and 5.

4.1.2 Occupation Selection

Transportation technology occupations are emerging, so standard occupation codes are not nuanced enough to capture all skills needed to meet current operational demands. Based on conversations with MDOT representatives and department-wide survey results of existing occupational skills needs, this study was narrowed to understand the present and future demands and skills gaps associated with five high-demand occupations. These occupations are Civil Engineers, Civil Engineering Technologists and Technicians, Electricians, Highway Maintenance Workers, and Surveyors.

4.2 Introduction

The advancement of transportation technologies is rapidly changing, as evidenced by new technologies such as big data analytics, connected and automated vehicle technologies (CAV), and civil integrated management (CIM), which alters how the industry operates. MDOT is challenged with upskilling the current workforce to keep pace with the advancement of core technologies of focus. Upskilling incumbent workers through training in advanced technologies as it becomes available will support the industry's needs while identifying emerging skills needed for entry-level workers. The scope of this guide includes five transportation-related occupations that were analyzed to gain insight into the skills, education requirements, and gaps existing for workers in these occupations. This report's recruitment and training sections feature the core technology focus areas identified in task one and analyze the most relevant emerging technology occupation skills needs. The technology focus areas identified in task one includes:

- Mobile Robotics
- Advanced Traffic Management Systems
- Data Analytics
- Mechanistic-Empirical Design and Engineering
- Complete Streets Design and Context-Sensitive Solutions

4.3 Analysis of Restructured Transportation Departments

When it comes to federal transportation policy, the Federal Highway Administration (FHWA) under the United States Department of Transportation (USDOT) and the National Highway Traffic Safety Administration (NHTSA) remain the preeminent sources. Many Departments of Transportation (DOTs) are experiencing staffing shortages and increased workloads, resulting in a shift from internal staff to external contractors performing critical tasks, such as inspection and contract administration services, construction surveying and job-staking, and quality assurance. This trend has been reflected in both Arizona and South Carolina, which consult with engineers to complete significant workload responsibilities. With a heavier reliance on needed consulting services, the staff receives greater responsibility for managing projects and higher compensation for performance accountability. The following case studies give high-level overviews of the changes made within other DOT's that have encouraged employee growth and retention while decreasing workloads.

Other strategies to manage decreased staffing include prioritizing inspections, reducing testing frequencies, phasing inspections (inspecting work at predetermined stages), reducing paperwork requirements, using student technical assistants and construction aids, implementing automated construction management systems, and using various innovative contracting procedures such as construction warranties and the design-build concept (AASHTO, 2020).

4.3.1 Arizona

The Arizona Department of Transportation (ADOT) uses consulting engineers for surveying, construction contract administration, and materials testing. ADO uses both full-service and on-call consulting engineer contracts to provide needed services. Full-service consulting engineers provide all the services required to monitor a specific project. These could include the use of a resident engineer, chief inspector, field office supervisor, materials laboratory supervisor, survey party chief, traffic control specialist, and landscape inspector. ADOT appoints a project monitor in charge to oversee the contractor's work. On-call consulting engineers provide needed services on a task-order basis. According to an ADOT official, using on-call contracts enables ADOT to negotiate a task order in 15 to 30 days, compared with the 60 to 90 days needed to advertise, sign a contract, and issue a notice to proceed with a project. Consequently, required work can begin more quickly with a task order.

To retain professional employees, ADOT restructured the pay system for engineers. Engineers received an initial 10-percent pay raise the first year, followed by a 5-percent pay raise in each of the two subsequent years. In addition, ADOT implemented Partnering—a teamwork-oriented construction management method that attempts to eliminate the adversarial relationship between owners and construction contractors inherent in traditional design and construction processes. The purpose of partnering was to proactively develop a spirit of cooperation through a structured, systematic methodology for developing teamwork and collaboration through shared goals, open communication, problem identification and resolution, conflict escalation procedures, and team performance monitoring. This program was designed to improve ADOT's relationships with contractors, obtain fair interpretations of specifications, and reduce contractors' claims, project time, and cost growth.

4.3.2 South Carolina

The South Carolina Department of Transportation (SCDOT) accelerates its efforts to compress the time needed to execute its workload without increasing in-house staffing levels. To accomplish this, it has initiated a program called Construction and Resource Manager (CRM). Through this program, SCDOT competitively hired two CRM contractors to provide support staff to assist SCDOT program managers in delivering projects on time and within budget. CRM staff act as extensions of the regular SCDOT staff, who make final decisions since this authority has not been given to contract personnel. CRM staff is assigned to various tasks, including project and program management, preliminary engineering, design supervision and review, acquisition of rights-of-way, construction engineering and inspection, financial management, and disadvantaged business enterprise use. Other contractors undertake the design work beyond the environmental impact stage of construction projects. Suppose SCDOT staff were to perform the work planned for the two CRM contractors. In that case, SCDOT estimates that it would have to hire about 500 personnel—200 for preliminary engineering and 300 for construction-related services. SCDOT did not calculate the cost difference between contracting for and hiring the increased staff.

As part of implementing the CRM contracts, SCDOT established 11 Work Process teams: Executive, Strategic Planning, Disadvantaged Business Enterprise (DBE), Financial, Procurement, Environmental/Design, Utilities, Program Development, Right-of-way, Construction, and Information Technology/WEB. These teams—comprised of representatives from SCDOT, the CRM contractors, and FHWA—have developed over 83 initiatives to improve SCDOT's procedures and practices. Some highlights of the completed initiatives include streamlining the contractor submittal processes, including value engineering proposals, developing a comprehensive quality assurance/quality control manual for preconstruction activities, improving and shortening the DBE certification process, improving utility relocation and payment.

4.4 Occupation Snapshots

The transportation infrastructure has been subjected to the same changes in technological expansion as seen in many other industry sectors. Businesses are struggling to find talent with the necessary skills to adapt to new processes, which are inevitable. The organization-wide survey results represent a broad range of respondents from MDOT, particularly those in supervisory, managerial, engineering, administrative, and directorial positions. The specified hard-to-fill jobs are categorized into six overarching occupation groups: Electrician, Engineering, Technician, Specialist, Analyst, and Other. The following five occupations have been identified as high-demand and hard to fill positions in the transportation industry by survey respondents, which are projected to change the operations of the transportation infrastructure:

- Civil Engineers
- Civil Engineering Technologists and Technicians
- Electricians
- Highway Maintenance Workers
- Surveyors

4.4.1 Civil Engineers (17-2051.00)

Civil engineers typically perform duties in planning, designing, and overseeing construction and maintenance of building structures and facilities, such as roads, railroads, airports, bridges, harbors, channels, dams, irrigation projects, pipelines, power plants, and water and sewage systems. Subset occupations encompassed under civil engineers include transportation engineers and water/wastewater engineers. As this occupation evolves in the transportation industry, it would primarily align with the mechanistic-empirical design and engineering focus area. This focus area provides a range of transportation and mobility-related services, where construction and maintenance of highway pavements is a core priority. This occupation's top job titles include transportation engineers, traffic engineers, civil engineers, transportation project engineers, and bridge engineers.

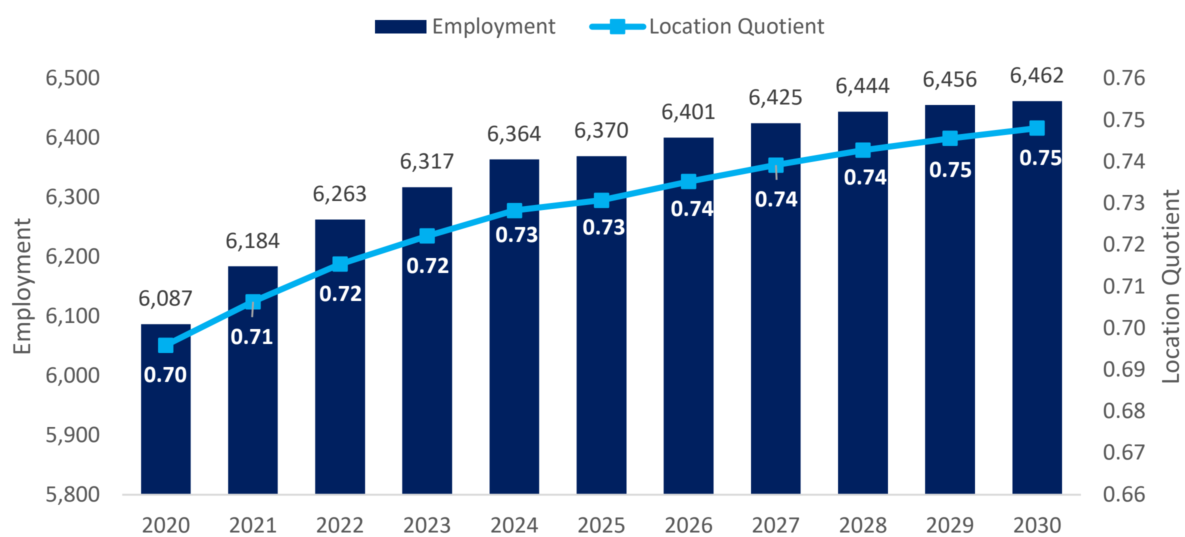
Workforce Insight

Civil engineers are essential to MDOT due to their close interaction with transportation planners and traffic management to inform decision-making on infrastructure and traffic management. In Michigan, employment for civil engineers is expected to grow through 2030 gradually. In 2021, employment reached 6,184 workers, an increase of 97 workers or 1.6 percent since 2020. However, this is lower than the national average[6] for this size area, which has 8,747 workers. The racial and gender diversity of the workforce lacks in the state, with 81.7 percent of the workers identifying as white and 85.6 percent as male. A large concentration of the workforce (68.5 percent) is between 25-54 years old, while 24.9 percent is 55 years or older. Compared to the national average (1,574 workers) for an area this size, the retirement risk in Michigan is about average with 1,515 workers. The location quotient represents how

[6] National average values are derived by taking the national value for Civil Engineers and scaling it down to account for the difference in overall workforce size between the nation and Michigan. In other words, the values represent the national average adjusted for region size.

concentrated an occupation is in the region compared to the nation. The location quotient is expected to increase from 0.71 in 2021 to 0.75 in 2030. While the increase in civil engineers in the area can benefit talent attraction for MDOT, the concentration of workers is lower than the nation, indicating a smaller talent pool of workers, making it more difficult to attract candidates. The automation index, a metric of automation risk for any given occupation based on individual job tasks, is essential to provide additional insight into employment growth trends and changes in the job description. The automation index captures an occupation's risk of being affected by automation using four measures: the percent of time spent on high-risk work, the percent of time spent on low-risk work, the number of high-risk jobs in compatible occupations, and overall industry automation risk (Emsi, 2021). Civil engineers have an automation index of 81.7 which indicates a lower-than-average risk of automation[7]. Figure 34 shows the relation between employment and the location quotient.

FIGURE 34: EMPLOYMENT COMPARED TO THE LOCATION QUOTIENT, 2020-2030

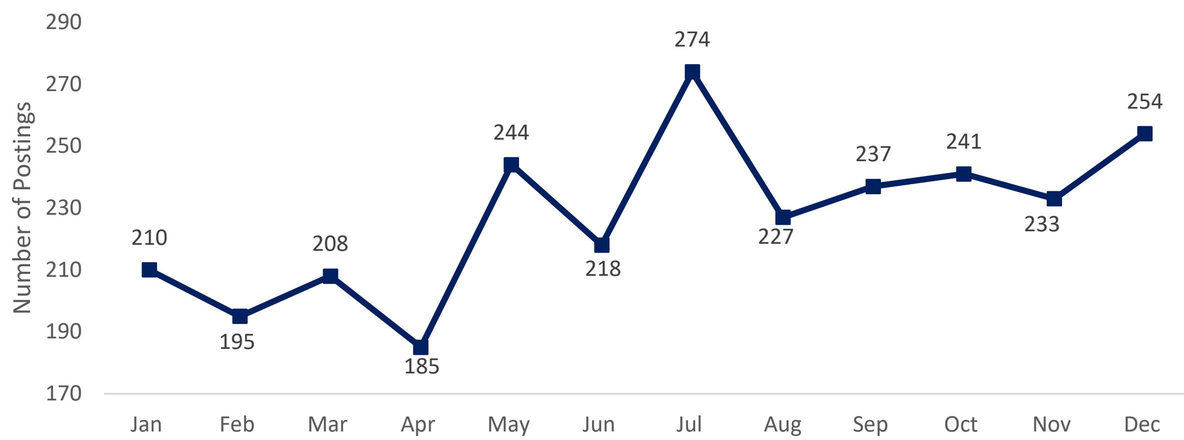


Data: Emsi | Analysis: Workforce Intelligence Network

Another method of analyzing regional demand concentration is to consider the volume of postings for civil engineering occupations. In 2019, there were 3,767 total online job postings for civil engineer occupations in Michigan. Nearly 1,081 of those were explicitly requested for transportation-related duties. Figure 35 displays the 2019 monthly postings for civil engineers.

[7] An automation index greater than 100 indicates a higher-than-average risk of automation; an automation index less than 100 indicates a lower-than-average risk of automation.

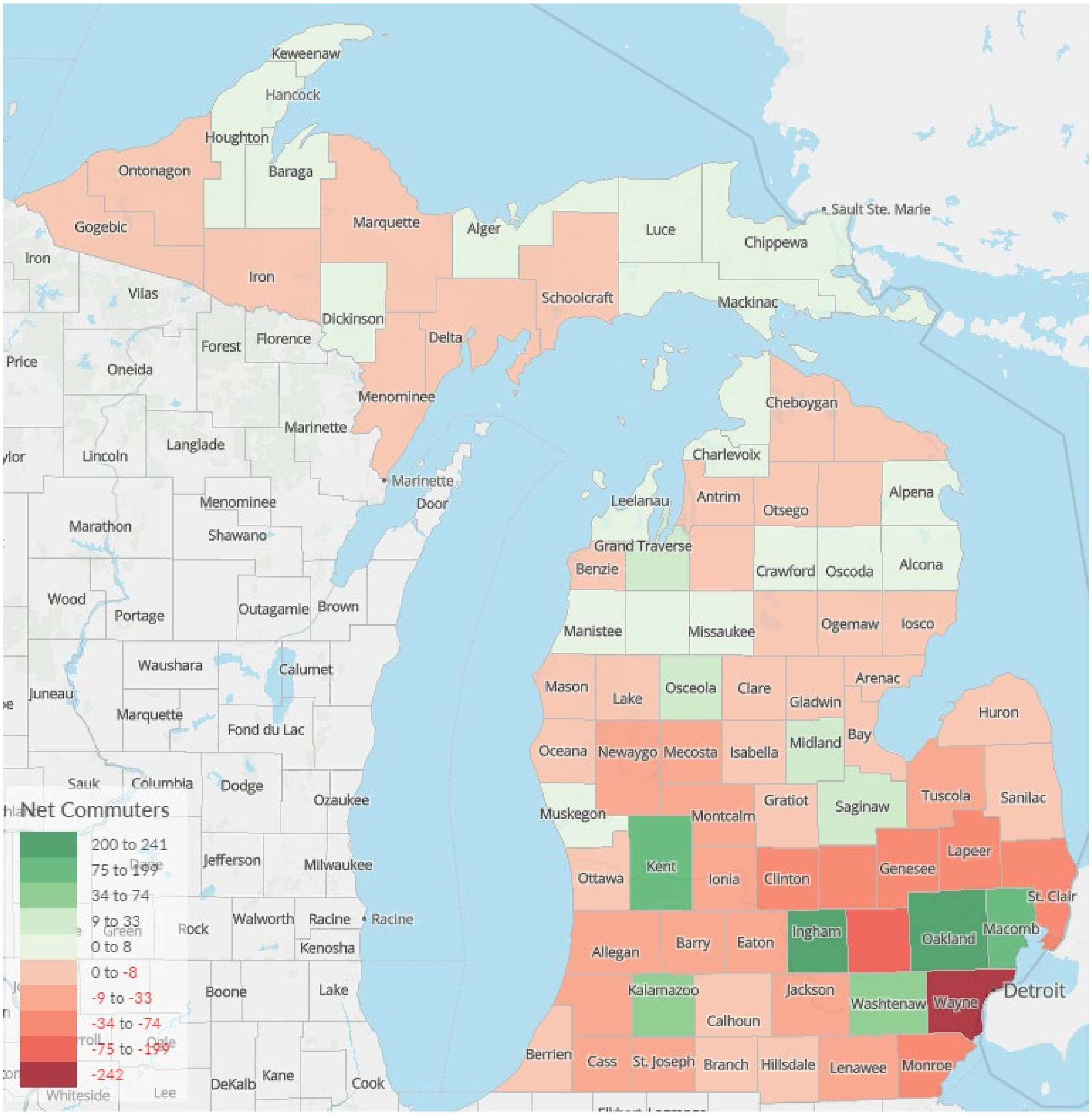
FIGURE 35: TRANSPORTATION-RELATED MONTHLY POSTINGS, 2019



Data: Emsi | Analysis: Workforce Intelligence Network

The counties employing the most civil engineers in the state include Oakland, Macomb, Wayne, Ingham, and Kent. Similarly, most workers in the state are employed and reside in Oakland, Macomb, Wayne, Ingham, and Kent counties. The volume of net commuters is vital to identify the difference between the occupational residents and occupational employment in the region. For counties with more workers living than jobs available, the net commuting is negative, indicating that workers commute out of the area for work. Figure 36 shows Michigan's net commuters by county.

FIGURE 36: MICHIGAN'S NET COMMUTERS BY COUNTY FOR CIVIL ENGINEERS



Data: Emsi | Analysis: Workforce Intelligence Network

Training Programs and Institutions

Educational providers have been working with industry employers to determine the skills and credentials needed for specialized occupational duties. Many institutions can meet the demand for civil engineering training in Michigan. There are eight specific training programs available, resulting in 1,011 completions for civil engineering occupations from 31 institutions throughout Michigan. Workers can acquire the skills needed through a combination of on-the-job experience, formal training, and higher education. The institutions that had the most completions in 2019 for civil engineering related programs were the Michigan State University (203 completions), Calvin University (114 completions), Michigan Technological University (107 completions), University of Michigan-Ann Arbor (105 completions), and Wayne State University (63 completions). Table 8: Programs Available and Completions, 2019Table 8 shows the completions for all related programs offered.

TABLE 8: PROGRAMS AVAILABLE AND COMPLETIONS, 2019

CIP Code	Program	2019 Completions
14.0801	Civil Engineering, General	434
14.0101	Engineering, General	424
14.0102	Pre-Engineering	96
14.3301	Construction Engineering	22
14.3801	Surveying Engineering	16
14.0803	Structural Engineering	10
14.0401	Architectural Engineering	7
14.0805	Water Resources Engineering	2

Data: Emsi | Analysis: Workforce Intelligence Network

Of the eight programs offered, only Engineering, General, and Pre-Engineering programs offer an associate degree, the lowest degree level available for this occupation. An associate degree can take up to two years to complete, indicating that these programs are entry pathways to specialized training programs. Table 9 illustrates programs and the degree levels offered.

Table 9: Civil Engineering Related-Programs Titles/CIP Codes and the Degree Level Offered, 2019

	Associate's Degree	Bachelor's Degree	Post-Baccalaureate Certificate	Master's Degree	Post-Master's Certificate	Doctoral Degree
Civil Engineering, General	No Completions Reported	X	No Completions Reported	X	No Completions Reported	X
Engineering, General	X	X	No Completions Reported	X	X	No Completions Reported
Pre-Engineering	X	No Completions Reported	No Completions Reported		No Completions Reported	No Completions Reported
Construction Engineering	No Completions Reported	No Completions Reported	No Completions Reported	X	No Completions Reported	No Completions Reported
Surveying Engineering	No Completions Reported	X	No Completions Reported	No Completions Reported	No Completions Reported	No Completions Reported

Structural Engineering	No Completions Reported	X		X	No Completions Reported	No Completions Reported
Architectural Engineering	No Completions Reported	X	No Completions Reported	X	No Completions Reported	No Completions Reported
Water Resources Engineering	No Completions Reported	No Completions Reported	X	No Completions Reported	No Completions Reported	No Completions Reported

*Program titles may vary by institution

Data: Emsi | Analysis: Workforce Intelligence Network

Desired Skills

In response to emerging technology, skills help to understand how occupation is changing. Workers can acquire the skills needed for civil engineering through a combination of on-the-job experience, formal training, and higher education. Specialty certifications are attractive to recruiters in this field. Transportation-related certifications for civil engineers in the state include professional engineers, engineers in training, and professional traffic operations engineer. Technical skills preferred for this occupation are civil engineering, MicroStation (CAD design software), transport engineering, AutoCAD, and computer-aided design. In contrast, foundational skills include construction, management, planning, communications, and coordinating. Through analyzing in-demand skills and identifying the skills necessary for mechanistic-empirical design and engineering in transportation, it can be summarily agreed that the emerging skills for this occupation include knowledge in analytical or scientific software, business intelligence and data analysis software, calendar and scheduling software, computer-aided design (CAD) software, and database user interface and query software. The following list displays the top foundational and technical skills in this occupation and emerging skills.

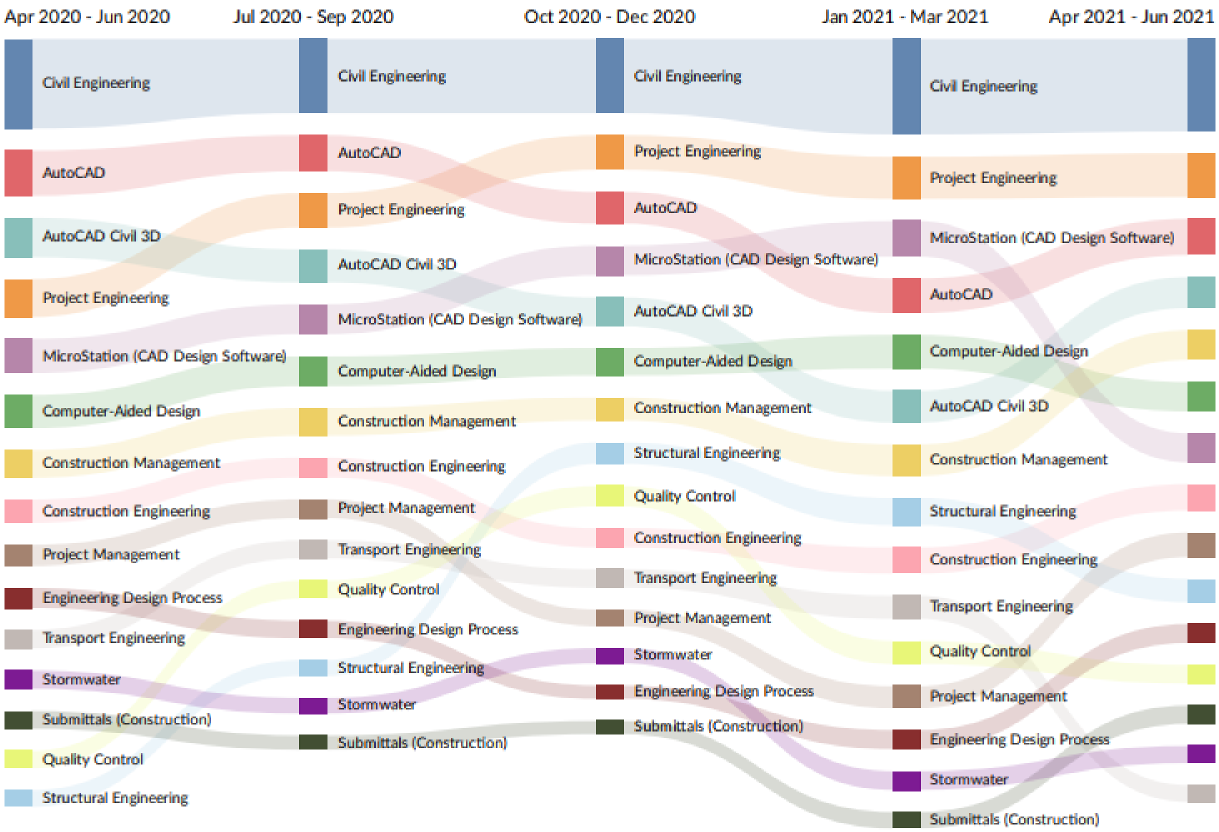
Figure 37 depicts the top 15 skills for civil engineers by quarter.

TABLE 10: IN-DEMAND SKILLS FOR CIVIL ENGINEERS

Top Technical Skills	Top Foundational Skills	Emerging Skills
Civil Engineering	Construction	Analytical or scientific software
Microstation (CAD Design Software)	Management	Business intelligence and data analysis software
Transport Engineering	Planning	Calendar and scheduling software
AutoCAD	Communications	Computer-aided design CAD software
Computer-Aided Design	Coordinating	Database user interface and query software
OpenRoads (Civil Design Software)	Valid Driver's License	Development environment software
Project Engineering	Operations	Document management software
Traffic Engineering	Mentorship	Enterprise application integration software
Construction Management	Written Communication	Enterprise resource planning ERP software
Engineering Design Process	Microsoft Office	Graphics or photo imaging software

Data: Emsi | Analysis: Workforce Intelligence Network

Figure 37: Top 15 Skills for Civil Engineers by Quarter

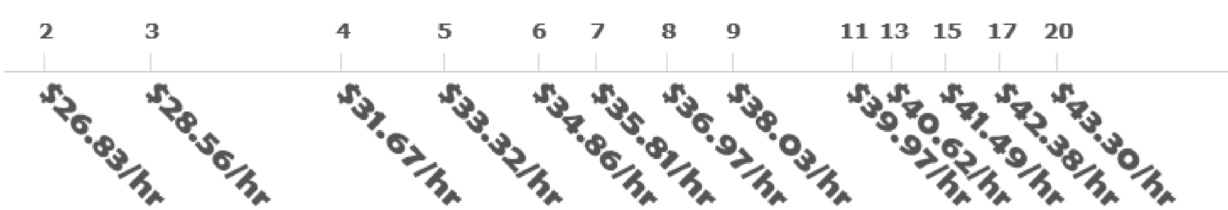


Data: Emsi | Analysis: Workforce Intelligence Network

Wage Analysis

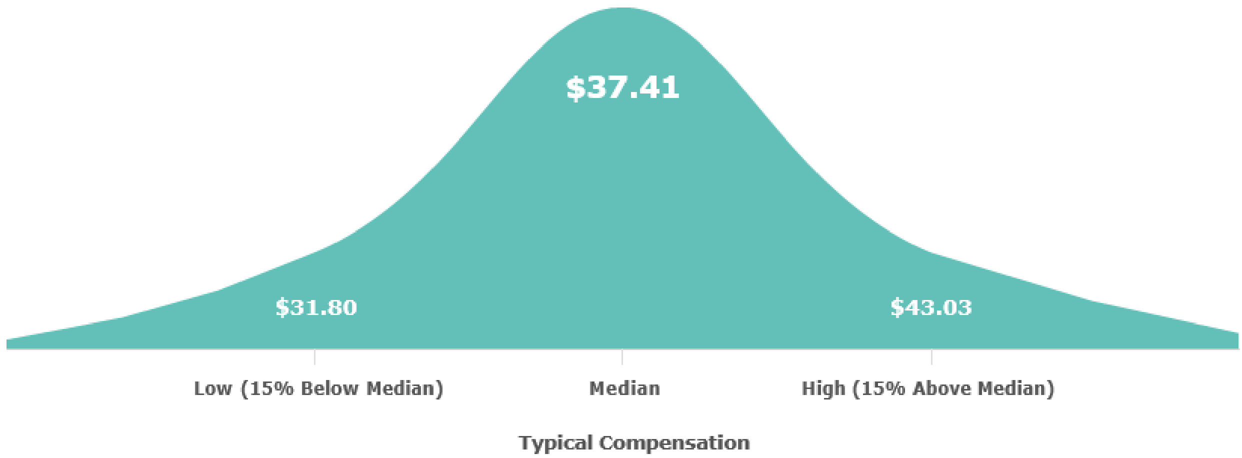
The relationship between education and experience determines the wages earned by civil engineers in the field, so typical compensation for these workers in Michigan ranges from USD26.33 to USD46.06 an hour. Figure 38 shows the median hourly wages by the experience a worker has in the state. It is important to note that wages will range above and below the plotted point. The median hourly salary is USD37.37, which is 12.1 percent lower than the national median. Figure 39 displays the typical median wages for civil engineers in Michigan.

Figure 38: Compensation by Years of Experience



Data: Emsi | Analysis: Workforce Intelligence Network

FIGURE 39: COMPENSATION WAGE SCALE



Data: Emsi | Analysis: Workforce Intelligence Network

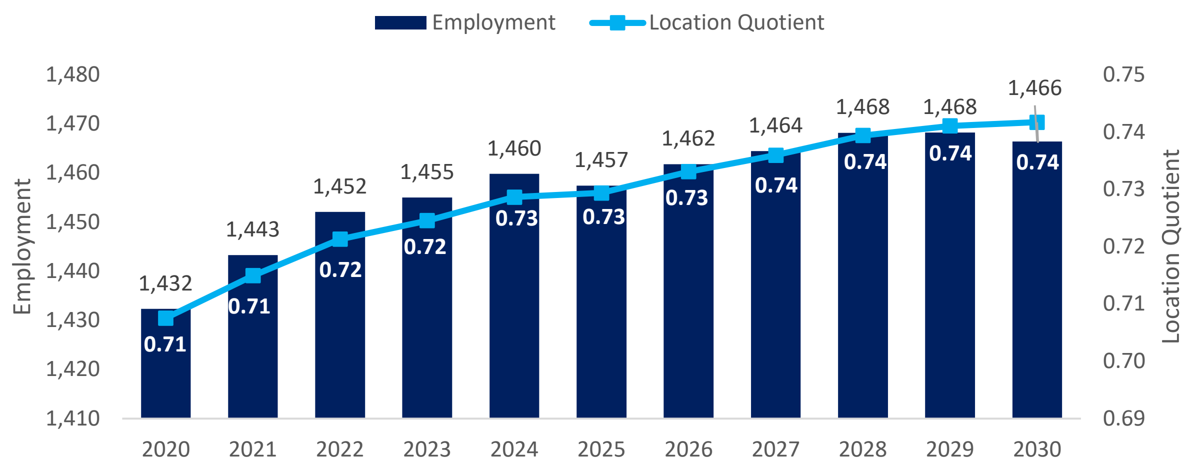
4.4.2 Civil Engineering Technologists and Technicians (17-3022.00)

Civil engineering technologists and technicians are responsible for applying theory and principles of civil engineering in planning, designing, and overseeing construction and maintenance of structures and facilities under the direction of engineering staff or physical scientists. As this occupation evolves in the transportation industry, it primarily would align with the data analytics focus area. This focus area determines what data is valuable and how it can be used, transforming data into actionable information requiring skill and experience. This occupation's top job titles include transportation technicians, engineering technicians, construction technicians, civil engineering technicians, and construction service technicians.

Workforce Insight

Civil engineering technologists and technicians are similar to civil engineers due to the strong interaction between transportation technicians and construction management to inform infrastructure and project management decision-making. In Michigan, employment for civil engineering technologists and technicians is expected to grow through 2030 gradually. In 2021, employment totaled 1,443 workers, an increase of 11 workers or 0.8 percent since 2020. However, this is lower than the national average for this size area, which has 2,024 workers. The racial and gender diversity of the workforce is low in the state, with 78.0 percent of the workers identifying as white and 80.0 percent as male. A large concentration of the workforce (64.3 percent) is between 25-54 years old, while 23.9 percent is 55 years or older. Compared to the national average (356 workers) for an area of similar size, the retirement risk in Michigan is about average with 342 workers. The location quotient is expected to increase from 0.71 in 2021 to 0.74 in 2030. While an increase in civil engineering technologists and technicians in the region is an advantage for talent attraction to MDOT, a lower concentration of workers than the nation, which indicates a smaller talent pool of workers, makes it more difficult to attract candidates. The automation index for civil engineering technologists and technicians is 92.4, which indicates a lower-than-average risk of automation[8]. However, an automation index greater than 100 indicates a higher-than-average chance of the occupation becoming automated and this occupation group is near the edge. Figure 40 shows the relation between employment and the location quotient.

FIGURE 40: EMPLOYMENT COMPARED TO THE LOCATION QUOTIENT, 2020-2030



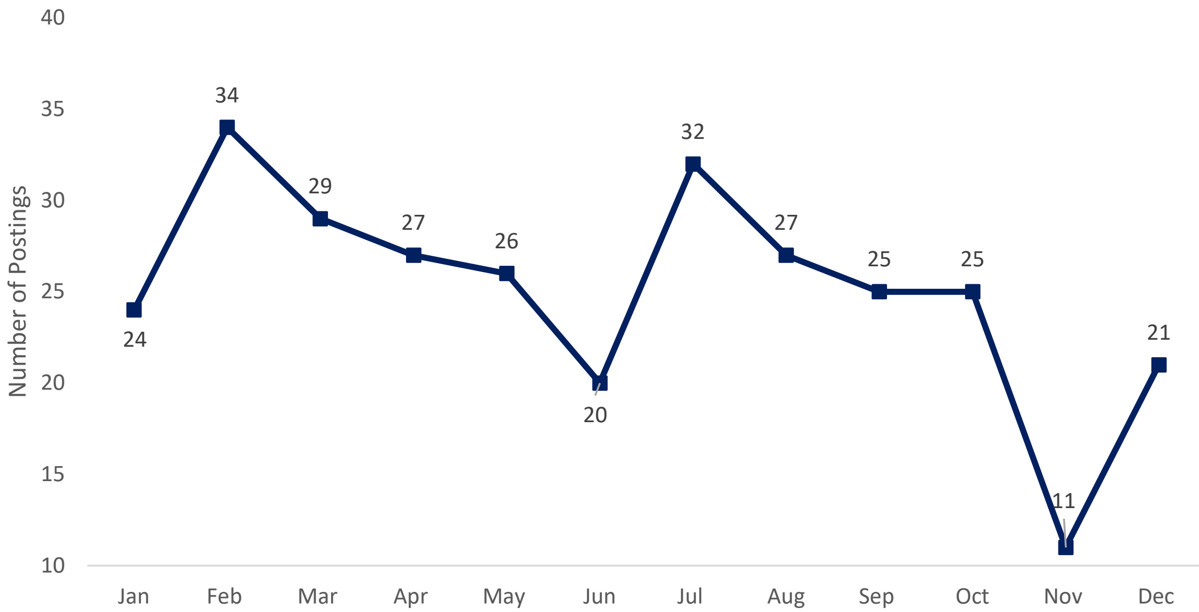
Data: Emsi | Analysis: Workforce Intelligence Network

Another method of analyzing regional demand concentration is considering the volume of postings for civil engineering technologists and technician occupations. In 2019, there were 567 total online job postings for civil engineering technologists and technician occupations in Michigan. Of those, 131 postings were explicitly requested for transportation-related duties.

Figure 41 displays the 2019 monthly postings for civil engineering technologists and technicians.

[8] An automation index greater than 100 indicates a higher-than-average risk of automation; an automation index less than 100 indicates a lower-than-average risk of automation.

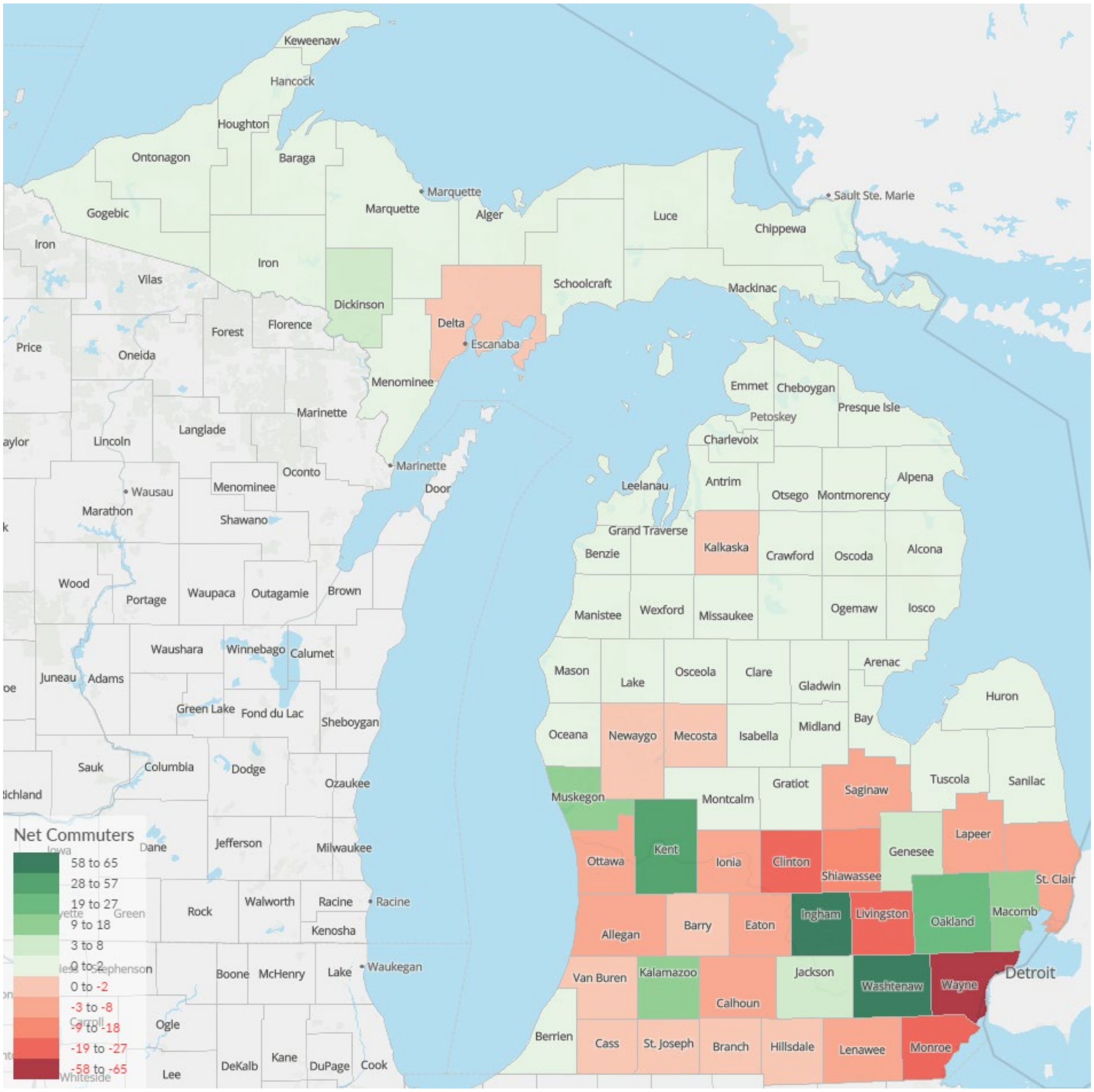
FIGURE 41: TRANSPORTATION-RELATED MONTHLY POSTINGS, 2019



Data: Emsi | Analysis: Workforce Intelligence Network

The counties employing the most civil engineering technologists and technicians include Oakland, Washtenaw, Ingham, Macomb, and Wayne. Most workers in the state are employed and reside in Oakland, Washtenaw, Ingham, Macomb, and Wayne counties. The volume of net commuters for this occupation is shown in Figure 42.

FIGURE 42: MICHIGAN'S NET COMMUTERS BY COUNTY FOR CIVIL ENGINEERING TECHNOLOGISTS AND TECHNICIANS



Data: Emsi | Analysis: Workforce Intelligence Network

Training Programs and Institutions

Educational providers have been working to assess the skills and credentials required for specialized occupational duties. Many institutions can meet the demand for civil engineering technologists and technician training in Michigan. Eight specific training programs are available, resulting in 577 completions for civil engineering technologists and technician occupations throughout Michigan. Workers can acquire the skills needed through a combination of on-the-job experience and formal training. The institutions with the most completions in 2019 for civil engineering technologist and technician-related programs were Michigan State University (12,707 completions), Eastern Michigan University (4,908 completions), Ferris State University (4,205 completions), Macomb Community College (2,991 completions), and Lawrence Technological University (654 completions). Table 11 shows the completions for all related programs offered.

TABLE 11: PROGRAMS AVAILABLE AND COMPLETIONS, 2019

CIP Code	Program	2019 Completions
15.1001	Construction Engineering Technology/Technician	164
45.0701	Geography	109
15.0000	Engineering Technology, General	102
15.9999	Engineering Technologies and Engineering-Related Fields, Other	94
15.0101	Architectural Engineering Technology/Technician	50
15.0201	Civil Engineering Technology/Technician	33
46.0415	Building Construction Technology	24
15.1103	Hydraulics and Fluid Power Technology/Technician	1

Data: Emsi | Analysis: Workforce Intelligence Network

Based on eight programs offered, only civil engineering technologists and technicians and building construction technology programs offer certificate awards of less than one academic year, the lowest degree level provided for this occupation. Other specific certificate-level training programs are longer, with programs of at least one year but less than two years. An associate's degree can take up to two years to complete, indicating that these programs are entry pathways to more specialized training programs. Table 12 displays programs and the degree levels offered.

Table 12: Civil Engineering Technologists and Technicians Related-Programs Titles/CIP Codes and the Degree Level Offered, 2019

	Award of less than 1 academic year	Award of at least 1 but less than 2 academic years	Associate's Degree	Bachelor's Degree	Post-Baccalaureate Certificate	Master's Degree	Doctoral Degree
Construction Engineering Technology/Technician	No Completions Reported	No Completions Reported	X	X	No Completions Reported	X	X
Geography	No Completions Reported	No Completions Reported	X	X	X	X	X
Engineering Technology, General	No Completions Reported	No Completions Reported	X	X	No Completions Reported	X	X
Engineering Technologies and Engineering-Related Fields, Other	No Completions Reported	X	X	X	No Completions Reported	X	No Completions Reported
Architectural Engineering Technology/Technician	No Completions Reported	No Completions Reported	X	X	No Completions Reported	No Completions Reported	No Completions Reported

Civil Engineering Technology/Technician	X	No Completions Reported	X	No Completions Reported	No Completions Reported	No Completions Reported	No Completions Reported
Building Construction Technology	X	No Completions Reported	No Completions Reported	No Completions Reported	No Completions Reported	No Completions Reported	No Completions Reported
Hydraulics and Fluid Power Technology/Technicians	No Completions Reported	X	No Completions Reported	No Completions Reported	No Completions Reported	No Completions Reported	No Completions Reported

*Program titles may vary by institution

Data: Emsi | Analysis: Workforce Intelligence Network

Desired Skills

Skills define the direction of an occupation. Workers can acquire the skills needed for civil engineering technologists and technicians through a combination of on-the-job experience and formal training. Specialty certifications are attractive to recruiters in this field. Transportation-related certifications for civil engineering technologists and technicians in the state include commercial driver's license (CDL), ACI concrete field-testing technician, chartered financial analysts, and NICET Level II certification. Technical skills preferred for this occupation are surveying, soil science, quality control, construction management, and computer science. At the same time, foundational skills also in demand include construction, basic math, valid driver's license, quality assurance, and planning. Through analyzing in-demand skills and identifying what skills would be necessary for data analytics in transportation, we can assess that those emerging skills for this occupation analytical and scientific software, computer-aided design (CAD) software, development environment software, electronic mail software, and enterprise resource planning (ERP) software. The following list displays the top foundational and technical skills in this occupation and emerging skills. Figure 43 shows the top 15 skills for civil engineering technologists and technicians by quarter.

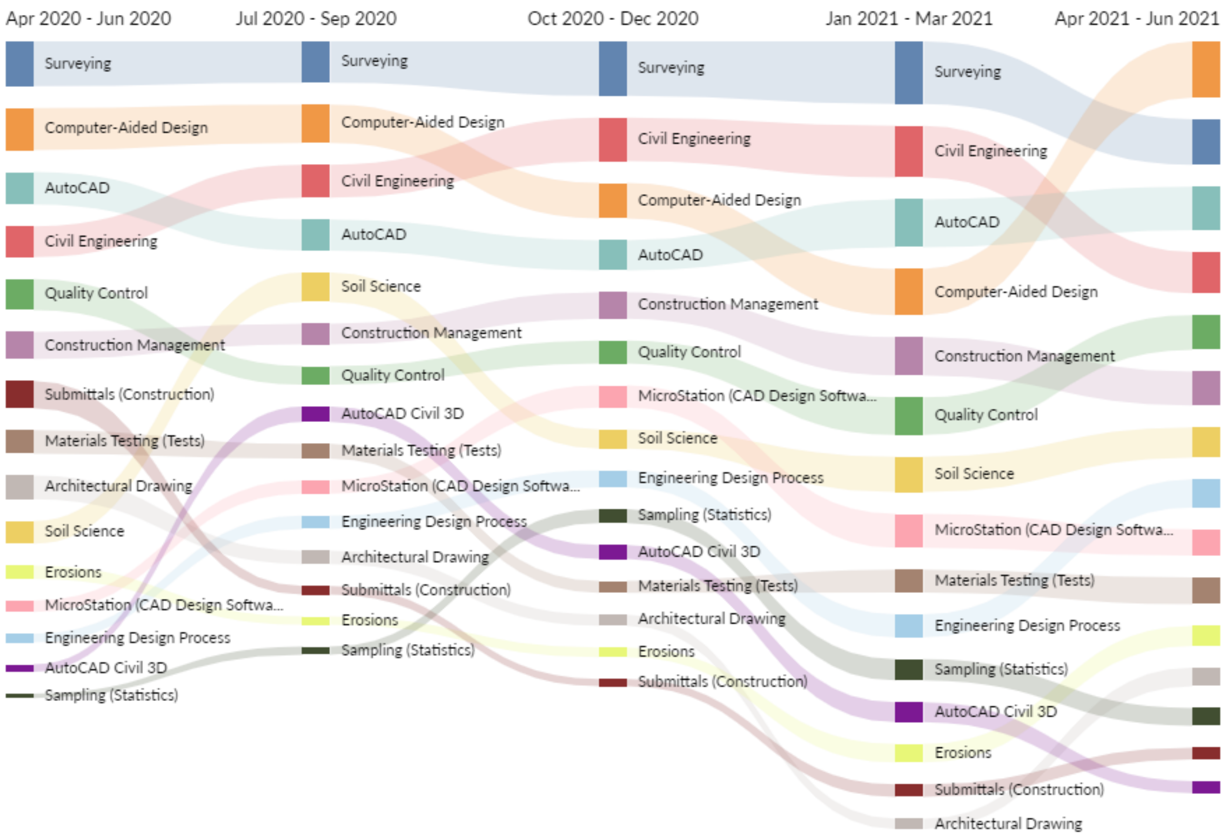
TABLE 13: IN-DEMAND SKILLS FOR CIVIL ENGINEERING TECHNOLOGISTS AND TECHNICIANS

Top Technical Skills	Top Foundational Skills	Emerging Skills
Surveying	Construction	Analytical or scientific software
Soil Science	Basic Math	Computer-aided design CAD software
Quality Control	Valid Driver's License	Development environment software
Construction Management	Quality Assurance	Enterprise resource planning ERP software
Computer Science	Planning	Graphics or photo imaging software
Concrete Mixing	Operations	Map creation software
Chemistry	Infrastructure	Office suite software
Applied Science	Communications	
Environmental Science	Verbal Communication Skills	

Geology	Filing

Data: Emsi | Analysis: Workforce Intelligence Network

FIGURE 43: TOP 15 SKILLS FOR CIVIL ENGINEERING TECHNOLOGISTS AND TECHNICIANS BY QUARTER

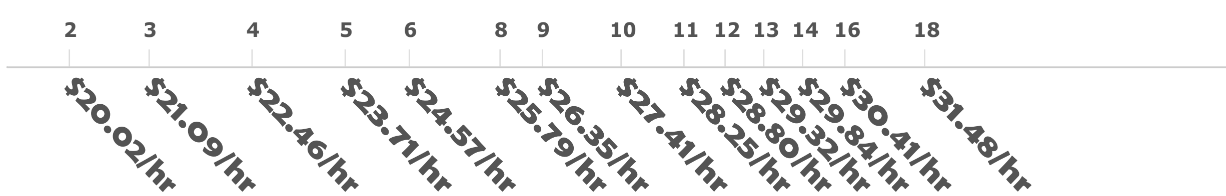


Data: Emsi | Analysis: Workforce Intelligence Network

Wage Analysis

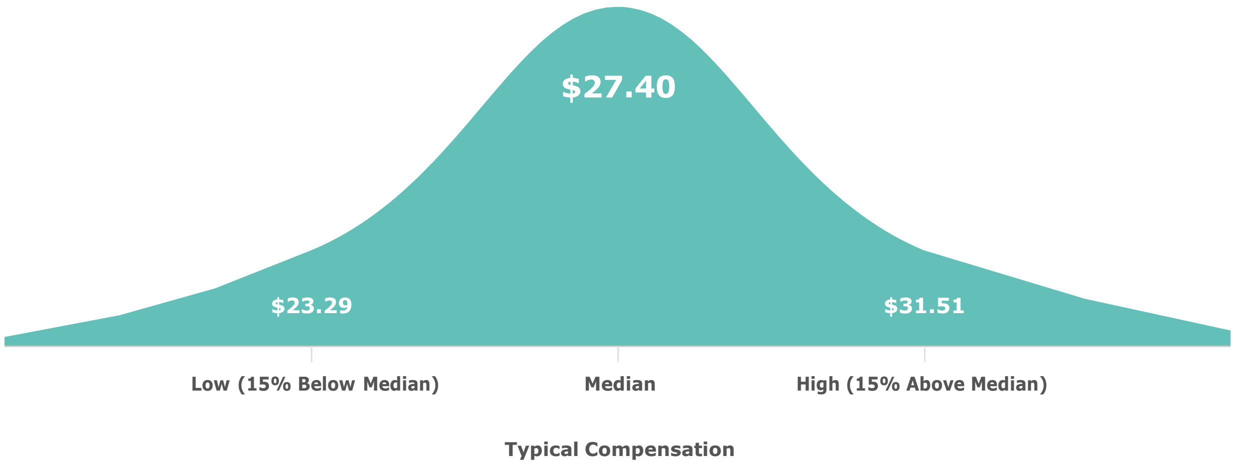
Typical compensation for these workers in Michigan ranges from USD17.27 to USD37.60 an hour. Figure 44 shows the median hourly wages by the experience a worker has in the state. It is important to note that wages will range above and below the plotted point. The median hourly salary is USD27.32, which is 5.4 percent higher than the national median. Figure 45 displays the typical median wages for civil engineers in Michigan.

FIGURE 44: COMPENSATION BY YEARS OF EXPERIENCE



Data: Emsi | Analysis: Workforce Intelligence Network

FIGURE 45: COMPENSATION WAGE SCALE



Data: Emsi | Analysis: Workforce Intelligence Network

Civil Engineering Technologists and Technicians Related Registered Apprenticeships

Apprenticeships for civil engineering technologists and technicians are entry pathways to civil engineering and enable employers to train apprentices for the needs of their department. Since civil engineering technologists and technicians within MDOT are relatively emerging as an in-demand occupation, investing in apprenticeships would attract entry-level workers to transportation careers due to the specialized training learned through on-the-job experience and formal education. Figure 46 and Figure 47 display two apprenticeship standards for CAD and civil drafter, all pathways to civil engineers.

FIGURE 46: CAD DRAFTER APPRENTICESHIP STANDARD

CAD Drafter

PUBLISHED

Competency-Based Apprenticeship

SPONSORING COMPANY:
CareerWise Colorado

Industries	
O*Net Code	17-3013.00
Rapids Code	
Req. Hours	0
State	CO
Created	Jul 16, 2021
Updated	Jul 16, 2021

Competency-Based Skills

12 skill sets | 12 total skills

Applied Mathematics

Applies basic concepts in geometry, trigonometry, and algebra to design.

Project Management

Plans, documents, and completes personal work activities to meet drafting project objectives and deadlines. Communicates effectively with supervisor regarding personal work activity plans.

Technical Drawings

Reads and interprets technical drawings.

Primary Drafting Software

Uses company's primary drafting software to create technical drawings.

Business Context

Incorporates knowledge of related business activities (ie. upstream or downstream) to drafting work and decisions.

General Engineering

Data: RapidSkills Generator Apprenticeship Standard

FIGURE 47: CIVIL DRAFTER APPRENTICESHIP STANDARD

Drafter, Civil

PUBLISHED

Time-Based Apprenticeship

SPONSORING COMPANY:
Unknown

Industries	
O*Net Code	17-3011.00
Rapids Code	0128
Req. Hours	6400
State	DC
Created	Jul 16, 2021
Updated	Jul 16, 2021

Time-Based Skills

4 skill sets | 29 total skills

Fundamentals of Drafting - 1650 req. hrs
Use and Care of Drafting Equipment
Lettering and Titling
Blueprint and Map Reading
Tracing
Plotting and Mapping
Filing of Plans
Basic Surveying and Care of Surveying Equipment
Preparation of Charts and Graphs
Model Making

Data: RapidSkills Generator Apprenticeship Standard

4.4.3 Electricians (47-2111.00)

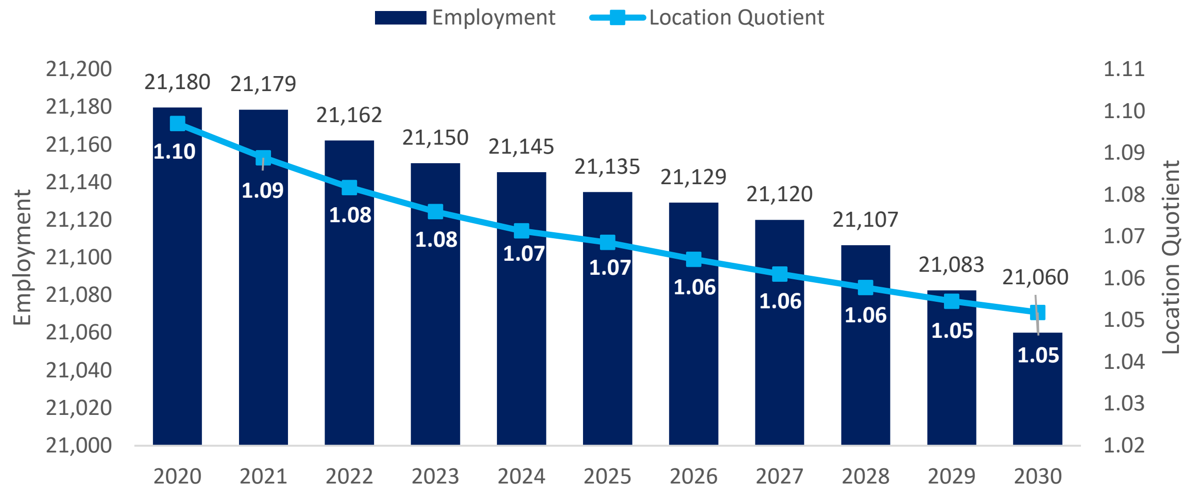
Electricians are generally responsible for installing, maintaining, and repairing electrical wiring, equipment, fixtures and ensuring that work follows relevant codes. They may install or service streetlights, intercom systems, or electrical control systems. As this occupation evolves in the transportation industry, it is expected to align with the mobile robotics focus area. This focus area provides valuable data while reducing risk to personnel. As electrician duties within the industry begin to alter with technology advancements, small robots for infrastructure inspection would allow more flexibility for MDOT electricians. This occupation's top job titles include journeyman electricians, electricians, service electricians, commercial electricians, and apprentice electricians.

Workforce Insight

Electricians are tasked with planning the layout of construction, installation, or repairs, installing electrical components, equipment, or systems, and testing electrical equipment or systems to ensure proper functions, among other duties. In Michigan, employment for electricians is expected to decline through 2030 gradually. In 2021, employment for totaled 21,179 workers, a decrease of one worker since 2020. However, electrician employment is higher than the national average for the state, with 19,306 workers. The racial and gender diversity of the workforce is low in the state, with 88.8 percent of the workers identifying as white and 97.3 percent as male. Much of the workforce (69.1 percent) is between 25-54 years old, while 20.3 percent of the workers are aged 55 or older. Compared to the national average (3,998 workers) for an area this size, the retirement risk in Michigan is about average with 4,295 workers. The location quotient is expected to decrease from 1.09 in 2021 to 1.05 in 2030. While the location quotient is higher than the national average for electricians in the state, the large talent pool of workers benefits talent attraction to MDOT. The automation index for civil engineering technologists and technicians is 110.3, which indicates a higher-than-average risk of automation[9]. Figure 48 shows the relation between employment and the location quotient.

[9] An automation index greater than 100 indicates a higher-than-average risk of automation; an automation index less than 100 indicates a lower-than-average risk of automation.

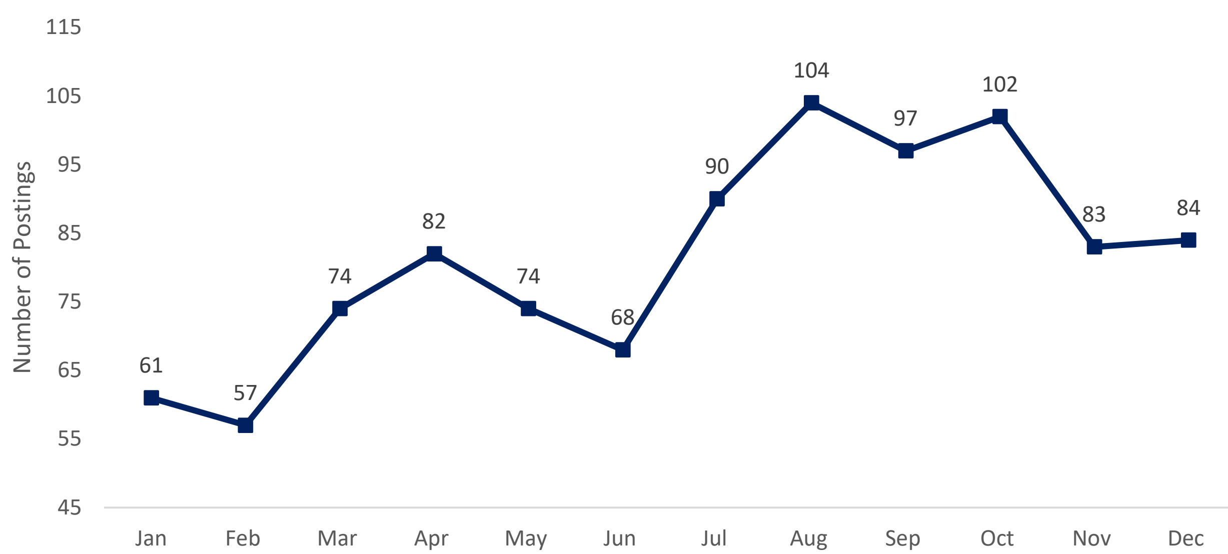
FIGURE 48: EMPLOYMENT COMPARED TO THE LOCATION QUOTIENT, 2020-2030



Data: Emsi | Analysis: Workforce Intelligence Network

Another method of analyzing regional demand concentration is to consider the volume of postings for electrician occupations. In 2019, there were 3,587 online job postings for electrician occupations in Michigan. Of those, 421 postings were explicitly requested for transportation-related duties. Figure 49 displays the 2019 monthly postings for electricians.

FIGURE 49: TRANSPORTATION-RELATED MONTHLY POSTINGS, 2019

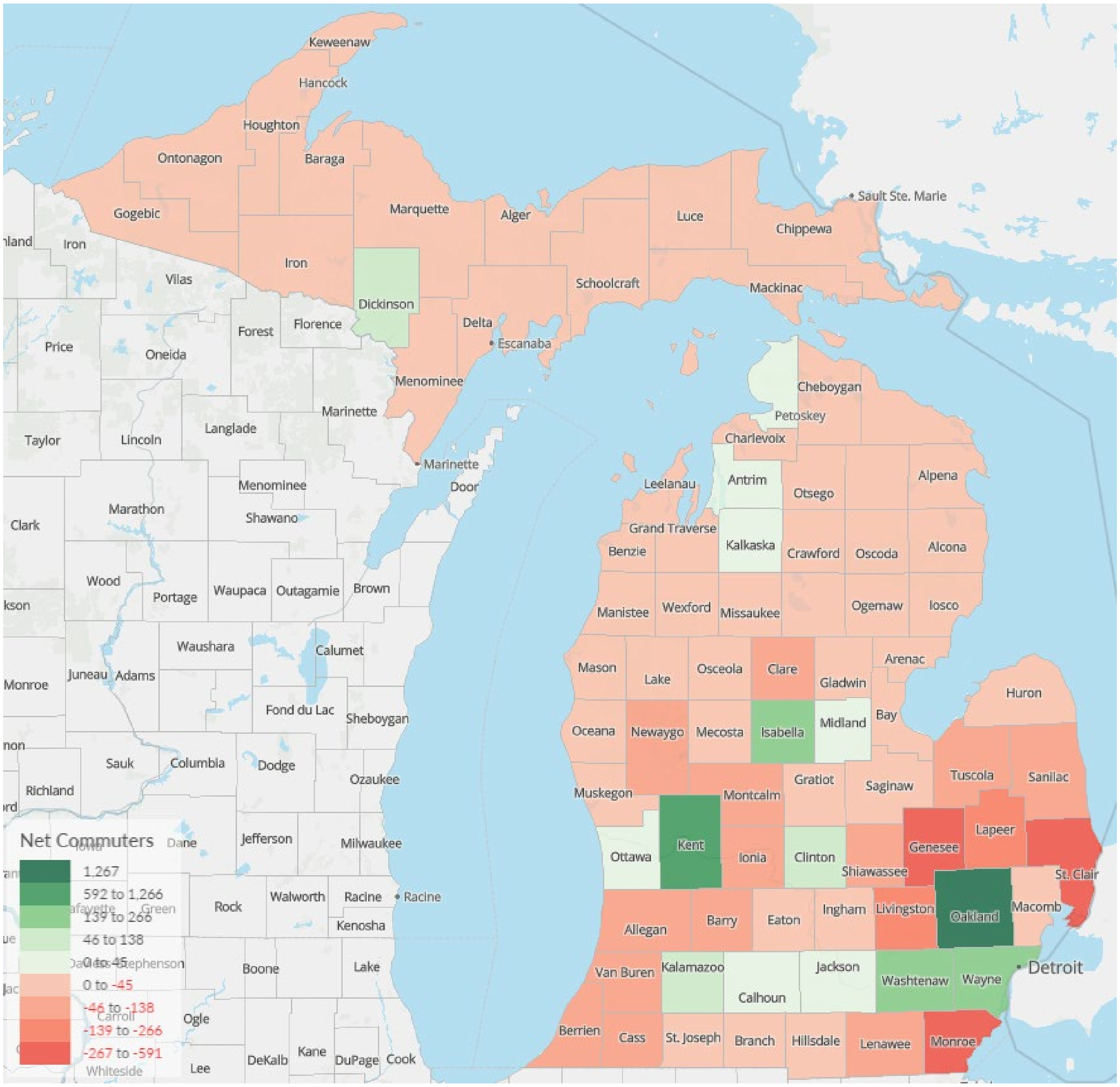


Data: Emsi | Analysis: Workforce Intelligence Network

The counties employing the most electricians in the state include Oakland, Wayne, Kent, Macomb, and Ottawa. Similarly, most workers in the state are employed and reside in Oakland, Wayne, Macomb, Kent, Ottawa, and Genesee counties. The volume of net commuters for this occupation is shown in

Figure 50.

FIGURE 50: MICHIGAN'S NET COMMUTERS BY COUNTY FOR ELECTRICIANS



Data: Emsi | Analysis: Workforce Intelligence Network

Training Programs and Institutions

Educational providers have been working to determine what skills and credentials are needed for specialized occupational duties. There are many institutions able to meet the demand for electrician training in Michigan. There are five specific training programs available, resulting in 278 completions for electrician occupations, available at 32 institutions for higher education throughout Michigan. Workers can acquire the skills needed through a combination of on-the-job experience and formal training. The institutions that had the most completions in 2019 for electrician-related programs were Macomb Community College (45 completions), Lansing Community College (37 completions), Jackson College (26 completions), St. Clair County Community College (26 completions), and Delta College (17 completions). Table 14 shows the completions for all related program offerings.

TABLE 14: PROGRAMS AVAILABLE AND COMPLETIONS, 2019

CIP Code	Program	2019 Completions
15.0613	Manufacturing Engineering Technology/Technician	173
46.0302	Electrician	80
46.0301	Electrical and Power Transmission Installation/Installer, General	14
46.0000	Construction Trades, General	8
46.9999	Construction Trades, Other	3

Data: Emsi | Analysis: Workforce Intelligence Network

Many of the five programs offer electrician certifications in less than one academic year, the lowest degree level provided for this occupation. Other specific certificate-level training programs are longer, with programs of at least one year but less than two years. An associate's degree can take up to two years to complete, indicating these programs are entry pathways to more specialized training programs. Table 15 displays programs and the degree levels offered.

TABLE 15: ELECTRICIAN RELATED-PROGRAMS TITLES/CIP CODES AND THE DEGREE LEVEL OFFERED, 2019

	Award of less than 1 academic year	Award of at least 1 but less than 2 academic years	Associate's Degree	Bachelor's Degree	Master's Degree
Manufacturing Engineering Technology/Technician	X	X	X	X	X
Electrician	X	X	X	No Completions Reported	No Completions Reported
Electrical and Power Transmission Installation/Installer, General	X	No Completions Reported	No Completions Reported	No Completions Reported	No Completions Reported
Construction Trades, General	X	X	X	No Completions Reported	No Completions Reported
Construction Trades, Other	No Completions Reported	No Completions Reported	X	No Completions Reported	No Completions Reported

*Program titles may vary by institution

Data: Emsi | Analysis: Workforce Intelligence Network

Desired Skills

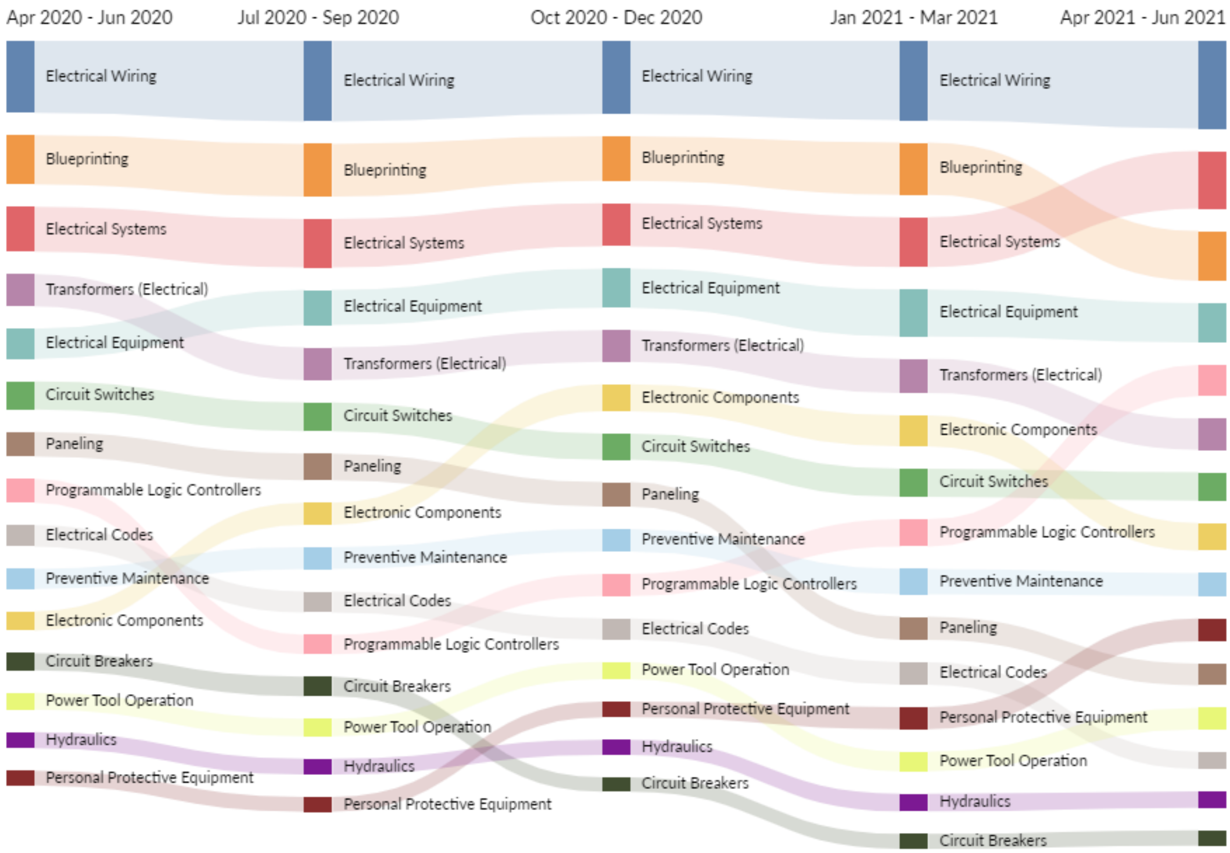
Skills help us understand how occupation is evolving. Workers can acquire the skills needed for electricians through a combination of on-the-job experience and formal training. Specialty certifications are attractive to recruiters in this field. Transportation-related certifications for electricians in the state include commercial driver's license (CDL), journeyman electrician, certified safety professional, certified novel engineer, and National Center for Construction Education and Research (NCCER) certification. Technical skills preferred for this occupation are electrical systems, electrical wiring, blueprinting, power tool operation, and electrical codes. At the same time, foundational skills also in demand include a valid driver's license, troubleshooting, communication, computer literacy, and a good driving record. Through analyzing in-demand skills and identifying what skills would be necessary for mobile robotics in transportation, we can assess that those emerging skills for this occupation analytical and scientific software, computer-aided design (CAD) software, database user interface and query software, enterprise resource planning (ERP) software, and industrial control software. The following list displays the top foundational and technical skills in this occupation and emerging skills. Figure 51 shows the top 15 skills for electricians by quarter.

TABLE 16: IN-DEMAND SKILLS FOR ELECTRICIANS

Top Technical Skills	Top Foundational Skills	Emerging Skills
Electrical Systems	Valid Driver's License	Analytical or scientific software
Electrical Wiring	Troubleshooting	Computer-aided design CAD software
Blueprinting	Communications	Database user interface and query software
Power Tool Operation	Computer Literacy	Enterprise Resource Planning (ERP) software
Electrical Codes	Good Driving Record	Industrial control software
Quality Control	Self-Motivation	Project management software
Transformers (Electrical)	Detail Oriented	
Electronic Components	Construction	
Paneling	Customer Service	
Personal Protective Equipment	Operations	

Data: Emsi | Analysis: Workforce Intelligence Network

FIGURE 51: TOP 15 SKILLS FOR ELECTRICIANS BY QUARTER



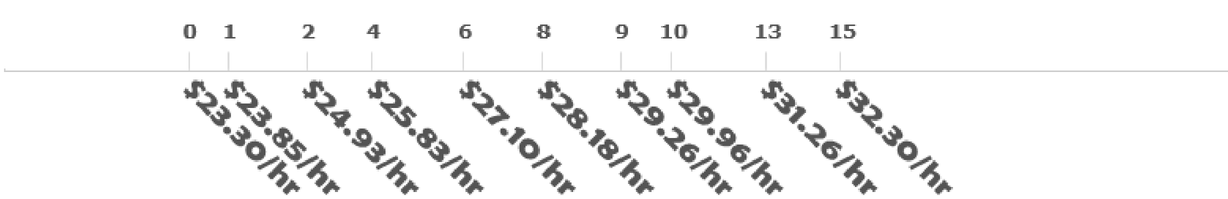
Data: Emsi | Analysis: Workforce Intelligence Network

Wage Analysis

TYPICAL COMPENSATION FOR THESE WORKERS IN MICHIGAN RANGES FROM USD16.39 TO USD43.36 AN HOUR. FIGURE 52 SHOWS THE MEDIAN HOURLY WAGES BY THE EXPERIENCE A WORKER HAS IN THE STATE. IT IS IMPORTANT TO NOTE THAT WAGES WILL RANGE ABOVE AND BELOW THE PLOTTED POINT. THE MEDIAN HOURLY SALARY IS USD29.64, WHICH IS 8.4 PERCENT HIGHER THAN THE NATIONAL MEDIAN.

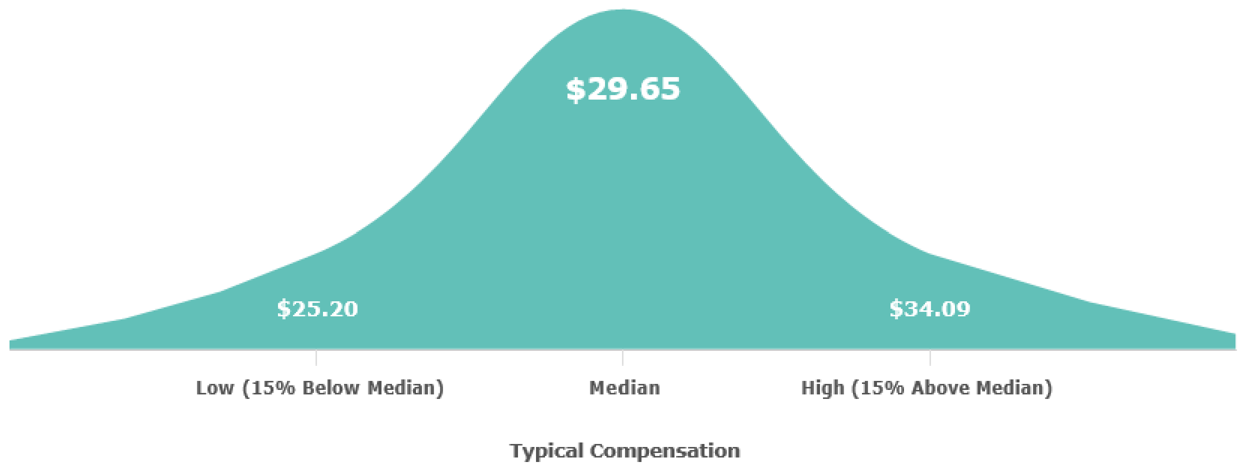
Figure 53 displays the typical median wages for electricians in Michigan.

FIGURE 52: COMPENSATION BY YEARS OF EXPERIENCE



Data: Emsi | Analysis: Workforce Intelligence Network

FIGURE 53: COMPENSATION WAGE SCALE



Data: Emsi | Analysis: Workforce Intelligence Network

Electrician Related Registered Apprenticeships

Most electricians learn through an apprenticeship program, but some start out by attending a technical school. Apprenticeships for electricians are entry pathways to the profession. However, given the technical nature of the occupation, most states require electricians to be licensed. In Michigan the electrician license programs have built-in stages of completion and experience before the license is awarded. Steps for occupational completion can include electrician apprentice, journeyman license, master electrician certification, and the final stage of a licensed electrical contractor. Since electricians within MDOT are in-demand occupations, investing in apprenticeships would attract entry-level workers to transportation careers due to the specialized training learned through on-the-job experience and formal education. Figure 54 and Figure 55 display two apprenticeship standards for electricians and maintenance electricians.

FIGURE 54: ELECTRICIAN APPRENTICESHIP STANDARD

Electrician

PUBLISHED

Time-Based Apprenticeship

SPONSORING COMPANY:
Power Design, Inc

Industries	
O*Net Code	47-2111.00
Rapids Code	0159
Req. Hours	28500
State	DC
Created	Jul 29, 2021
Updated	Jul 29, 2021

Time-Based Skills

17 skill sets | 59 total skills

Preliminary Work: Learn names and uses of equipment in the trade - 480 req. hrs	
Commodity electrical material	160 hrs
Quotable electrical material	160 hrs
HVAC and plumbing equipment	160 hrs
Preliminary Work: Learn Basic material handling skills - 1440 req. hrs	
Loading Trucks	480 hrs
Securing Loads	480 hrs
Safe Work Practices	480 hrs
Preliminary Work: Learn Proper Job Etiquette - 80 req. hrs	
Jobsite entry and exit	40 hrs

Data: RapidSkills Generator Apprenticeship Standard

FIGURE 55: MAINTENANCE ELECTRICIAN APPRENTICESHIP STANDARD

Electrician, Maintenance

PUBLISHED

Time-Based Apprenticeship

SPONSORING COMPANY:
General Dynamics Ordnance and Tactical Systems, Inc.

Industries	
O*Net Code	47-2111.00
Rapids Code	0643
Req. Hours	19900
State	DC
Created	Jul 29, 2021
Updated	Jul 29, 2021

Time-Based Skills

8 skill sets | 19 total skills

Electrical Measuring Instruments - 300 req. hrs	
	300 hrs
Transformers, storage masteries, etc. - 300 req. hrs	
	300 hrs
Electrical Wiring - 1500 req. hrs	
	1500 hrs
Rebuild and repair electrical equipment - 4800 req. hrs	
D.C. motors and generators	1200 hrs
A.C. motors	1200 hrs
Generators and rectifiers	1200 hrs
Solenoids	1200 hrs

Data: RapidSkills Generator Apprenticeship Standard

4.4.4 Highway Maintenance Workers (47-4051.00)

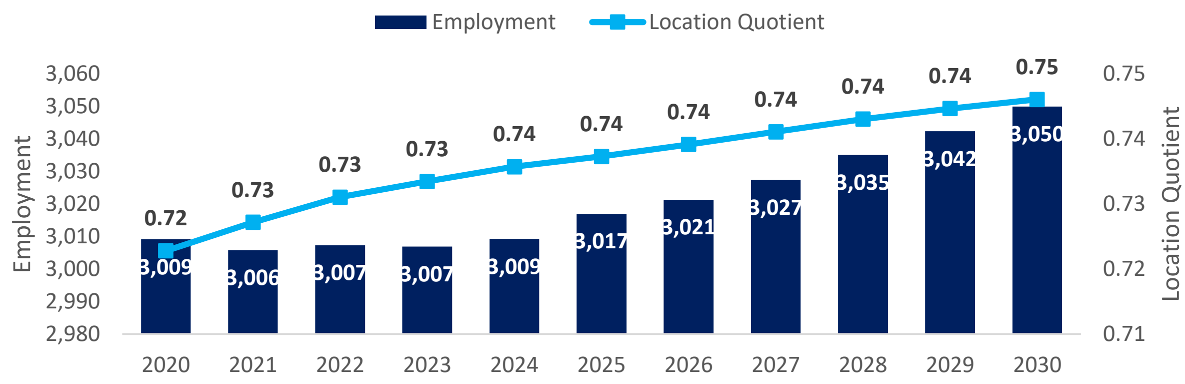
Highway maintenance workers typically maintain highways, municipal and rural roads, airport runways, and rights-of-way. Duties can include patching broken or eroded pavement and repairing guard rails, highway markers, and snow fences. Highway maintenance workers may also mow or clear brush from roadways or plow snow from the street. As demand for this occupation increases and evolves in the transportation industry, it will primarily align with the advanced traffic management systems focus area. This focus area leverages information and communications technology for active traffic control interventions. With workers deployed directly on the roadways, they immediately know traffic and congestion times, road conditions along routes, and traffic issues as they arise, among other observations. This occupation's top job titles include snowplow drivers, equipment operators, removal technicians, highway maintenance workers, and transportation maintenance specialists.

Workforce Insight

Highway maintenance workers are in the field, maintaining and observing roads and conditions. Since this occupation has experienced an increase in demand since the end of 2019, skills and duties are changing within the industry. In Michigan, employment for highway maintenance workers is expected to grow through 2030 gradually. In 2021, employment totaled 3,006 workers, a decrease of 3 workers or 0.1 percent since 2020. However, this is lower than the national average for this size area, which has 4,163 workers. The racial and gender diversity of the workforce is low in the state, with 84.0 percent of the workers identifying as white and 95.6 percent as male. Much of the workforce (63.7 percent) is between 25-54 years old, while 27.4 percent of the workers are aged 55 or older. Compared to the national average (849 workers) for an area this size, the retirement risk in Michigan is about average with 823 workers. The location quotient is expected to increase from 0.73 in 2021 to 0.75 in 2030. While the increase in highway maintenance workers in the region benefits talent attraction to MDOT, the concentration of workers is lower than the nation, indicating a smaller talent pool of workers and making it more difficult to find candidates. The automation index for highway maintenance workers is 121.6, which indicates this occupation has a higher-than-average risk of becoming automated[10]. This is likely due to most observation duties utilizing advanced technologies (i.e. drones that can cover aerial views of areas more efficiently). Figure 56 shows the relation between employment and the location quotient.

[10] An automation index greater than 100 indicates a higher-than-average risk of automation; an automation index less than 100 indicates a lower-than-average risk of automation.

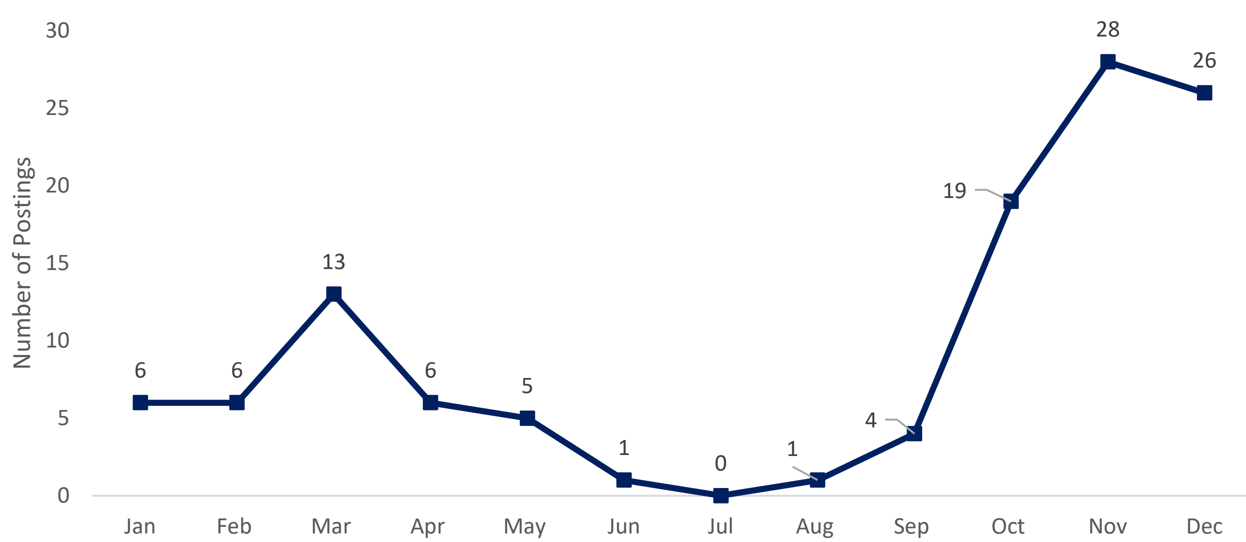
FIGURE 56: EMPLOYMENT COMPARED TO THE LOCATION QUOTIENT, 2020-2030



Data: Emsi | Analysis: Workforce Intelligence Network

Another method of analyzing regional demand concentration is considering the volume of postings for highway maintenance worker occupations. In 2019, there were 240 online job postings for highway maintenance worker occupations in Michigan. Of those, 68 postings were explicitly requested for transportation-related duties. Figure 57 displays the 2019 monthly postings for highway maintenance workers.

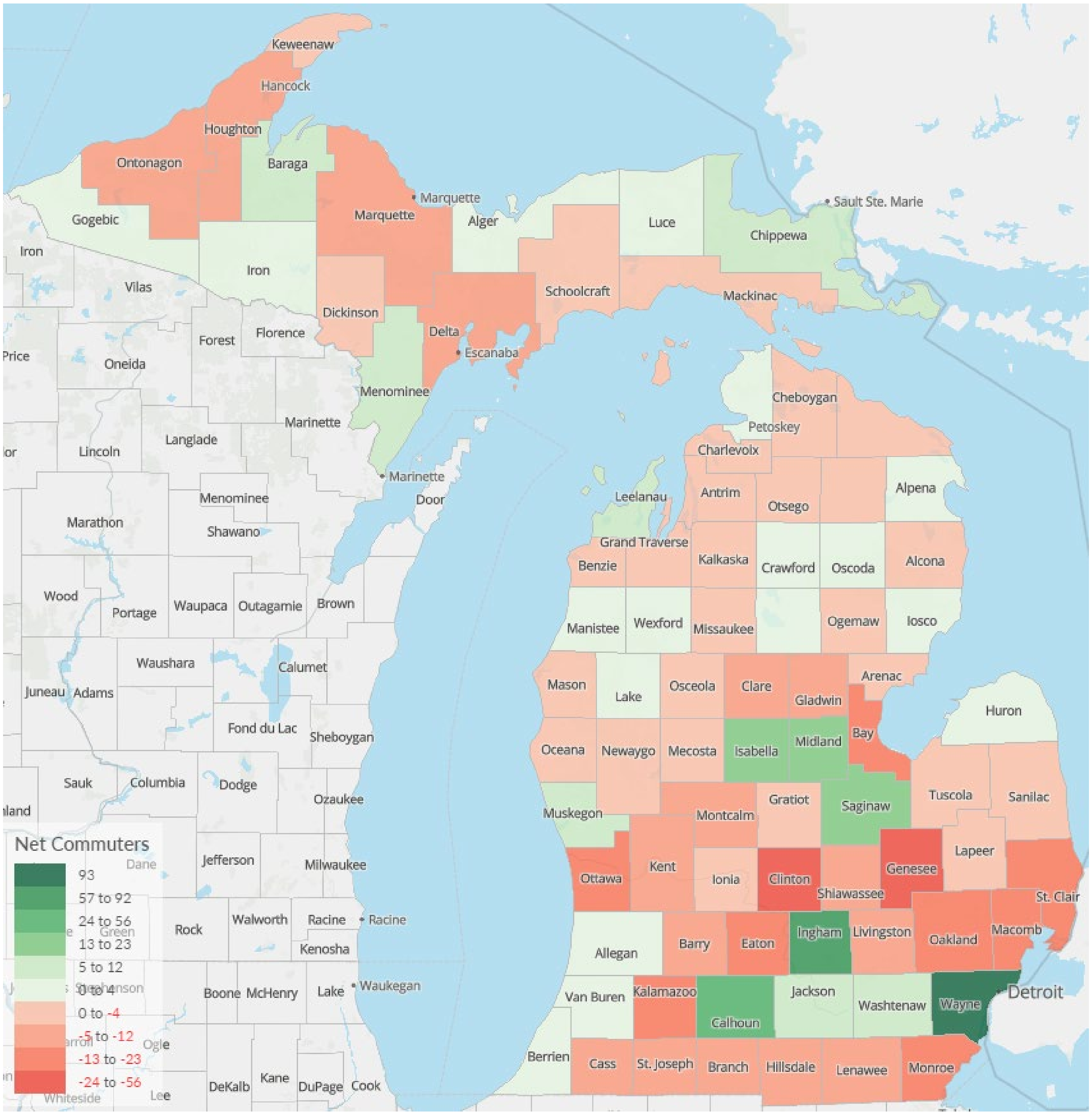
FIGURE 57: TRANSPORTATION-RELATED MONTHLY POSTINGS, 2019



Data: Emsi | Analysis: Workforce Intelligence Network

The counties employing the most highway maintenance workers in the state include Wayne, Oakland, Ingham, Macomb, and Calhoun. Similarly, most workers in the state are employed and reside in Wayne, Oakland, Ingham, Macomb, Calhoun, and Kent counties. The volume of net commuters for this occupation is shown in Figure 58.

FIGURE 58: MICHIGAN'S NET COMMUTERS BY COUNTY FOR HIGHWAY MAINTENANCE WORKERS



Data: Emsi | Analysis: Workforce Intelligence Network

Training Programs and Institutions

Educational providers have been working to determine what skills and credentials are needed for specialized occupational duties. There are many institutions able to meet the demand for highway maintenance worker training in Michigan. In 2019, Lansing Community College offered a program for workers to acquire the skills needed through a combination of on-the-job experience and formal training. Since highway maintenance workers is an entry-level occupation to transportation careers, most program awards of less than one academic year are typically required. Table 17 shows the completions for all related programs offered.

TABLE 17: PROGRAMS AVAILABLE AND COMPLETIONS, 2019

CIP Code	Program	2019 Completions
49.0202	Construction/Heavy Equipment/Earthmoving Equipment Operation	No Completions Reported

Data: Emsi | Analysis: Workforce Intelligence Network

Desired Skills

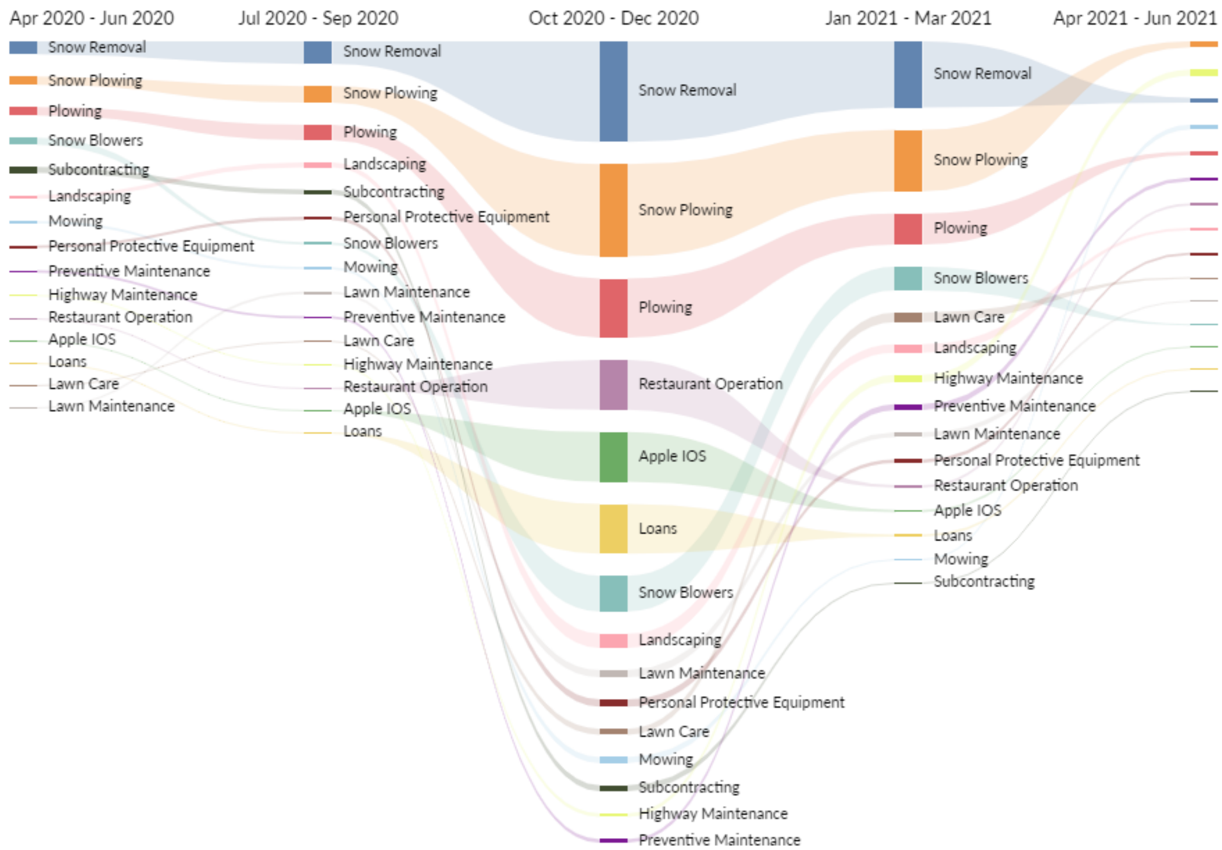
Skills help us understand the dynamic direction of an occupation. Workers can acquire the skills needed for highway maintenance workers through a combination of on-the-job experience and formal training. Specialty certifications are attractive to recruiters in this field. Transportation-related certifications for highway maintenance workers in the state include a commercial driver's license (CDL), pesticide applicator license, professional engineer, and tanker endorsement. Technical skills preferred for this occupation are snow removal, snow plowing, snow blowers, spooling, and plowing. At the same time, foundational skills also in demand include communications, valid driver's license, good driving record, operations, and construction. Through analyzing in-demand skills and identifying what skills would be necessary for advanced traffic management systems in transportation, we can assess that an emerging skill for this occupation database user interface and query software. The following list displays the top foundational and technical skills in this occupation and emerging skills. Figure 59 shows the top 15 skills for highway maintenance workers by quarter.

TABLE 18: IN-DEMAND SKILLS FOR HIGHWAY MAINTENANCE WORKERS

Top Technical Skills	Top Foundational Skills	Emerging Skills
Snow Removal	Communications	Database user interface and query software
Snow Plowing	Valid Driver's License	
Snow Blowers	Good Driving Record	
Spooling	Operations	
Plowing	Construction	
Highway Maintenance	Detail Oriented	
Physical Tests	Loading And Unloading	
Traffic Control	Scheduling	
Heavy Equipment	Management	
Erosions	Physical Stamina	

Data: Emsi | Analysis: Workforce Intelligence Network

FIGURE 59: TOP 15 SKILLS FOR HIGHWAY MAINTENANCE WORKERS BY QUARTER

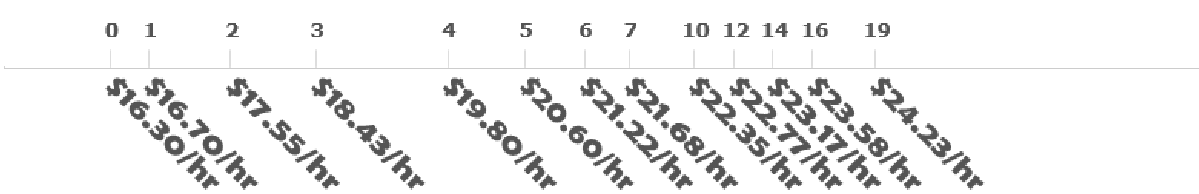


Data: Emsi | Analysis: Workforce Intelligence Network

Wage Analysis

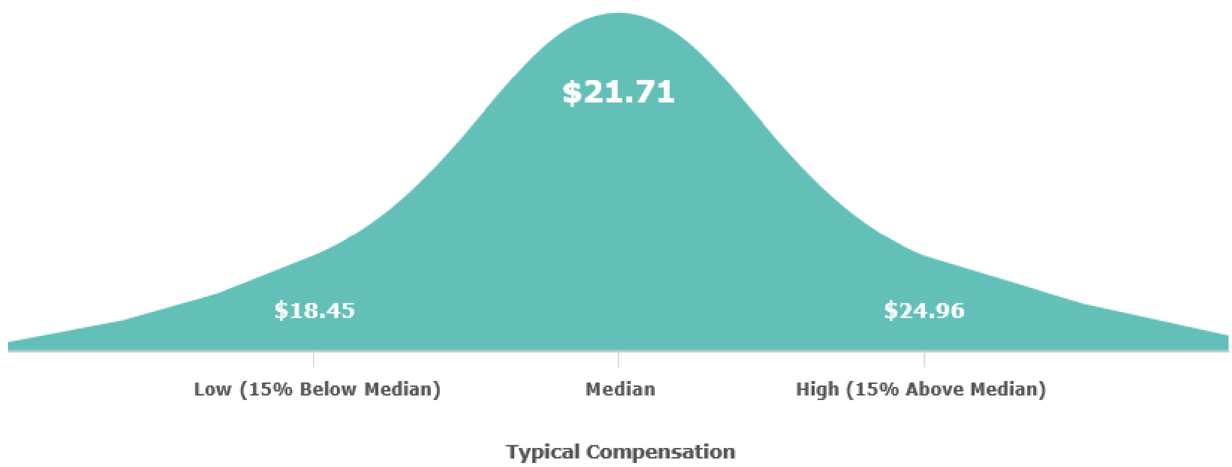
Typical compensation for these workers in Michigan ranges from USD15.20 to USD28.23 an hour. Figure 60 shows the median hourly wages by the experience a worker has in the state. It is important to note that wages will range above and below the plotted point. The median hourly salary is USD21.83, which is 8.4 percent higher than the national median. Figure 61 displays the typical median wages for civil engineers in Michigan.

FIGURE 60: COMPENSATION BY YEARS OF EXPERIENCE



Data: Emsi | Analysis: Workforce Intelligence Network

FIGURE 61: COMPENSATION WAGE SCALE



Data: Emsi | Analysis: Workforce Intelligence Network

Highway Maintenance Workers Related Registered Apprenticeships

Since highway maintenance workers are entry-level occupations requiring moderate-term on-the-job training, there are no apprenticeships.

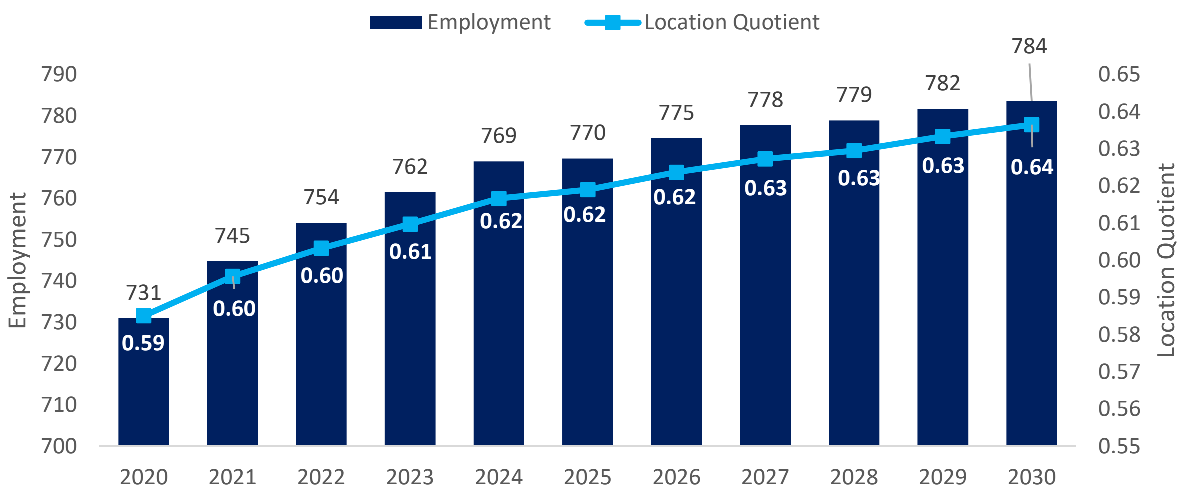
4.4.5 Surveyors (17-1022.00)

Surveyors are generally responsible for making exact measurements and determine property boundaries. They also provide data relevant to the shape, contour, gravitation, location, elevation, or dimension of land or land features on or near the earth's surface for engineering, mapmaking, mining, land evaluation, construction, and other purposes. As this occupation evolves in the transportation industry, it will best align with the complete streets design and context-sensitive solutions focus area. This focus area determines road design elements, realizing that roads are no longer about auto-mobility but creating an overall network that serves all users. This occupation's top job titles include site surveyors, registered professional land surveyors, land surveyors, and licensed land surveyors.

Workforce Insight

Surveyors are essential to the transportation infrastructure because they verify the accuracy of survey data. In Michigan, employment for surveyors is expected to grow through 2030 gradually. In 2021, employment for 745 workers, an increase of 14 workers or 1.9 percent since 2020, is lower than the national average for an area this size, which has 1,249 workers. The racial and gender diversity of the workforce is low in the state, with 92.1 percent of the workers identifying as white and 84.1 percent as male. Much of the workforce (70.1 percent) is between 25-54 years old, while 22.5 percent of the workers are aged 55 or older. Compared to the national average (178 workers) for an area this size, the retirement risk in Michigan is about average with 165 workers. The location quotient is expected to increase from 0.60 in 2021 to 0.64 in 2030. While the increase in civil engineering technologists and technicians in the region benefits talent attraction to MDOT, the concentration of workers is lower than the nation, indicating a smaller talent pool of workers, making it more difficult to find candidates. The automation index for surveyors is 95.8, which indicates this occupation has a lower-than-average risk of becoming automated[11]. However, this occupation is close to having a higher-than-average chance of becoming automated. Figure 62 shows the relation between employment and the location quotient.

FIGURE 62: EMPLOYMENT COMPARED TO THE LOCATION QUOTIENT, 2020-2030

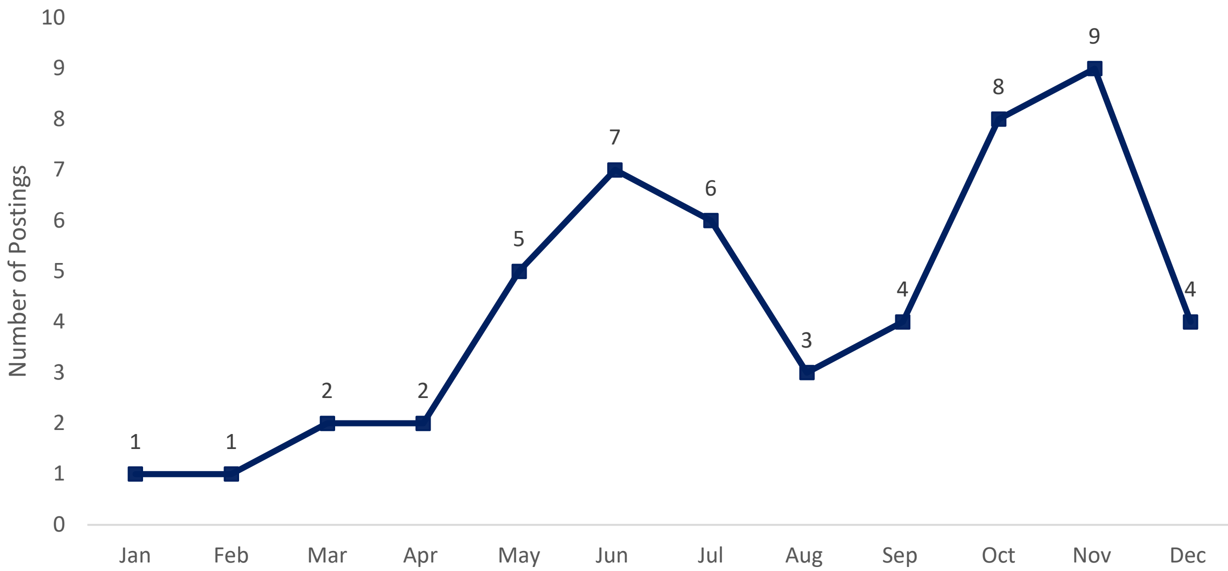


Data: Emsi | Analysis: Workforce Intelligence Network

Another method of analyzing regional demand concentration is to consider the volume of postings for surveyor occupations. In 2019, there were 514 online job postings for surveyor occupations in Michigan. Of those, 28 postings were explicitly requested for transportation-related duties. Figure 63 displays the 2019 monthly postings for surveyors.

[11] An automation index greater than 100 indicates a higher-than-average risk of automation; an automation index less than 100 indicates a lower-than-average risk of automation.

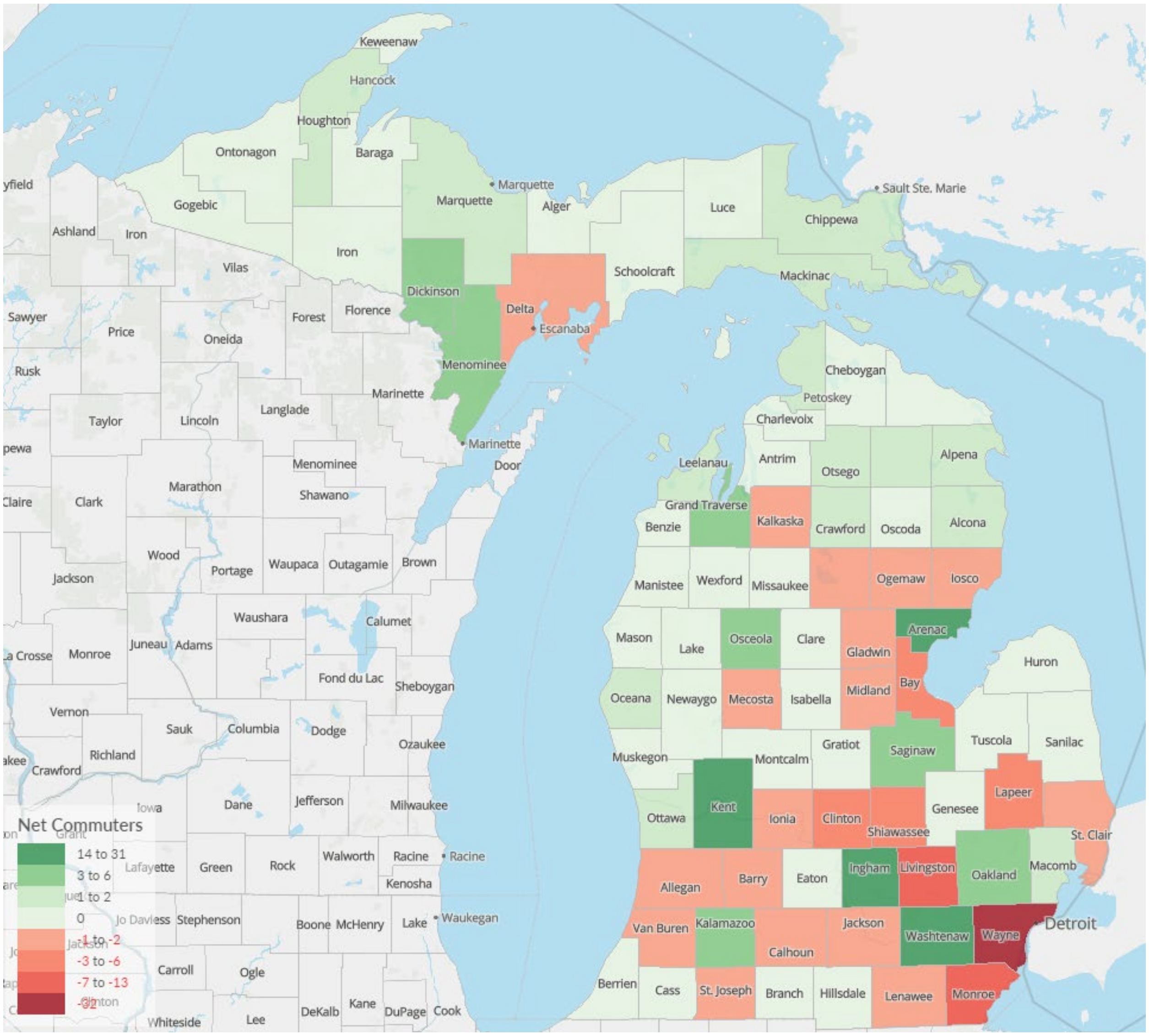
FIGURE 63: TRANSPORTATION-RELATED MONTHLY POSTINGS, 2019



Data: Emsi | Analysis: Workforce Intelligence Network

The counties employing the most surveyors include Oakland, Macomb, Washtenaw, Kent, and Wayne. Similarly, most workers in the state are employed and reside in Oakland, Macomb, Washtenaw, Kent, and Wayne counties. The volume of net commuters for this occupation is shown in Figure 64.

Figure 64: Michigan's Net Commuters by County for Surveyors



Data: Emsi | Analysis: Workforce Intelligence Network

Training Programs and Institutions

Educational providers have been working to determine what skills and credentials are needed for specialized occupational duties. There are many institutions able to meet the demand for surveyor training in Michigan. Four specific training programs are available, resulting in 258 completions for surveyor occupations, between 23 institutions throughout Michigan. Workers can acquire the skills needed through a combination of on-the-job experience and formal training. The institutions that had the most completions in 2019 for surveyor related programs were the University of Michigan-Ann Arbor (43 completions), Ferris State University (33 completions), Michigan Technological University (14 completions), Lansing Community College (9 completions), and Macomb Community College (2 completions). Table 19 shows the completions for all related programs offered.

TABLE 19: PROGRAMS AVAILABLE AND COMPLETIONS, 2019

CIP Code	Program	2019 Completions
40.0601	Geology/Earth Science, General	198
15.0201	Civil Engineering Technology/Technician	33
14.3801	Surveying Engineering	16
15.1102	Surveying Technology/Surveying	11

Data: Emsi | Analysis: Workforce Intelligence Network

Of the four programs offered, only surveying technology/surveying programs offer certificate awards of less than one academic year, the lowest degree level provided for this occupation. An associate degree can take up to two years to complete, indicating that these programs are entry pathways to more specialized training programs. Table 20 displays programs and the degree levels offered.

TABLE 20: SURVEYOR RELATED-PROGRAMS TITLES/CIP CODES AND THE DEGREE LEVEL OFFERED, 2019

	Award of less than 1 academic year	Award of at least 1 but less than 2 academic years	Associate's Degree	Bachelor's Degree	Master's Degree	Doctoral Degree
Geology/Earth Science, General	No Completions Reported	No Completions Reported	No Completions Reported	X	X	X
Civil Engineering Technology/Technician	X	No Completions Reported	X	No Completions Reported	No Completions Reported	No Completions Reported
Surveying Engineering	No Completions Reported	No Completions Reported	No Completions Reported	X	No Completions Reported	No Completions Reported
Surveying Technology/Surveying	No Completions Reported	X	X	No Completions Reported	No Completions Reported	No Completions Reported

*Program titles may vary by institution

Data: Emsi | Analysis: Workforce Intelligence Network

Desired Skills

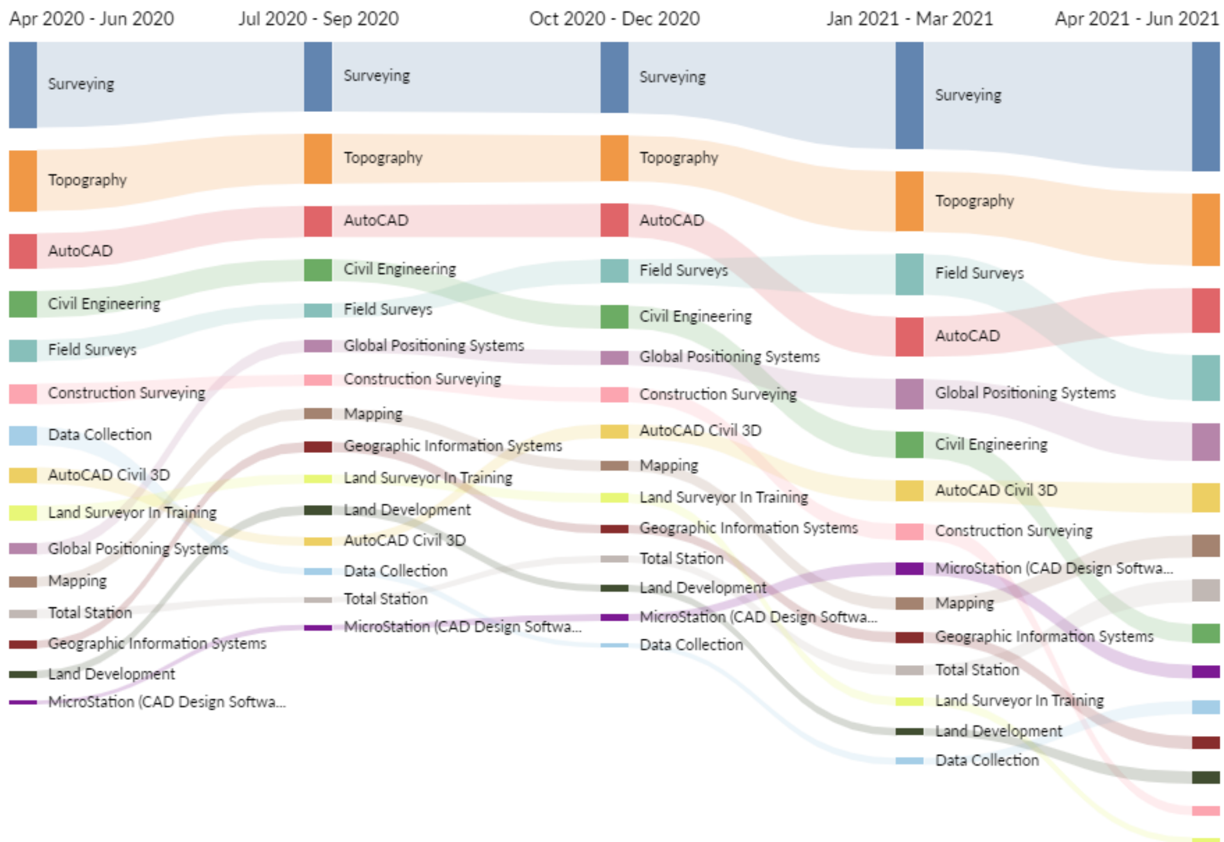
Skills help us understand the trajectory of an occupation. Workers can acquire the skills needed for surveyors through a combination of on-the-job experience and formal training. Technical skills preferred for this occupation are surveying, auditing, data collection, facility management, and topography, while foundational skills also in demand include smartphone operation, communications, Microsoft word, management, and mentorship. By analyzing in-demand skills and identifying skills necessary for data analytics in transportation, the emerging skills for this occupation are analytical and scientific software, application server software, computer-aided design (CAD) software, database user interface and query software, and data conversion software. The following list displays the top foundational and technical skills in this occupation and emerging skills. Figure 65 shows the top 15 skills for surveyors by quarter.

TABLE 21: IN-DEMAND SKILLS FOR SURVEYORS

Top Technical Skills	Top Foundational Skills	Emerging Skills
Surveying	Smartphone Operation	Analytical or scientific software
Auditing	Communications	Application server software
Data Collection	Microsoft Word	Computer-aided design CAD software
Facility Management	Management	Database user interface and query software
Google Play	Mentorship	Data conversion software
Topography	Real Estate	Document management software
Computer-Aided Design	Organizational Skills	Graphics or photo imaging software
Construction Surveying	Valid Driver's License	Information retrieval or search software
Civil Engineering	Planning	Map creation software
Mapping	Motivational Skills	

Data: Emsi | Analysis: Workforce Intelligence Network

FIGURE 65: TOP 15 SKILLS FOR SURVEYORS BY QUARTER

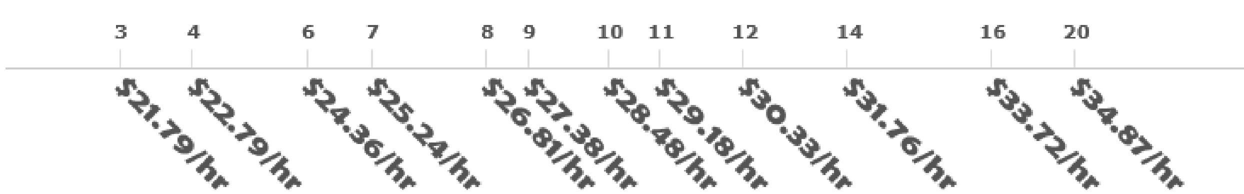


Data: Emsi | Analysis: Workforce Intelligence Network

Wage Analysis

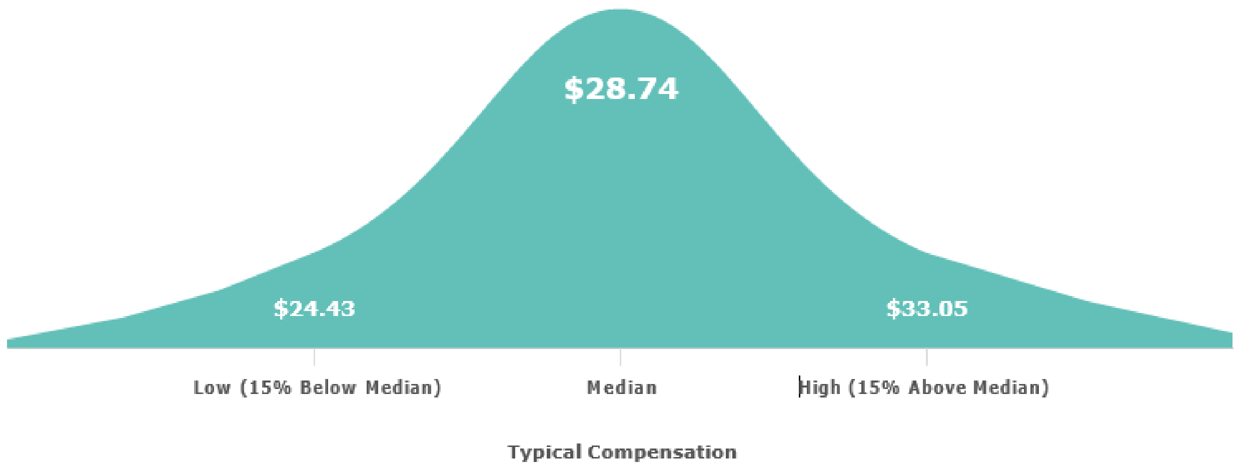
Typical compensation for these workers in Michigan ranges from USD19.84 to USD44.24 an hour. Figure 66 shows the median hourly wages by the experience a worker has in the state. It is important to note that wages will range above and below the plotted point. The median hourly salary is USD28.71, which is 8.9 percent lower than the national median. Figure 67 displays the typical median wages for civil engineers in Michigan.

FIGURE 66: COMPENSATION BY YEARS OF EXPERIENCE



Data: Emsi | Analysis: Workforce Intelligence Network

FIGURE 67: COMPENSATION WAGE SCALE



Data: Emsi | Analysis: Workforce Intelligence Network

Surveyor Related Registered Apprenticeships

Apprenticeships for civil engineering technologists and technicians are entry pathways to civil engineering and enable employers to train apprentices for the needs of their department. Since civil engineering technologists and technicians within MDOT are relatively emerging as an in-demand occupation, investing in apprenticeships would attract entry-level workers to transportation careers due to the specialized training learned through on-the-job experience and formal education. Figure 68 displays the surveyor assistant instrument apprenticeship standard.

FIGURE 68: SURVEY ASSISTANT INSTRUMENT APPRENTICESHIP STANDARD

Surveyor Assistant Instrument

PUBLISHED

Time-Based Apprenticeship

SPONSORING COMPANY:
International Union of Operating Engineers

Industries	
O*Net Code	17-3031.00
Rapids Code	0551
Req. Hours	3298
State	DC
Created	Jul 16, 2021
Updated	Jul 16, 2021

Time-Based Skills

7 skill sets | 7 total skills

Use and care for hand tools (other than survey equipment) - 340 req. hrs
Use and care for survey hand tools - 500 req. hrs
Use and care for rods, chains and related equipment - 1000 req. hrs
Hand signals, land surveying terms and definitions - 100 req. hrs
Marker Stakes - 350 req. hrs
Bench marks and turning points - 1000 req. hrs
First Aid - 8 req. hrs

Data: RapidSkills Generator Apprenticeship Standard

4.5 Current Training Landscape

MDOT currently provides workforce training through virtual and in-person classes offered through partnering institutions and training providers, in addition to soft recruitment through MDOT classes offered at the middle and high school levels. MDOT also provides current employees with training needed for upskilling incumbent workers based on needs and offers new occupation pathways for employees interested in upskilling to new positions. The resources that are currently available for employees and future talent are identified below.

4.5.1 MDOT Training Website: Virtual and In-Person Training

MDOT currently offers two main programs geared toward high school students and recent high school graduates, a Youth Development and Mentoring Program (YDMP) and Transportation and Civil Engineering program (TRAC). Both programs invite students to participate in hands-on educational programs designed to integrate science, math, and social science classes, providing MDOT exposure opportunities to transportation careers. Exposure opportunities include mentoring activities and sessions to teach job and life skills, introduce college/university options, and present information about careers in civil engineering, road construction and maintenance, planning, and other areas of transportation.

MDOT also has internship programs aimed at undergraduate, graduate students, and veterans to gain experience, develop professional competence and long-range career goals, integrate work experiences with academic knowledge, and establish a professional network. It is important to note that veteran internship information is not online accessible, as it has a password-protected website link. The other training programs offered include a construction on-the-job training program and technical training courses. MDOT specific technical training courses offered both online and virtually include:

- Bridge Construction/Rehabilitation Inspection & Bridge Paint
- Computerized Office Technician (Field Manager Training highly recommended before this course)
- Computerized Office Technician Exam-Recertification (Recertification Exam Only- No Review)
- Concrete Paving
- Density Certification Training (FSU)
- Drilled Shaft Inspectors Training
- Field Manager Training
- Hot Mix Asphalt Paving Operations
- Hot Mix Asphalt Paving Operations-Recertification
- MDOT Certification Training for Superpave Asphalt Mix Design
- Prevailing Wage Training
- Structural Steel Bolting Workshop
- Structural Steel Welding Workshop

4.5.2 Educational Support for Current MDOT Employees

Currently, MDOT offers unpaid time off for current employees interested in professional development, re-skilling, and upskilling. The lack of an employee assistance program hinders the ability of MDOT, and employees, to fill the jobs gaps needed for operation. It also limits employee growth, creating high turnover for the department.

4.5.3 Existing Institutional Partnerships

MDOT has pre-existing relationships with institutions that provide training aligned precisely for roles within MDOT. Current institutions offering specific training include the American Council of Engineering Companies of Michigan, Center for Technology and Training, Ferris State University, Lawrence Technological University, Michigan Association of Planning, and the Michigan Public Transit Administration.

4.5.4 MDOT Benefits of Registered Apprenticeships

Investing in talent provides employees with the stability and advancement opportunities needed to reduce turnover. Registered apprenticeships are an excellent option for MDOT to invest in training a highly skilled workforce. Apprenticeships use industry-driven talent development strategies, combining on-the-job experience with formal classroom learning. This combination provides a more reasonable manner within the MDOT structure for apprentices to gain specific skills and fill the gap between entry-level and more technical positions. Apprenticeships offer the unemployed, underemployed, and high school graduates the opportunity to hire into an organization at approximately 40 percent of a marketable wage and obtain in-demand occupational skills employers need to meet productivity demands while receiving post-secondary education or related technical instruction. Registered apprenticeships are collaboratively developed and deployed through partnerships between employers, training and education providers, and the U.S. Department of Labor (DOL). The U.S. DOL registers the programs to ensure they are high-quality and high value for apprentices and employers. MI-Apprenticeship is a DOL grant-funded state program managed by WIN and its partners to connect Michigan employers to resources for streamlining the apprenticeship process. The benefits of registered apprenticeships to employers, as stated by MI-Apprenticeship, include:

- Developing a highly skilled workforce
- Reducing turnover and fostering loyalty among employees
- Creating customized, flexible training solutions to meet employer needs
- Building a sustainable, long-term talent pipeline
- Consideration for funding opportunities tied to apprenticeship
- Developing a world-class workforce, enhancing industry’s bottom line, and building for the future
- Succession planning, achieved by aging workers mentoring new talent on internal processes and current occupational skills needs

A significant challenge for creating job pathways through formal job training programs like apprenticeship is that companies and their training partners can find it challenging to identify, articulate, and update the skills and competencies required for a given job or occupation. It is challenging to identify reliable information sources for fast-changing sectors and fields. It is also difficult to effectively link training to the higher education pathways that many workers, especially younger workers, are seeking. Registered apprenticeships have grown from traditional time-based programs, expanding to include two additional types: competency-based and hybrid apprenticeships. These apprenticeship options promote flexibility for both MDOT, future talent, and current employees. WIN manages two apprenticeship websites for employers and industry professionals to consistently provide additional information on apprenticeships as they continue to build their programs. The MI-Apprenticeship website is a grant-funded government program created to encourage and support apprenticeships as an emerging workforce solution. MI-Apprenticeship works with employers to develop, implement, and optimize an apprenticeship program that meets vacancy needs (Department of Labor, 2021). The RapidSkills Generator website is an open-source, online repository of time-based, competency-based, and hybrid occupational frameworks for registered apprenticeship programs. RapidSkills Generator will help the workforce, employer, and educational professionals build robust apprenticeship programs by drawing from a wide variety of sample skills outlines. Occupational frameworks can be customed to create functional work process schedules and related instruction plans for apprenticeship programs (Rapid Skills Generator - How it Works, 2021). The defined types of registered programs are as follows

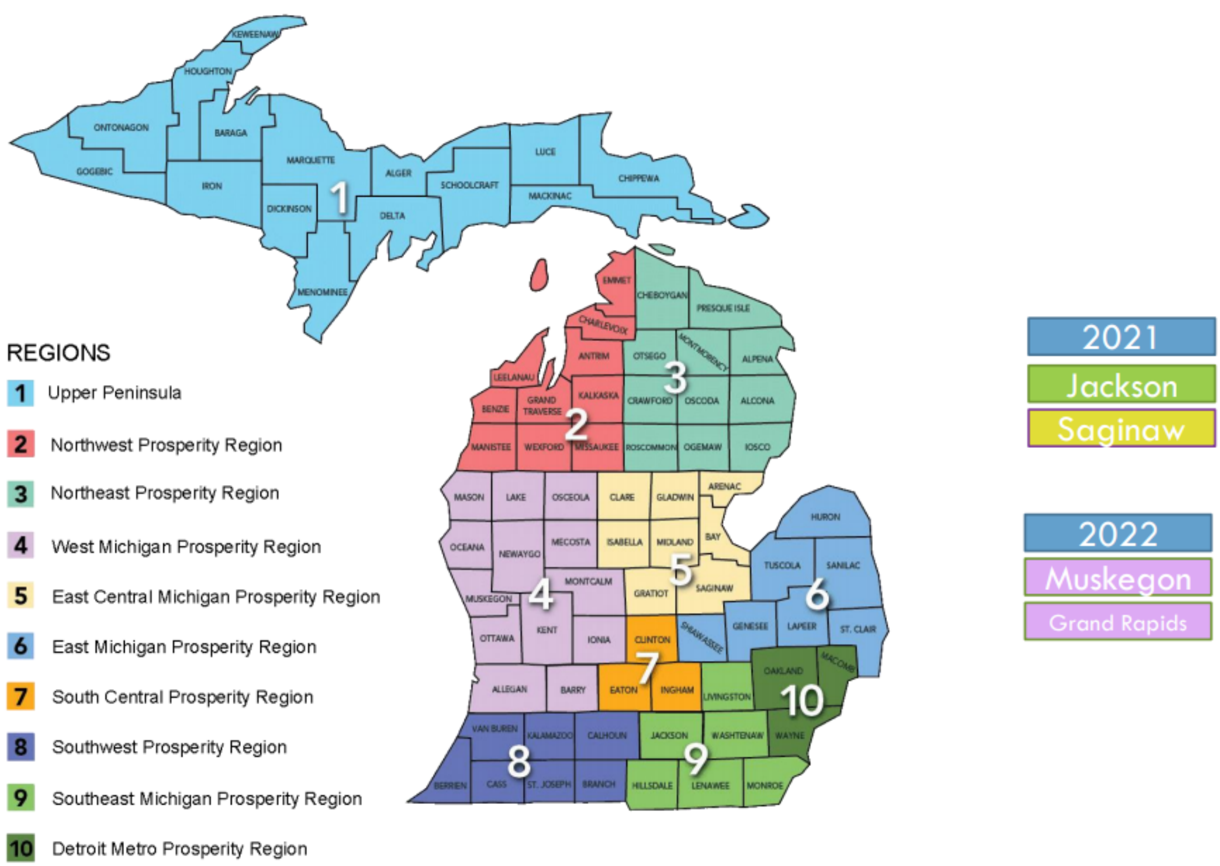
- **Competency-Based Apprenticeships –** Competency-based apprentices learn and progress through training by mastering and performing specific skills and competencies needed for both the individual and the job. Workers advance at their own pace, and employers can monitor progress and reward individual initiative efficiently.
- **Time-Based Apprenticeships –** Time-based apprentices have a more structured approach, measured by the number of hours spent on specific on-the-job tasks.
- **Hybrid Apprenticeships –** Hybrid apprenticeship gives employers flexibility in establishing registered apprenticeships, with the option to reduce the time required to complete an apprenticeship program significantly. A hybrid apprentice's progress is measured by combining hours spent in the program and competencies demonstrated in the workplace.

The *New Geography of Skills: Regional Skills Shapes for the New Learning Ecosystem* report addresses the challenge imposed by the diffusion of technology in the acceleration of change in the labor market and the imperative for workers to adapt, maintain, and advance their skills. "Real-time labor market information, such as job postings and professional profiles, is being combined with cutting-edge analytical methods to provide a unique lens we call "skill shapes." A skill shape refers to the unique skill demands of a given career field, region, or individual. A skill shape goes beyond traditional labor market data from government surveys to understand regional workforce needs. With taxonomies of industries and occupations updated only once or twice per decade, skills gaps have often been identified at a broad occupation or industry level, such as a nursing shortage. Today, however, sources of "big," unstructured data—such as job postings and online professional profiles—can be updated as frequently as every few weeks to isolate actionable, real-time data. Skill shapes provide a new lens into the job market and the unique skill demands of a career field, region, or individual worker. By looking underneath occupations and industries, we can precisely understand the skills employers are looking for and how they compare to the supply of skills in the regional workforce. Ultimately, a better understanding of skill shapes empowers stakeholders to design "precision education"—learning personalized programs aligned with regional workforce demands, and efficiently designed to help learners keep pace with rapidly evolving skill demands. This report, therefore, delves into a concrete means by which state, city, and regional leaders can identify local skills gaps and deploy workforce dollars with precision through just-in-time training programs (Weise, Hanson, & Saleh, 2019)."

4.5.5 Existing Apprenticeship Program: Access for All

MDOT is an active partner in the Access for All (AFA) program. The Access for All Apprenticeship Readiness Training Program was developed to create career opportunities in the building trades for underserved job seekers in Detroit. The program has been successfully replicated in Kalamazoo and Battle Creek. AFA helps create a sustainable pipeline of talent for the construction industry, knowing that many of the journey workers are projected to retire over the next 5 to 10 years, thereby creating a demand for skilled workers. AFA targets underserved populations, i.e., minorities, females, veterans, and youth. The program was developed in partnership with the building trades and aligned with the entrance requirements for DOL registered apprenticeships. Figure 69 displays the access for all expansion for 2021-2022.

FIGURE 69: ACCESS FOR ALL 2021-2022 EXPANSION



Data: Access for All

AFA applicants are subjected to a recruitment process including application, orientation, assessment, and interview before acceptance to the program. Accepted participants then participate in 300 hours of classroom training and 24-32 hours of work experience. The goal is placement either into a registered apprenticeship program or direct employment. Graduates seeking apprenticeships are employed in fields including operating engineers, cement masons, and electricians—all occupations high on the list for future MDOT recruitment as identified by survey responses. Industry-related employment is relatively high at 76 percent, with many participants entering the road maintenance field with employers such as Dan's Excavating and Ajax Pavement. AFA successfully serves a highly diverse developing workforce and can also be a source of diversity recruitment for MDOT. Figure 70 displays the 2020 program statistics.

FIGURE 70: ACCESS FOR ALL 2020 NUMBERS

Categories	Totals	Percentages
Enrolled	352	
Completed	274	78%
Employed	223	81%
Industry Related Employment	169	76%
Apprenticeships	153	56%
Average Wage at Placement	$17.46	

Data: Access for All

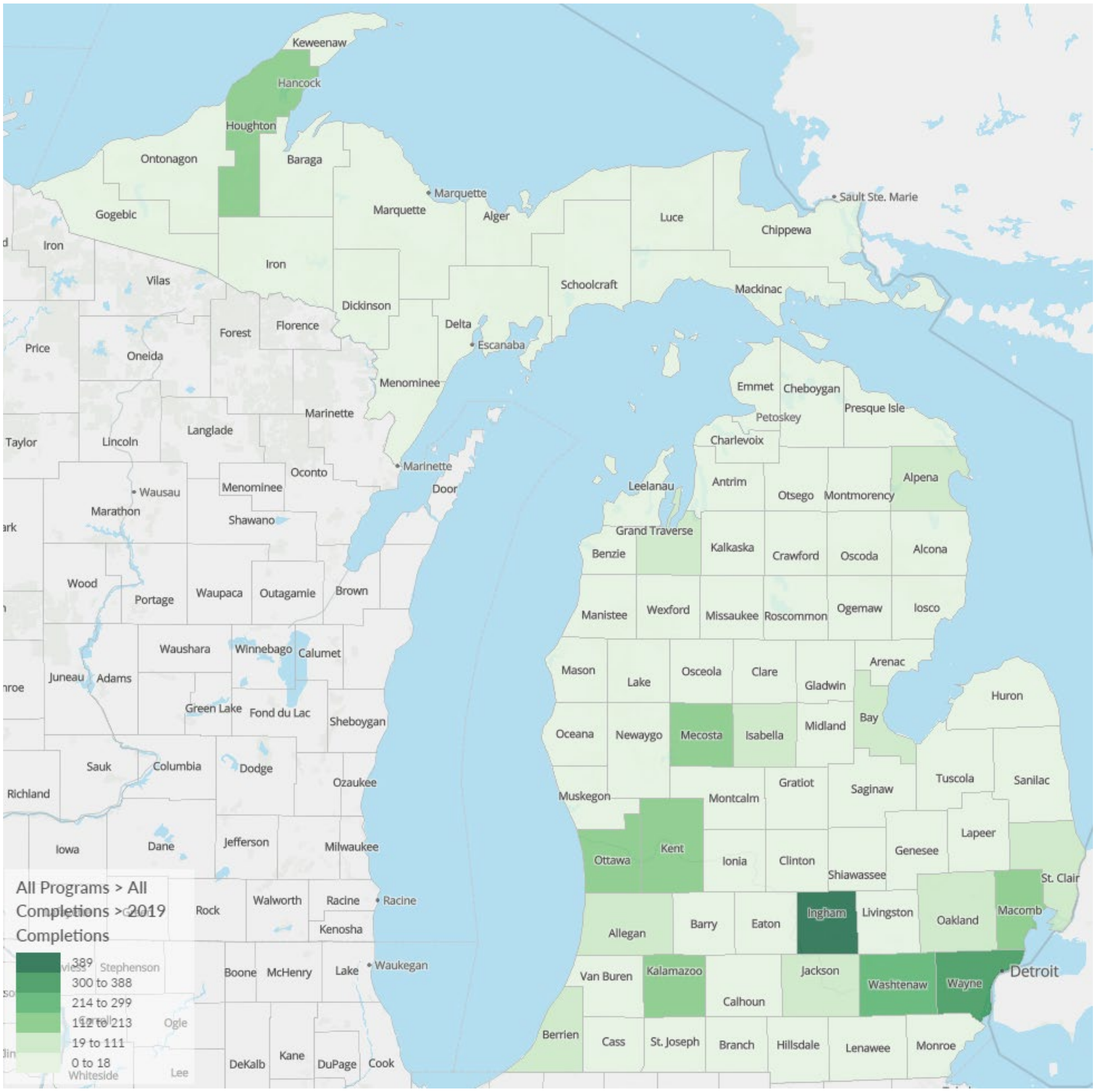
4.6 Gap Analysis

Identifying the educational gaps between MDOT and talent is important to maintain the department's daily operations. For the five occupations identified, many institutions are offering MDOT related programs in addition to direct partners currently offering training opportunities. MDOT offers classes and internships for students interested in transportation careers. However, the possibility for apprenticeships and work-and-learn opportunities within the department does not currently exist. Creating an educational curriculum specified for MDOT occupations benefits the department by bridging the talent needs and skills needed for the changing technological advancements. It also can provide employment and hands-on experiences for students, fostering a positive relationship for future jobs.

4.6.1 Potential Partnering Institutions

While MDOT maintains pre-existing training partnerships, identifying other institutions provides a regional training network to aid in regional recruitment. Programs housed in more institutions around the state remove the location barrier of where classes are offered and enable more candidates to attend. Nearly 66 institutions in the state provide transportation-related curriculum. The institutions with the most completions for transportation-related courses include Calvin University, Ferris State University, Lansing Community College, Lawrence Technological University, Macomb Community College, Michigan Technological University, and Michigan State University. Many survey responses also identified these institutions for programs related to the transportation industry. Institutions in Ingham and Wayne counties provided the most completions in 2019, ranging from 300-389 students. Based on the map in Figure 71, the upper peninsula and northern Michigan all have fewer institutions with completions for transportation-related programs. The upper north portion of the thumb also has limited related programs. In the areas identified, the location of these institutions may hinder a candidate's ability to commute daily. Building relationships in these areas may prove helpful to recruitment.

Figure 71: Counties of Institutions with the Most Completions



Data: Emsi | Analysis: Workforce Intelligence Network

4.6.2 Existing Training Partners

As previously mentioned, MDOT already maintains partnerships with training institutions throughout the state. These programs are for both entry-level workers and current employees. The American Council of Engineering Companies of Michigan, Center for Technology and Training, Ferris State University, Lawrence Technological University, Michigan Association of Planning, and the Michigan Public Transit Administration have been identified as providing MDOT specific training. Most class times are offered during the daytime, which deters current employees unable to take off. While MDOT does provide time off for class completion, it is usually unpaid. Offering late afternoon and evening class options is essential to bolstering employee enrollment. In turn, employees would aid in job shortages, gaining the ability to shift current duties to cover skill gaps needed for vacancies and to maneuver into new roles given the new skills learned through classroom training and hands-on experiences.

4.6.3 Certificates and Degrees Offered

There are many certificates and degrees offered for transportation-related programs around the state. Certificate levels offered range from minimum time requirements of awards less than one year, at least one year, and less than four years. There are also several four or more-year related degrees. These programs provide an excellent opportunity to fill the gap in experience by creating related apprenticeships needed for promotional job pathways, which typically require more than two years of experience. Michigan has substantial completion numbers for most program degrees, such as a bachelor's degree, associate degree, and master's degree. In contrast, awards of less than one academic year and doctoral degrees have lower completions. Based on the institution providing classes, i.e., community college, university, training partner, counties can specialize in certificates and degrees offered. For example, Wayne County has a high number of completions for associate degrees, while Washtenaw has high completions with masters and doctoral degrees. Ingham, Kalamazoo, and Wayne counties' institutions provide the most degree option types in the state. Figure 72 shows the community colleges, public universities, and independent colleges and universities in the state.

FIGURE 72: COMMUNITY COLLEGES, PUBLIC UNIVERSITIES, AND INDEPENDENT COLLEGES AND UNIVERSITIES, MICHIGAN, 2019

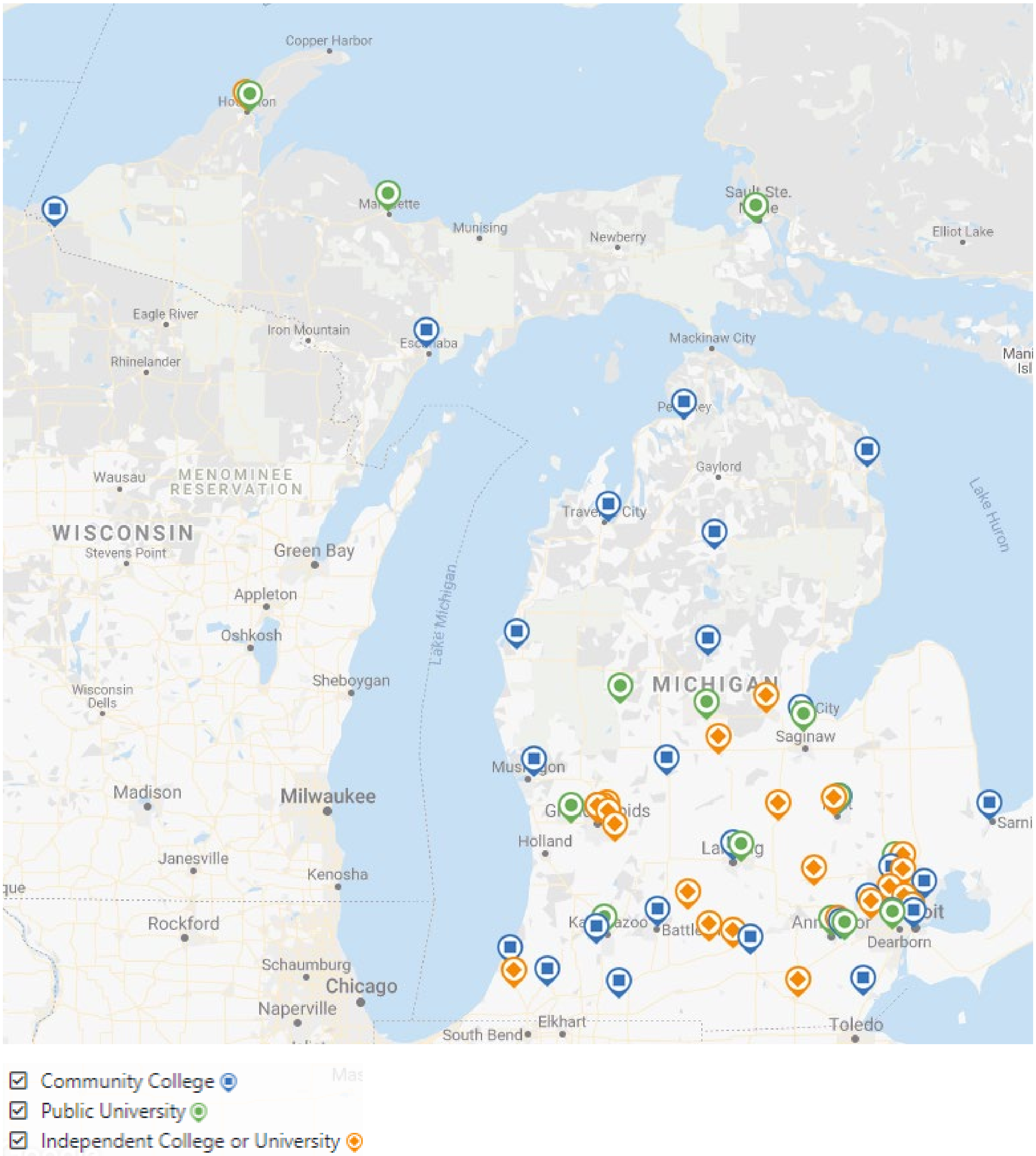


FIGURE 73: MICHIGAN ACADEMIC INSTITUTIONS, 2019

Community Colleges

Alpena Community College
Bay de Noc Community College
Delta College
Glen Oaks Community College
Gogebic Community College
Grand Rapids Community College
Henry Ford College
Jackson College
Kalamazoo Valley Community College
Kellogg Community College
Kirtland Community College
Lake Michigan College
Lansing Community College
Macomb Community College
Mid Michigan College
Monroe County Community College
Montcalm Community College
Mott Community College
Muskegon Community College
North Central Michigan College
Northwestern Michigan College
Oakland Community College
Schoolcraft College
Southwestern Michigan College
St. Clair County Community College
Washtenaw Community College
Wayne County Community College District
West Shore Community College

Public Universities

Central Michigan University
Eastern Michigan University
Ferris State University
Grand Valley State University
Lake Superior State University
Michigan State University
Michigan Technological University
Northern Michigan University
Oakland University
Saginaw Valley State University
University of Michigan-Ann Arbor
University of Michigan-Dearborn
University of Michigan-Flint
Wayne State University
Western Michigan University

Independent Colleges and Universities

Albion College
Alma College
Andrews University
Aquinas College
Baker College
Calvin University
Cleary University
College for Creative Studies
Compass College of Cinematic Arts
Concordia University Ann Arbor
Cornerstone University
Davenport University
Finlandia University
Kettering University
Lawrence Technological University
Madonna University
Northwood University
Olivet College
Rochester University
Siena Heights University
Spring Arbor University
University of Detroit Mercy
Walsh College

Data: MItransfer.org

Community Colleges are also at the forefront of developing advanced transportation programming. Community colleges typically have two departments, credit and non-credit. For-credit programs do tend to change more slowly on pace with university programs. However, workforce development and non-credit programs can be an excellent fit for short-term training for both entry-level workers and incumbents. While in the past, community college automotive and transportation-related programs focused on mechanics and troubleshooting, vehicle technology has developed to require technician training in various software, electronic, and electrical components. These technician roles must transition as it relates to testing and infrastructure to support smart streets technology.

Two exemplary programs in Southeast Michigan, which MDOT can consider partnering and actively recruiting talent, are available at community colleges. The Washtenaw Community College Advanced Transportation Center (WCC-ATC) has been designed to respond to the ever-changing technical skills required in the industry. WCC is uniquely positioned in the state to be near:

- The University of Michigan Transportation Research Institute (UMTRI), currently conducting a USDOT-sponsored Connected Vehicle Safety Pilot Program
- MCity, UMTRI's one-of-a-kind urban test facility for on-road deployments (formerly known as Mobility Transformation Center)
- American Center for Mobility at Willow Run
- US Environmental Protection Agency's National Fuel and Emissions Laboratory

- The Center for Automotive Research (CAR)
- The University of Michigan's College of Engineering and School of Information
- Merit Network, a research and education network supporting fiber optic connectivity and the Michigan Cyber Range, the nation's largest unclassified private cybersecurity training cloud
- Google regional offices in Ann Arbor and Birmingham
- Engineering facilities for global automakers and suppliers

WCC supports achieving the necessary talent pipeline in this industry by focusing on two phases of development. The first is to work with high school students and recent graduates to attract them to these programs and careers. The second is to work with incumbent workers who simply need skills upgrades. These individuals are typically not seeking another degree or even college credit but need more skills to maintain their position or advance at their employer. WCC has been approached by Toyota, GM, and others to specifically design programs for their incumbent workers, which also informs the content for other training curriculums.

The Macomb Community College Center for Advanced Automotive Technology (MCC-CAAT) continuously improves programs to build the future workforce. Similar to the WCC program, CAAT at MCC started as an automotive technician program. As technology is constantly changing, the courses and program content began evolving as well. While certain elements have been baked into the automotive technician programs MCC-CAAT is currently offering, additional studies are planned to extend to complete street design and transportation infrastructure programs. MCC-CAAT relies heavily on an advisory board to develop curriculum programs.

Both institutions work directly with employers to design specific programs. MDOT could approach the community college system and request specific course progressions to better train individuals to the required skillsets. General Motors, Toyota, Bosch, and Continental have worked directly with colleges to design programs to address their needs specifically. The programs are offered to the public for enrollment, and these companies know they can find the skillset they are looking for in students completing these programs.

4.6.4 Gap Identification

Michigan possesses 24 institutional programs available for candidates and incumbent workers interested in lifelong learning. While these programs are extensively offered through 102 different providers, there are areas in Michigan, such as the upper peninsula and northern Michigan, that primarily have institutions in two counties that cover a five to six-county reach. Barriers to educational opportunities exist both externally in need for talent and interest in MDOT programs and internally with the lack of educational programs outside of regular business hours, such as the evening. There are programs offered for specific MDOT duties. Building new partnerships with institutions expands the reach for program enrollment and recruitable talent, so examining institutions and the geography is essential to see hidden talent pools in the state and activating institutions to create, promote, and enroll individuals into the MDOT pathway programs. The following strategies are recommended to enhance the current curriculum enrollment and partnership opportunities for the department.

- We recommend MDOT work with the MWAs to encourage workers and job seekers to pursue career pathways that lead to transportation industry-recognized stackable credentials, so these individuals can fill in-demand jobs within MDOT while promoting current and future employees' growth in wages with specialty skillsets. Providing classes that are after conventional daytime class hours would aid in employee participation and enrollment.
- Due to technological advancements facing MDOT operations, the department should encourage current employees to use workforce programs available to grow their skillset. As a result of the limited work-to-school programs available for employees and Civil Service rules, MDOT employee retention and interested talent will remain low, reducing the departments' competitive ability to attract talent in the state. MDOT should work with the MWAs and partnering training institutions to harness funding provided by the state and federal government that will help to upskill incumbent workers, decrease turnover, and increase wages.
- Work-and-learn opportunities such as apprenticeships, job shadowing, and co-ops are deficient within the organization. MDOT should continue to work closely with institutions to increase the availability of internships and other work-based learning opportunities to ensure that job seekers will gain access to jobs in the transportation industry.

Task 5: Future Workforce Recruitment Planning

5.1 Recruitment Overview

5.1.1 Purpose/Main Objective

MDOT needs to provide upskilling opportunities for incumbent workers and understand emerging skills needs for attracting and developing talent with the desired skill set for vacant positions. The following analysis explores recommendations for workforce development and recruitment strategies.

5.1.2 Methods

To assist with the development of the recruitment strategy, WIN analyzed the survey results obtained through the MDOT organization-wide survey in February 2020, as well as in-demand training programs, skills, certifications, and wages to provide the entire landscape of the projected change in operations within the transportation industry. In addition, WIN conducted one-on-one interviews with transportation infrastructure education experts to inform additional research on recruitment and strategy. WIN also performed a literature review of various recruitment best practices in southeast Michigan and the state. The following recruitment recommendations are provided to identify fundamental techniques needed to manage the changing transportation infrastructure.

5.2 Recruitment Landscape

5.2.1 Changing Composition of Workforce and Conditions Affecting Recruitment

The need for upskilling talent to keep pace with technological advancement is an undeniably tough challenge for every industry, including transportation. Michigan Governor Gretchen Whitmer has been vocal about the poor condition of Michigan's roadway systems and the need to fix the roads – but the skills gap must first be resolved. According to a recent Brookings Institute article, "physical infrastructure systems are aging and in need of attention as well as the workers who design, construct, operate, and oversee these systems. The problem is that many transportation industry workers are nearing or are eligible for retirement, and there is not a strong training pipeline to educate and equip a new generation of talent with the skills they need." In 2018, just 13 percent of infrastructure workers had a bachelor's degree or higher, compared to 37 percent of all workers nationally. And more than half—54 percent—had a high school diploma or less. Although managers, engineers, and several infrastructure workers demand more advanced degrees, most technicians, mechanics, and other workers do not. Instead, many of these workers require more extensive on-the-job training and develop competencies in a wide range of transferable skills, including mechanical, technical, and scientific knowledge."

5.2.2 Human Capital Trends, Open Talent Economy, and Recruitment Tools

Deloitte Insights has published a series of *Human Capital Trends* reports annually since 2017, based on surveying thousands of business leaders to establish new leadership and Human Resources strategies for attracting, developing, and retaining talent. The top ten human capital trends include (Deloitte Insights):

- **Building the Organization of the Future**, which is trending toward a flattened and agile team-centric model
- **Lifelong Learning** for challenging the half-life of skills
- **Talent Acquisition and the Open Talent Economy** is a growing strategy of partnering with temporary labor marketplace companies (such as ShiftGig and BountyJobs), e-staffing agencies (such as HIRED and CloserIQ), freelance management systems (such as OnForce and JobBliss), and crowdsourced recruitment systems (such as Amazon's Mechanical Turk and Gigwalk)
- **Employee Experience** for addressing the needs of younger workers by using net promoter scores, examining the employee journey, and redesigning the workplace to improve well-being and productivity
- **Performance Management** is the shifting paradigm from an emphasis on the annual appraisal to providing coaching and professional development training to increase retention of younger workforce professionals
- **Disrupted Leadership** is the trend of challenging traditional boundaries and creating a more agile, diverse, and digital way to run a business with young leaders
- **Digital HR: Platforms, People, and Work** means deploying digitized HR platforms, and technology that can change how people work and the way they relate to each other at work
- **People Analytics: Recalculating the Route** refers to the process of obtaining data about people at work to understand the talent factors that drive performance
- **Diversity and Inclusion** is reshaping corporate cultures to have a stronger emphasis on fairness, equity, inclusion, accountability, transparency, and diversity through a process
- **Future of Work: The Augmented Workforce** is redesigning almost every job due to robotics, artificial intelligence, sensors, and cognitive computing going mainstream, along with the open talent economy

The local talent pool is a numbers game. The WIN Data and Research team publishes quarterly labor market reports on the top job posting for 11 industry groups and performs studies by comparing real-time job posting information against postsecondary degree or certification training completions (WIN Intelligence, 2021).

5.3 Desired Recruitment

5.3.1 Specific skillsets, eligibility requirements, application requirements, assessments, or others that MDOT may employ in searching for these occupations

Many occupations have additional hiring requirements beyond the educational and skills requirements, affecting recruitment sources and entry. In developing assessments, specific requirements will need to be considered to ensure that any unqualified candidates are screened out early in the process. Nearly all identified occupations require employees to withstand outdoor weather conditions regularly, often dealing with dirt, chemicals, and highway debris of various types. All positions also require the ability to lift and transport up to 50 pounds. On-the-job conditions will need to be addressed in the assessment process to ensure the best fit for the job. Career awareness events are an opportunity to describe work trends, conditions, and opportunities within the industry sector.

5.3.2 How will these occupations shift in the next five years?

According to survey results, MDOT management envisions the staff in their department to remain the same over the next five years, while others expect their staffing levels to decrease. Respondents expressed that the growth or shrinkage would only average around 1-3 workers per department, including employees receiving promotions or retiring. The greatest challenge was the salary limitations associated with new technologically advanced workers, with a 42.0 percent response rate. Other challenges include training and retraining financial and educational resources and opportunities (22.6 percent) and the ability to develop a workforce plan and analyze skill gaps (6.5 percent). Respondents also cited specific challenges, which are provided below:

Most survey respondents, 81.3 percent, do not foresee any significant construction, bridge, railway, or major infrastructure projects that would trigger a hiring event in their unit. However, teams on such projects as the Plaza Expansion, Design Build, and Management of the Connected and Automated Vehicle Infrastructure would instead have increased support from temporary staff than consultants. Respondents fear increased funding would put more pressure on staff already working with heavy workloads, causing more turnover for MDOT.

Over half of MDOT survey respondents (60.7 percent) have added new technical or soft skill requirements to their job postings over the past three years. As illustrated in the training strategy, many of these new skills stem from emerging technologies and the changes needed to maintain the current infrastructure. New skills are also required to close the gap of departmental vacancies by promoting from within. The technical and foundational skills currently requested in units around MDOT are noted below. GIS seems to be the most common requested technical skill from survey respondents.

- “Even a journey electrician is expected to know how to program a traffic signal controller, which is a highly complex computer set up to a communications network on which people's safety relies.”
- “Planisware, Jobnet, GIS.”
- ‘We try to incorporate items that refer to the Mission, Vision, and Values statements.”
- “I believe leadership type of items have been added to postings and interview questions.”
- “The ability to learn TAMS.”
- “Focus on leadership skills and competencies.”
- "Data analytics including Power BI, Google Analytics, Business Objects.”
- “LCPtracker.”
- “Data analysis has been a skill, but task and project management to implement the results from the analysis has been added.”
- “Stressing communications skills of all staff members.”
- ‘Independent actions, teamwork, and communication skills.”
- “Redefined roles of assistant construction engineers. Dual role as a construction engineer and designated rep for LAP projects based on geography than the balance of workload.”
- ‘Yes, adding modeling/drafting software requirements.”

- "Creating a positive work environment."
- "Knowledge of computer systems."
- "Utilization of excel for maintenance budget tracking."
- "GIS duties, asset management, performance-based practical design awareness."
- "GIS database management, Arc GIS Online management, Traffic data collection software specialties."
- "Proficiency in survey technology to support 3D model usage."
- "Updated the software skills required to be consistent with our current needs."
- "Use of GPS technology for Transportation Technicians."
- "Many tied to new software programs or technology."
- "Projects and Contracts focus."
- "Drone and limited GIS."
- 'Project management skills."
- "Use of TAMS software for lead maintenance workers."
- "Experience or familiarity in the use of geotechnical investigation methods and equipment."
- "Visioning, Leadership, Group dynamics, leadership standards of excellence."
- "GIS and collaboration."
- "Leadership."
- "Team Oriented."

There are also many new industry certifications and external training programs that have been created over the past three years to meet the needs of the transportation field, with 38.8 percent of respondents identifying new certifications below. Again GIS, but also DISC, and bias and diversity training appear frequently in responses.

- "Training provided by Engineering Support for design software. Design Basic Training."
- "MDOT House, talent reviews."
- "Training avail through OOD (soft skill)."
- "Plenty of technical training also available."
- "With the pandemic and greater availability of training and conferences virtually, these opportunities have been made available to more staff members."
- "Drone pilot certification."
- "Project PDF and Open Roads Designer."
- "Certified Project Manager, a lot of Federal Training opportunities."
- "State supplied implicit bias training and another group that targets Women in Engineering."
- "Bias training."
- "With conferences going virtual, this has opened up more staff opportunities to attend and gain knowledge."
- "TAMS and MDSS."
- "DISC, MDOT House training, Diversity, Equity and Inclusion, IT Security, COVID, Implicit Bias."
- "We've been intentional about making more leadership training available."
- "Claims analysis."
- "FHWA core curriculum."

- “Innovative Contracting methods."
- “Access Database Training.”
- “Implicit bias training, cybersecurity.”
- “Connected vehicle/infrastructure, various computer training, great variety of training from IBTTA.”
- “GPS Training and Computer skills training (Bluebeam).”
- “Level 1 Multistrand Post-Tensioning Field Installation.”
- “Level 1 Multistrand and Grouted Post-Tensioning Inspector.”
- “GPS and total station training to assist field staff in the inspection of construction work.”
- “New PM training that is specific to MDOT practices.”
- “IMSA.”
- “ArcGIS training.”
- “We administer a tiered GIS training program in partnership with a local university and ad hoc training of Traffic Data Management System to internal and external partners including other state agencies, local transportation agencies, consultants and the public.”
- “Available GIS training and training for Geopak Design software.”
- “ESRI MOOC, ESRI R&H, conferences, SOM classes, MSU, and Roadsoft classes.”
- “Yes, the current virtual training has created many new opportunities for staff.”
- “ITE-Road Safety Professional certification and PTOE certification (not currently encouraged by MDOT).”
- “DiSC certification; project management knowledge or certification (not necessarily a PMP - Project Management Professional).”
- “We offer the availability of workshops to staff to learn and upskill new technologies becoming available.”
- “Inspection of self-consolidating concrete, ArcGIS.”

5.4 Challenges to Fill Positions

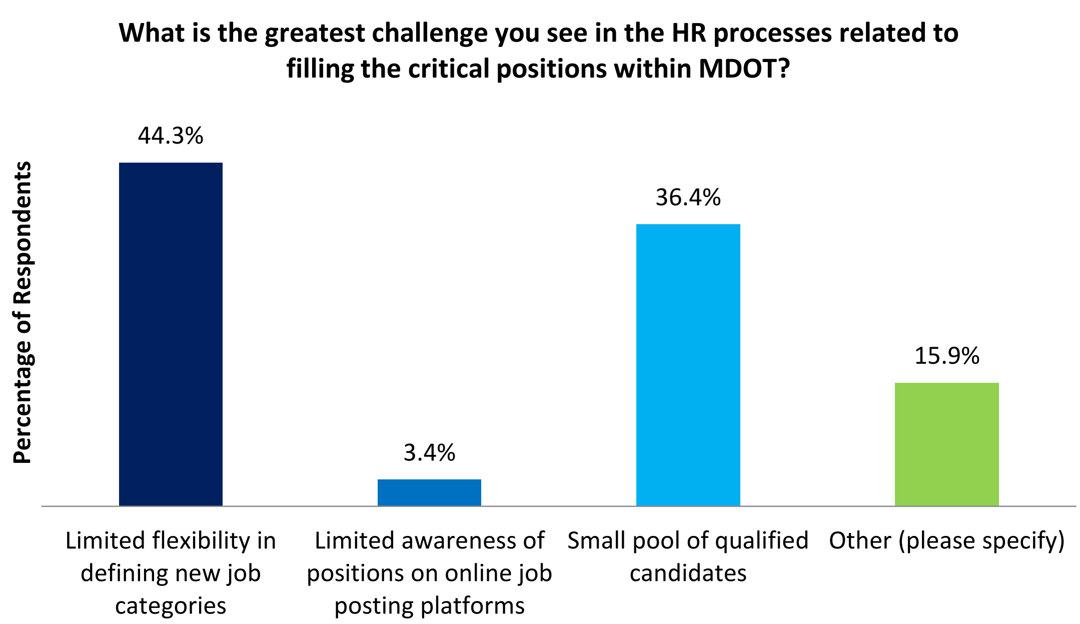
5.4.1 Challenges to recruitment by occupation

MDOT Survey respondents identified significant challenges to recruitment in emerging skills positions as salary and benefits (82.8 percent), attracting workers to Michigan and MDOT (75.3 percent), and lack of interest in positions posted (41.9 percent). Survey respondents also express hiring concerns regarding their limited flexibility in defining new job categories (44.3 responses), having a small pool of qualified candidates (36.4 percent), long human resource processes, and limited flexibility to increase wages for workers.

There have been many challenges identified facing MDOT management. Other than wages, training, and recruitment, MDOT also has a very high turnover. Federal compliance, regulation, and flexibility hinder the organization from maintaining and growing, particularly during the COVID-19 pandemic. Uncertainty around employment and benefits are contributing turnover factors, while heavy workloads, outdated schedules, and low wages promote a sterile environment where employees often part from MDOT. Other challenges identified are below, while Figure 74 displays the responses to question 16.

- “Signal electricians need their own classification so that they can be compensated appropriately for the very high level of skill needed.”
- “Civil service not changing with the times and not fitting new skills into a position description.”
- “The time it takes to fill positions.”
- “Pay rates.”
- “Lack of experience with what we're asking for in the position.”
- “Recruiting people to parts of the state that many are not interested in working.”
- “Official procedures for overlap to allow mentoring of new staff.”
- “Probably limited resources and limited time to train current force and no new FTEs.”
- “Limited flexibility and long lag time in HR processes.”
- “Zero candidates due to pay/benefit structure.”
- “The students we interview as interns all want Engineering Careers. The candidate pool of individuals that want a career that is working with your hands sometimes labor-intensive fieldwork seems to be getting smaller and smaller.”
- “Limited flexibility in an archaic classification system and wage structure.”
- “Small pool of willing candidates. Hard to compete at times with the private sector if our salary/compensation isn't competitive.”
- “Limited flexibility to set pay for new employees.”

FIGURE 74: SURVEY Q.16 RESULTS, MDOT, 2021



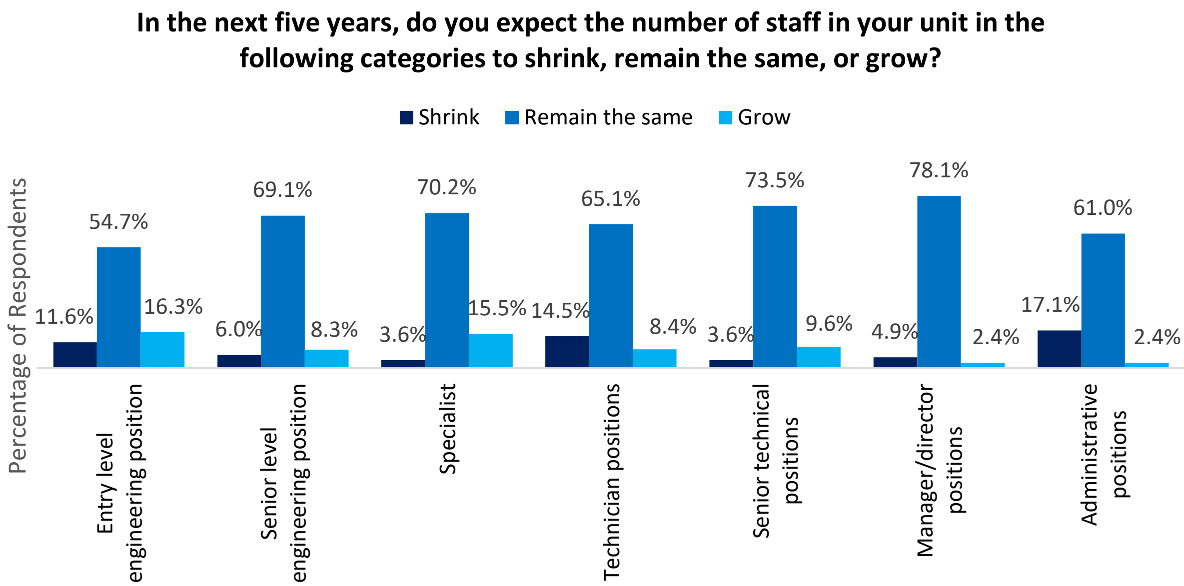
Data: MDOT Survey Results | Analysis: Workforce Intelligence Network

Below are the internal responses on additional challenges and concerns facing MDOT management in the short and long terms.

- “We need qualified electricians. To get them and keep them, you need to pay them what they are worth. They are worth quite a bit more than we are paying them now.”

- “Staffing levels in Superior seem adequate for the program we expect in coming years, although I'd like to hire few TMWs and then need fewer LT TMWs.”
- “It can be frustrating when you can’t hire outside of the current staff. We aren’t getting the right fit for the job.”
- “We have at times difficulty in classifying staff (with Civil Service) to higher levels based on their higher-level duties that would allow one to advance in their current role. Region Resource Analyst and Region Property Specialists come to mind.”
- “If help is needed, we have not been able to grow staff but become more reliant on consultants.”
- “I am a new supervisor (working out of class)—three months in the position. In my opinion, the starting wage in the positions I’m trying to fill isn’t allowing employees to want to stay and make this a career like when I first started. The wages are not keeping up with the market. This is the biggest reason why employees are leaving.”
- “Flexibility with MDOT organizational structure and definition of roles, and rules with flexibility on overlapping duties during transitional periods, such as retirements, should be areas to focus on promoting knowledge transfer.”
- "It's all about the $ and benefits.”
- “Consultants pay twice as much, and now their benefits are the same or equal to MDOT. They also offer the same flexible schedule as MDOT. There is no reason to stay anymore."
- "Other areas our unit would like to work on or obtain training on in the future.”
- “Use of survey data with GIS to document construction work and include in MDOT asset management system.”
- “New uses for drones to conduct quantity surveys and measurements of completed construction work.”
- “New ways to utilize software to develop working maps with photos and other information to help facilitate communication with contractor staff in the field."
- “Change is happening so quickly, hard to anticipate technical needs that will be critical in next five years, let alone 10 or 20 yrs.”
- “Federal and state reporting requirements typically dictate the knowledge, skills, and educational requirements of my workgroup. More recently, industry and public expectations have started to influence a change.”
- “The Office of Business Development is responsible for all regulatory Federal Civil Rights Compliance for MDOT.”
- “We need an increase a competitive, if not better, benefits and salary package than the private sector to get a better and more qualified pool of candidates.”
- “I am very concerned that there is not a long-term career path for individuals wanting to focus on design engineering. The typical design engineer is essentially topped out as a TE 12 after approximately five years.”

FIGURE 75: SURVEY Q.20 RESULTS, MDOT, 2021



Data: MDOT Survey Results | Analysis: Workforce Intelligence Network

5.5 Recruitment Recommendations

5.5.1 Status quo direction at MDOT

MDOT understands the need to plan and maintain exceptional levels of experience, knowledge, and leadership. Due to the need to evolve in this changing world of work, where the talent competition is more incredible each day, the Workforce Programs and Recruitment Strategy Development Team has created the strategy to align with the Employee Life Cycle (ELC).

MDOT views workforce programs and recruitment as a continuum of engagement to establish a talent pipeline for high-demand occupations experiencing significant labor shortages. MDOT first strives to utilize existing talent pools in workforce programs and the upskilling of incumbent workers through clearly defined career pathways for open positions. For filling senior-level and highly technical positions, such as those included in this report, requires additional external recruitment strategies.

The ELC at MDOT begins with career awareness and advances to career exploration, career preparation, pre-employment training, total productivity, and retention. The recruitment strategy and focus of this report include four phases that lead to total productivity.

MDOT is already engaged in a few activities leading to talent pipeline construction but is currently assessing strategies and metrics to maximize return on investment. Career preparation and pre-employment strategies are the most direct recruitment for entry-level positions. MDOT plans to assess relationships over the next two years to use data sources to determine the highest quality sources of talent. Figure 76 shows existing MDOT activities in each pre-recruitment category is listed below.

FIGURE 76: MDOT PRE-RECRUITMENT ACTIVITIES, MDOT, 2021

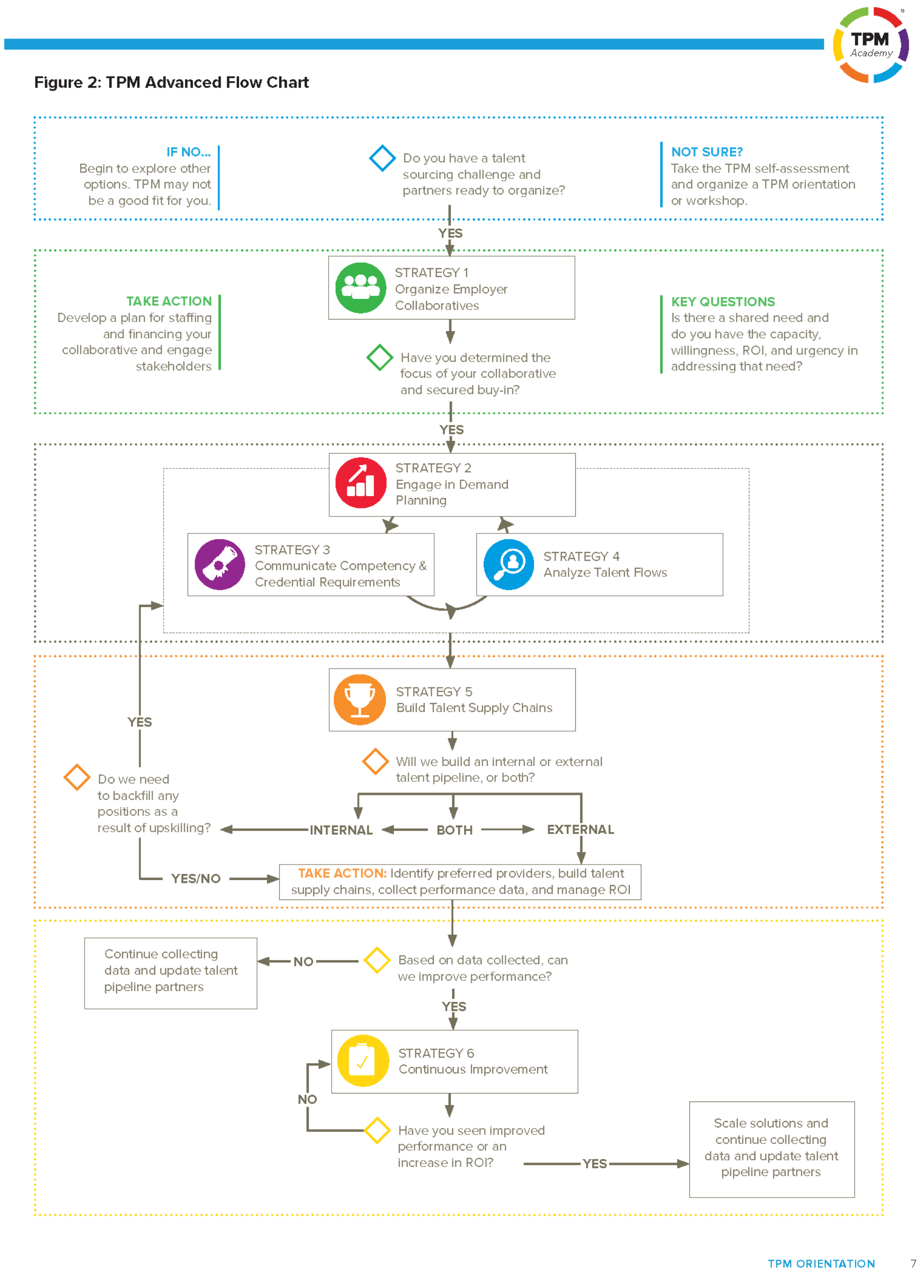
Source: MDOT

5.5.2 Additional Recommended Recruitment Strategies

A broad range of recruitment tactics and strategies are necessary to recruit the large and diverse workforce needed to support MDOT and transportation infrastructure in the state of Michigan. Recommendations for partnerships and strategies are essential for both recruitment and talent pipeline development. To best identify high-priority occupations for recruitment, one overarching recommendation is to utilize the Talent Pipeline Management model to decide what recruitment disconnects are and how to target recruitment to what is needed.

Talent Pipeline Management (TPM) started in 2014 by applying lessons learned from supply chain management to education and workforce partnerships. Suppose employers can play an expanded leadership role as "end-customers" of a talent supply chain. In that case, they can more effectively determine their most critical workforce needs, communicate those needs to trusted partners, and manage and improve the talent pipeline over time. TPM provides a systematic framework for how employers can engage effectively in workforce development and career pathways. This methodology has been highly effective in various industries across the country and a broad community of TPM Practitioners. The general method is illustrated in Figure 77. While TPM methodology has been considered throughout this section of recruitment recommendations, MDOT should ultimately follow the process as closely as possible to achieve effective talent pipeline management. MDOT's staff has been trained in TPM methodology, and WIN or another consultant can facilitate the process.

FIGURE 77: TPM PRACTITIONERS METHODOLOGY, 2014



Source: U.S. Chamber of Commerce

5.6 Current MDOT Recruitment

The current workforce programs and recruitment strategy at MDOT were described in Task 3, Section 2.1, Review of MDOT Existing Strategic Plans. MDOT's Workforce Programs and Recruitment Unit is responsible for actively recruiting from numerous candidate sources for MDOT's hard-to-fill positions.

5.6.1 Understanding the Need

The list of contractors and consultants with whom MDOT works is extensive, partially due to talent issues. Outsourcing jobs can become costly over time, so the need for action is now before the gap widens further. Most survey responses (86.0 percent) of units regularly work with contractors and consultants to fill the gaps. Frequently used contractors and consultants are found in the list below.

- Abonmarche
- AECOM
- Ajax
- Alta Planning
- Anlaan Construction
- Arcadis
- Asphalt Pavement Association of Michigan
- Bacco Construction Company
- Benesch
- Bergmann Associates
- BLN
- C2AE
- CA Hull
- Cadillac
- Cambridge Systematics
- CDM Smith.
- Coleman Engineering
- CTC
- Davis
- DBEs
- Detroit pump
- DJ McQuestion
- DLZ Michigan
- Elmer's Crane & Dozer
- Esri
- Fahrner Asphalt
- G&J Site Solutions Inc.
- Give Em A Brake
- Gourdie Fraser and Associates
- Great Lakes Engineering Group
- Hebert Construction
- HNTB
- Hubbell Roth and Clark
- IBI
- Integral Blue
- K&R
- Kennedy Industrial
- Kimley Horn
- L.S. Engineering
- Lake State Land Surveying Inc.
- M&M Excavating
- MAA
- MCA
- Mannik & Smith
- Michigan Paving and Materials Company
- Michigan State University
- Milbocker
- Mixon-Hill
- Modjeski & Masters
- Motor City Electric
- National Industrial Maintenance
- OHM
- Parsons (Delcan). Salt and other material vendors
- Parsons Transportation Group
- Payne and Dolan
- PK Contracting
- Prein and Newhof
- Prime Construction Contractors
- Rowe Engineering
- ROWE Professional Services Company
- RS&H
- RSG
- SME
- Somat Engineering
- Spalding DeDecker
- Spicer Group
- SSI
- Strain Electric
- Surveying Solutions Inc.
- Tetra Tech
- Toebe Construction
- Toole Design
- Trojan development

- TY Lin
- Tyme Engineering
- University of Michigan
- URS
- Various consultants for designing road and bridge work
- Wade Trim
- Wayne State University
- Western Michigan University
- Wightman
- WSP
- Z contractors

Department-wide survey respondents identified that they would like to bring more work in-house to MDOT instead of outsourcing. Regardless of where the talent is employed, understanding the workforce from a subcontractor and consultant point of view will be necessary to understand the greater depth and breadth of the workforce, available talent pool, and skills needed to accomplish MDOT contracted projects. Additional research and surveying need to be done following the TPM method to determine the skills needs of contractors and cross-walked with those in this report identified by MDOT. In addition, connections between contractors and consultants throughout this process may lead to a more robust extended network that can respond to requests more quickly for the state DOT.

***Facilitate a focused workforce survey among primary contractors and consultants. To the extent possible, invite them to join in a larger conversation about workforce needs and how they can work together to develop a more robust, supportive, and effective talent ecosystem. Ensure consultant/contractor participation in ITS events, advisory boards and convenings, and collaborative transportation efforts.**

5.6.2 Workforce Development Boards

One primary goal around community contacts for this unit is to "develop a network of recruitment contacts with community, professional, disadvantaged or under-represented, disabled and veteran groups that can refer qualified applicants." The State of Michigan Workforce Development structure can assist MDOT in accomplishing the stated goal of developing a vast network of recruitment contacts with access and the ability to recruit from various special populations.

The Michigan Office of Labor and Economic Opportunity, Workforce Development (LEO-WD) comprehensively oversees Michigan's workforce development system. LEO-WD supports a demand-driven approach, supporting employers in finding the talent they need to remain as economic drivers in their communities. The overall goal is to match a quality, skilled talent base using guidance from Michigan's employers.

To deliver services, Michigan utilizes the Michigan Works! system, which was the first unified workforce development system in the United States. Michigan Works! Agencies oversee workforce development services in their area and correspond locally to workforce development boards. Each Workforce Development Board, typically in partnership with locally elected officials, is responsible for overseeing workforce development programs in their local area. There are 16 Michigan Works! agencies comprising the system, operating a statewide network of 92 American Job Centers (AJC). AJCs are designed to provide a one-stop career center assistance model for job seekers. AJCs was initially established as a part of the Workforce Investment Act and reauthorized under the Workforce Investment and Opportunity Act (WIOA). MWAs oversee all WIOA programming in the state. Centers offer such services to jobseekers as intake and orientation, eligibility services and application services to various programs, comprehensive and specialized assessments, training referrals, career counseling, job posting, case management, resume and interview services, and more (Michigan Works Agency, 2021).

In addition, MWAs are adept at delivering complex recruitment models in various capacities on behalf of employers. The population entering AJCs includes all special populations mentioned in the MDOT recruitment plan (differently-abled persons, veterans, dislocated workers/professionals, minority groups) and can provide mechanisms for outreach to specific populations as needed. MWAs also provide ability and interest assessments to determine the best fit for training programs and occupations. MWAs listed goals include convening and implementation of sector partnerships, working with training providers and businesses to develop in-demand training programs to address employer needs.

***To this end, MDOT should ensure relationships have been developed with all 16 MWAs. Contact information is provided in Table 22. Designing a mechanism to communicate with MWAs and AJC staff to identify high-demand occupations consistently and regularly at MDOT both now and in the future will recruit appropriate talent for high-demand occupations with the MWA system.**

TABLE 22: MWA CONTACT LIST, 2021

Location	Address	Email/Website	Telephone	Contacts
UPPER PENINSULA MICHIGAN WORKS!	2950 College Avenue Escanaba, MI 49829	e. mwjob@upmichiganworks.org www.upmichiganworks.org	p. (906) 789-9732 f. (906) 789-9952	▪ Michigan Works Director: William L. Raymond ▪ Workforce Development Board Chair: Mark Massicotte ▪ Local Elected Official: Gerald Corkin
MICHIGAN WORKS! NORTHEAST CONSORTIUM	20709 State Street PO Box 711 Onaway, MI 49765	e. general@nemcworks.org www.nemcworks.org	p. (989) 733-8548 f. (989) 733-8069	▪ Michigan Works Director: Marisue Moreau ▪ Workforce Development Board Chair: Sheryl Coyne ▪ Local Elected Official: John Wallace
NORTHWEST MICHIGAN WORKS!	600 East Front Street P.O. Box 506 Traverse City, MI 49685	e. nwmwa@networksnorthwest.org www.networksnorthwest.org	p. (231) 929-5000 f. (231) 929-5012	▪ Michigan Works Director: Matt McCauley ▪ Workforce Development Board Chair: Gary Fedus ▪ Local Elected Official: Chris Christensen
MICHIGAN WORKS! WEST CENTRAL	14330 Northland Drive Big Rapids, MI 49307	e. info@michworkswc.org www.michworkswc.org	p. (231) 796-0049 f. (231) 796-8316	▪ Michigan Works Director: Shelly Keene ▪ Workforce Development Board Chair: Deborah Smith-Olson ▪ Local Elected Official: Larry Emig
WEST MICHIGAN WORKS!	1550 Leonard N.E.Grand Rapids, MI 49505	e. info@westmiworks.org www.westmiworks.org	p. (616) 336-4100 f. (616) 336-4118	▪ Michigan Works Director: Jacob Maas ▪ Workforce Development Board Chair: Mark Bergsma ▪ Local Elected Official: Robert Womack

MICHIGAN WORKS! BERRIEN, CASS, VAN BUREN POWERED BY KINEXUS	499 West Main Street Benton Harbor, MI 49022	e. info@miworks.org www.kinexus.org www.miworks.org	p. (269) 927-1799 f. (269) 927-1399	▪ Michigan Works Director: Kinexus Group President & CEO: Todd Gustafson // Executive ▪ Director for Michigan Works! Berrien, Cass, Van Buren: Lily Brewer ▪ Workforce Development Board Chair: Christopher Randall ▪ Local Elected Official: Don Hanson
MICHIGAN WORKS! REGION 7B CONSORTIUM	402 North First Street Harrison, MI 48625	e. reg7b@michworks4u.org www.michworks4u.org	p. (989) 539-2173 f. (989) 539-0127	▪ Michigan Works Director: Mark L. Berdan ▪ Workforce Development Board Chair: Norman J. Fullmer ▪ Local Elected Official: D. Jay O'Farrell
GREAT LAKES BAY MICHIGAN WORKS!	1409 Washington Street Midland, MI 48640	e. glb@michiganworks.com www.michiganworks.com	p. (989) 754-1144 f. (989) 754-1439	▪ Michigan Works Director: Chris Rishko ▪ Workforce Development Board Chair: Brian Sheets ▪ Local Elected Official: Carl Ruth
CAPITAL AREA MICHIGAN WORKS!	2110 South Cedar Street Lansing, MI 48910	e. LansingGreeter@camw.net www.camw.org	p. (517) 492-5500 f. (517) 487-0113	▪ Michigan Works Director: Carrie Rosingana ▪ Workforce Development Board Chair: Jane Doty ▪ Local Elected Official: Robert Showers
MICHIGAN WORKS! SOUTHWEST	222 South Westnedge Avenue Kalamazoo, MI 49007	e. miworks@upjohn.org www.michiganworkssouthwest.org/	p. (269) 349-1533 f. (269) 349-5505	▪ Michigan Works Director: Ben Damerow ▪ Workforce Development Board Chair: Randall Hazelbaker ▪ Local Elected Official: Tracy Hall
GST MICHIGAN WORKS!	3270 Wilson Street Marlette, MI 48453	e. customerservice@gstmiworks.org www.gstmiworks.org	p. (989) 635-3561 f. (989) 233-8652	▪ Michigan Works Director: Jody Kerbyson ▪ Workforce Development Board Chair: Leanne Panduren ▪ Local Elected Official: Bryant Nolden
MICHIGAN WORKS! SOUTHEAST	336 Harriet Street Ypsilanti, MI 48197	www.mwse.org	p. 844-200-3206 f. 734-481-2520	▪ Michigan Works Director: Shamar Herron ▪ Workforce Development Board Chair: Marcus James ▪ Local Elected Official: Karol Bolton
MACOMB-ST. CLAIR MICHIGAN WORKS!	21885 Dunham Road, Suite 11 Clinton Township, MI 48036	e. info@macomb-stclairworks.org www.macomb-stclairworks.org	p. (586) 469-5220 f. (586) 469-7448	▪ Michigan Works Director: John Bierbusse ▪ Workforce Development Board Chair: Mike Kramer ▪ Local Elected Official: J.P. Rea
OAKLAND COUNTY MICHIGAN WORKS!	2100 Pontiac Lake Road Waterford, MI 48323	e. oaklandcountymiworks@oakgov.com www.oaklandcountymiworks.com	p. (248) 858-5520	▪ Michigan Works Director: Jennifer Llewellyn ▪ Workforce Development Board Chair: Paula Boegner ▪ Local Elected Official: David Coulter

DETROIT EMPLOYMENT SOLUTIONS CORPORATION	115 Erskine, 2nd Floor Detroit, MI 48201	e. info@detempsol.org www.DESCmiworks.com	p. (313) 876-0674 f. (313) 664-5505	▪ Michigan Works Director: Terri Weems ▪ Workforce Development Board Co-Chairs: David Meador and Cynthia Pasky ▪ Local Elected Official: Mayor Mike Duggan
SOUTHEAST MICHIGAN COMMUNITY ALLIANCE	25363 Eureka Road Taylor, MI 48180	e. semca@semca.org www.semca.org	p. (734) 229-3500 f. (734) 229-3501	▪ Michigan Works Director: Gregory E. Pitoniak ▪ Workforce Development Board Chair: Charlotte (Charlie) Mahoney ▪ Local Elected Official: Commissioner Abdul (Al) Haidous

Data: Michigan Works

5.7 Michigan Works! Turnover Study

The T*urnover Study Results: WIN Region: Genesee, Hillsdale, Huron, Jackson, Lapeer, Lenawee, Livingston, Macomb, Monroe, Oakland, Saint Clair, Sanilac, Shiawassee, Tuscola, Washtenaw, and Wayne Counties, August 2019* report was compiled by the Workforce Intelligence Network for Southeast Michigan on behalf of Detroit Employment Solutions Corporation, GST Michigan Works!, Michigan Works! Macomb/St. Clair, Michigan Works! Southeast, Oakland County Michigan Works!, and Southeast Michigan Community Alliance Michigan Works! The report was aimed at providing the Michigan Works! Agencies with a comprehensive understanding of the root causes of employee turnover and the potential gaps that exist in the development of career pathways for those with barriers to employment by gathering information from a region-wide employer survey with 612 respondents, convenings of local employers, and national best practice research (Michigan Works, 2019). Key report findings are summarized below.

- **The occupations experiencing the highest rates of turnover in the 16-county WIN region are low-training, low-wage positions.** Workers in each of these occupations typically remain with a company for under two years. However, occupations with high average tenure face retention challenges. Engineering, skilled trades, and computer systems roles also typically take a long time to fill, and an oncoming retirement cliff for these workers may leave employers with small talent pools to choose from in the future.
- **Employers in the 16-county WIN region estimate median turnover costs of USD4,500 per worker.** This figure includes factors such as search costs, training, and lost revenue, and productivity. Training costs alone are estimated to be about USD1,500 per employee. Additional training and detailed onboarding are reported as crucial retention strategies, but also expensive ones. Transportation, warehousing, energy, and utility employers reported exceptionally high costs of turnover.
- **The most common reason cited "very frequently" for employee turnover is a desire for higher pay or benefits, followed by transportation, childcare, and other personal conflicts.** Reasons cited "often" also include opportunities to advance within the company and pursue different

career paths. These reasons were consistently in the top two for each MWA, as well as most industry groups. However, professional, technical, and scientific service employers reported advancement opportunities, poaching, and changing career tracks as more significant concerns.

- **Competition for a shrinking talent pool is driving changes in retention strategy for many employers.** Employers often face fierce competition for workers, and most are experimenting with changes in pay, benefits, and other workplace features to attract and retain talent. Flexible scheduling and opportunities such as tuition reimbursement and training benefits, most often implemented by health care and professional, technical, and scientific service employers, were reported as being especially effective for attracting and keeping a younger workforce.

5.8 Virtual Job Fairs

Virtual career fairs have become a best practice in the state and around the country. Traditional career fairs often present many challenges, from expensive venue costs to low attendance volume due to the inability to travel or attend on the scheduled date. Virtual job fairs have been widely recognized as improving recruitment efficiency, increasing attendance and traffic to the fair, and building candidate pipelines. Virtual job fairs are also cost-effective and often do not require complex logistics. The results are real-time and measurable.

In 2020, as COVID-19 disrupted the workforce, the State of Michigan Office of Labor and Economic Opportunity, Workforce Development (LEO-WD) turned to virtual job fairs to support both employers and job seekers in this challenging time. LEO-WD purchased a software called Brazen, which is now available to various organizations, collaboratives, and employers looking to host an event. Brazen is an online platform that allows job seekers, employers, and workforce development professionals to connect safely and professionally from wherever they have an internet connection. Nine months after introducing this software tool, LEO Employment and Training Virtual Job Fairs have connected 5,840 job seekers with 1,140 employers through 49 events. The hosting and hiring agencies have access to the individuals' information who attended their booth and all registered attendees of the entire fair. Hosts and hiring companies walk away from the event with prospect databases that can be utilized not only for existing hiring needs but also for future needs.

MDOT has hosted one virtual job fair with the platform thus far. As the state continues to offer the tool, MDOT can continue to take advantage of this new reality of recruitment. Conversion rates in attendance to job fairs and success in recruitment vary widely by channel and industry. Still, they are often reliant on the marketing and promotion efforts made before the event. Based on general google analytics, approximately 10-15 percent of website traffic clicks on a landing page to learn about an event and begins registration. Roughly 78 percent of those complete registration, but 40-50 percent of the total number of people registered will attend an event. Conferences with a higher conversion rate of registered attendees used focused marketing campaigns and strategies to ensure that participants had a complete understanding of the event, how to get connected, and where to go for troubleshooting.

Best practices to consider throughout the development of virtual job fairs are below. MDOT may also consider consulting with a professional in designing and marketing these events for best participation.

- Utilize all marketing channels available.
- Email- Create short, easily digestible content with the most pertinent details of the event, keeping in mind that the goal is to drive users to the registration page. 2-3 email campaigns are necessary per event. All subject lines should indicate some benefit to attending the event.
- Website- Use a combination of pdf flyers, plugin event advertisement, and an online event calendar to market virtual events.
- Social media- Post 2-4 times on each channel for each event at both 7 days and 1 and 2 days before the event. Include images with large text, so they are easy to read and only a very brief description of the event. The goal is to drive traffic to the registration link, which should be shortened for easy access.
- Use tracking links provided by Brazen to identify where success occurs in marketing strategy.
- Customize follow-up emails. The registrants will be receiving reminders on a schedule before the event. MDOT should personalize branded emails to remind potential attendees why they should attend and the value of the event.
- Minimize registration fields to only what is required to encourage completion of registration.
- Continue reminders up to the time of the event, including email blasts minutes before to give the event one last push for attendance.
- Ensure informational links are available to job seekers to help them understand the job fair, how it works, and where to troubleshoot any issues.
- Distribute press releases and participate in traditional media promotion as possible.
- Partner with local interest groups and community-based organizations to promote the event to potential candidates.

5.9 Improving, Expanding, and Populating the Educational Pipeline

5.9.1 Career Awareness

MDOTs primary career awareness efforts have centered around MiCareerQuest, Maker Faire, Engineering Week, Michigan Construction Career Days, Touch a Truck and TRAC Program, and Bridge Competition. These opportunities, while important, can also be challenging to measure ROI. However, most individuals chose their careers based on one memorable event or speaker. MDOT does plan to continue to participate in these events.

However, participation in career awareness events does often relate to a past engagement with students and teachers. All CTE programs, including those in engineering and other fields that might be of interest to MDOT, are required to have advisory board meetings. These boards present another opportunity for transportation careers to be included in curriculum development and career awareness in classrooms early and often.

***Develop partnerships beyond one-time events to ensure consistent input, feedback, and participation from the transportation industry in K-12.**

5.9.2 Virtual Career Awareness Opportunities

Educational software companies, which allow students to connect to employers and work-based learning opportunities, have become more popular with school districts in Michigan over the last five years. These virtual career awareness opportunities present options for companies along a spectrum of engagement, meeting them where they are in terms of capacity and availability to provide career awareness efforts to students.

- Nepris (Nepris, 2021) facilitates virtual connections to employers by matching requests from educators and students to workforce professionals willing to share their experiences. Through virtual volunteering, offering virtual industry chats, giving learners virtual tours, or conducting mock interviews, employers can quickly and easily connect to students across the country and promote their industry. Companies and professionals also have profiles where students can learn more about careers, career pathways, and how to attain success in those careers.
- Naviance (Naviance, 2021) is a platform used by some schools in the state of Michigan. Naviance helps students understand their interests, strengths, and needs to design a customized career and college pathway. Naviance includes career assessments, resume builders, a “road trip nation” designed to introduce students to careers not necessarily in their backyards, and access to work-based learning opportunities such as job shadowing, internships, apprenticeships, and more.
- Xello (Xello, 2021) is another platform similar to Naviance, which many schools in Michigan utilize to assist in career and college readiness for high school students. Students can explore careers and learn about the pathways to achieve success in those careers. Xello offers an additional platform yet to be brought to scale, which allows for virtual career coaching, access to work-based learning opportunities, group events, and more.

All the above software platforms offer a format to crowd-source transportation career awareness across MDOT. Rather than relying on a small subset of one department that focuses on career awareness, individual employees company-wide can participate in promoting the message of transportation careers.

In addition to these opportunities, many schools and community partners organize events similar to virtual career fairs that focus on the awareness and exposure component. Events like this are relatively light touch to manage and effectively assist youth in determining careers of interest.

***MDOT should support efforts to acquire educational software tools and explore virtual career awareness opportunities to engage company employees to crowd-source participation in transportation career awareness.**

5.9.3 Internal Mobility

MDOT has some internal training programs already to assist individuals in moving between positions. MDOT also has prioritized career planning for individuals as a part of their Workforce Strategic Plan, indicating that career development resources would be made available to employees to empower them to engage in a transportation career more broadly. Survey respondents identified Mid-level and supervisory roles as in high demand. These roles may be a good fit for internal promotion strategies while then backfilling more entry-level positions.

According to a study conducted by Harvard Business Review of internal mobility within the Marriott hotel chains, people become significantly more likely to stay at Marriott as the number of jobs they have performed there increased. This cultivation of an emotional attachment is critical in the enterprise's success because it ensures that turnover does not occur while rewarding high-quality employees who are already a culture fit. Based on MDOT Human Resources data, MDOT's turnover rate is at 42 percent, and a strategy that encourages retention while addressing high-demand occupations from internal positions is essential. Utilizing the Talent Pipeline Management (TPM) methodology developed by the U.S. Chamber of Commerce, MDOT can closely examine the talent flow and create internal pathways for candidates and career-minded individuals. Research demonstrates that mobility pathways must be clearly defined, or individual employees will not act. This program may take time to develop, but a careful examination of career pathway flows within MDOT defines what kind of mobility, mobility for whom, and how much mobility would greatly benefit the organization.

***Development of internal mobility plans that address filling critical positions at mid and senior levels while backfilling entry-level positions.**

5.10 Marketing of Transportation Careers

Marketing campaigns targeting specific industries, but not particular occupations, have become more common. Careers In Energy Week, organized by DTE and Consumers Energy, is an example of a statewide collaborative effort to communicate about careers generally, without advertising specific occupations. The goal is to encourage students and young people to consider what these careers are like and provide them with hands-on activities, competitions, learning sessions, networking sessions, and more. The 2020 Careers in Energy schedule listed below is an example that encompasses many of the other recommendations in this section.

Monday, Oct. 19

- Consumers Energy hosts a virtual panel discussion, Pathways to Careers in Energy 1 – 2:30 p.m.
- DTE Energy hosts Career Exploration, a virtual tour of energy careers for high school students 12:30 – 1:30 p.m.

- DTE Energy hosts panel discussion for high school FIRST Robotics teams on Careers in Energy 5 – 6 p.m.
- DTE Energy hosts Ace Your Behavioral Based Interview 11:30 a.m. – 12:00 p.m. and 6:30 – 7:30 p.m.

Tuesday, Oct. 20

- Michigan Energy Workforce Development Consortium (MEWDC) hosts MI Energy Careers 2020: High school and adult learners career exploration event via Brazen 1 – 4 p.m.

Wednesday, Oct. 21

- CEWD Energy Careers 2020: National conference and virtual career fair for students and adults 1-6 p.m.

Thursday, Oct. 22

- MEWDC hosts Transitioning to a Career in Energy: Panel discussion and resources for educators, veterans, parents, and students, 12:00 p.m. Lunchtime discussion. Register here for the Virtual Panel Discussion

Friday, Oct. 23

- MEWDC hosts Michigan Careers in Energy Week Virtual Job Fair: Job-seekers virtual career fair via Brazen 10 a.m.- 2 p.m.
- Henry Ford College (Energy Employers identified) virtual career fair for job seekers 11 a.m.-1:30 p.m.
- DTE Energy hosts a virtual tour of energy careers for high school students 10-11 a.m.

Based on earlier recruitment recommendations made in section 2.4 of the CAR report, communication about the competitive salaries and benefits available through state employment is essential for marketing.

***Consider a broader marketing campaign targeting the transportation industry and the potential for high-demand, career-sustaining positions.**

5.11 Industry Infinity Transportation Collaborative

Modeled on WIN's other successful employer-led collaboratives in the Advanced Mobility and Healthcare spaces, WIN will begin convening an Industry Infinity Transportation Collaborative and regional Curriculum Development Committee involving ten community colleges, industry experts, and private training providers. The purpose of these collaboratives is to bring together employers with common talent issues to develop workforce solutions, career pathways, scaling strategies, and update educational programs to address current occupational skills needs. MDOT supported WIN's attainment of the H1-B One Workforce grant. WIN has funding to support this collaborative for the next four years while also seeking sustainability options to ensure the cooperative exist long-term.

The new Industry Infinity Transportation Collaborative is aimed at keeping higher education, workforce development, and relevant community-based organizations informed of:

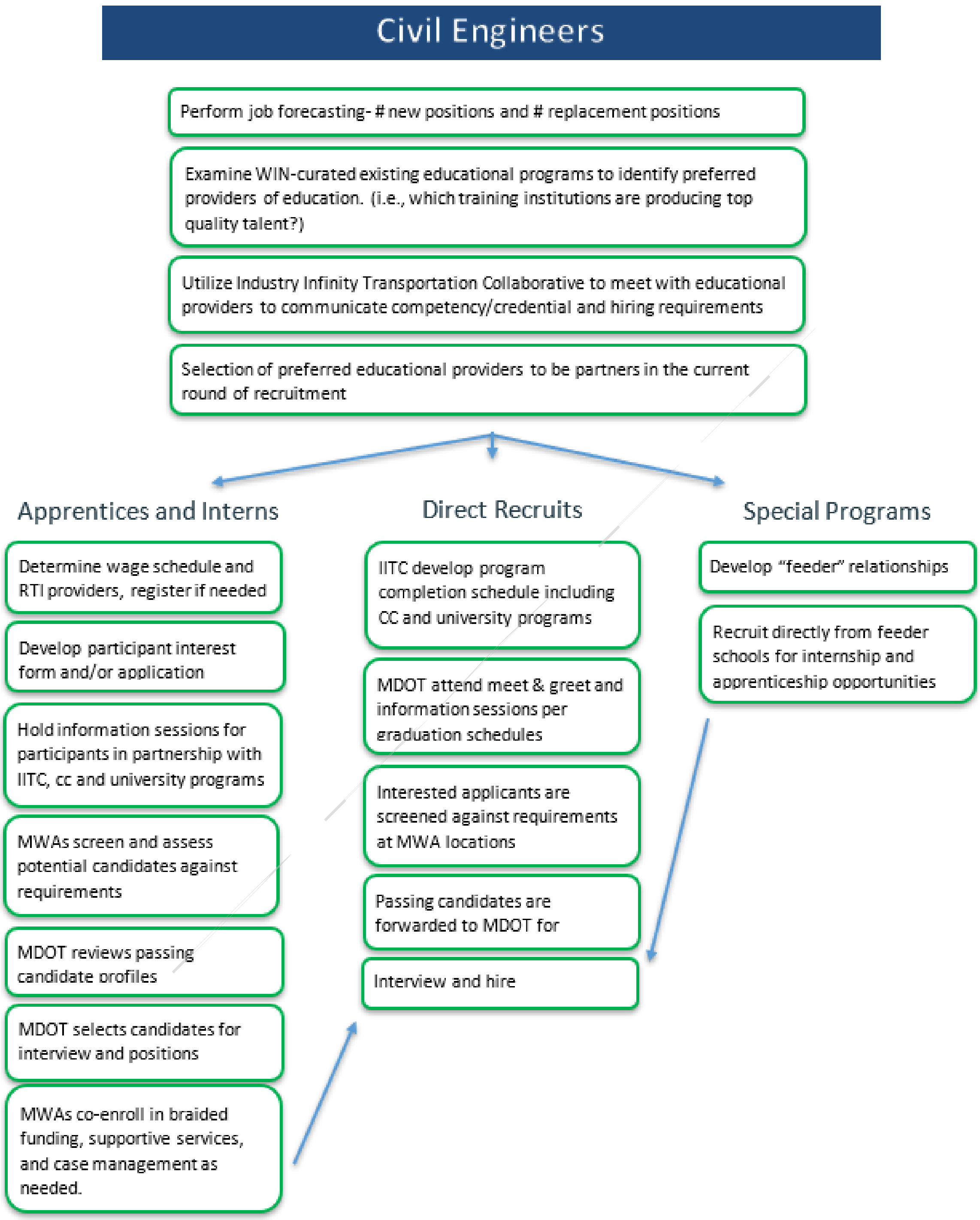
- Transportation training and recruitment strategy updates
- Occupation updates
- Community college curriculum development updates
- Input for industry credentialing needs
- Assistance with training cohorts and scheduling
- Creating and updating the RapidSkills Generator competency-based occupation frameworks can be used to update job descriptions and create an apprenticeship program. Collaboratives also assist in designing recruitment events such as virtual job fairs and other recruitment processes to ensure participating employers understand where to go to find the talent they need.

***MDOT should plan to have consistent representation from one or two individuals with a wide range of knowledge related to workforce issues and implementation of solutions on the Industry Infinity Transportation Collaborative group.**

5.12 Recommended Comprehensive Recruitment Flow

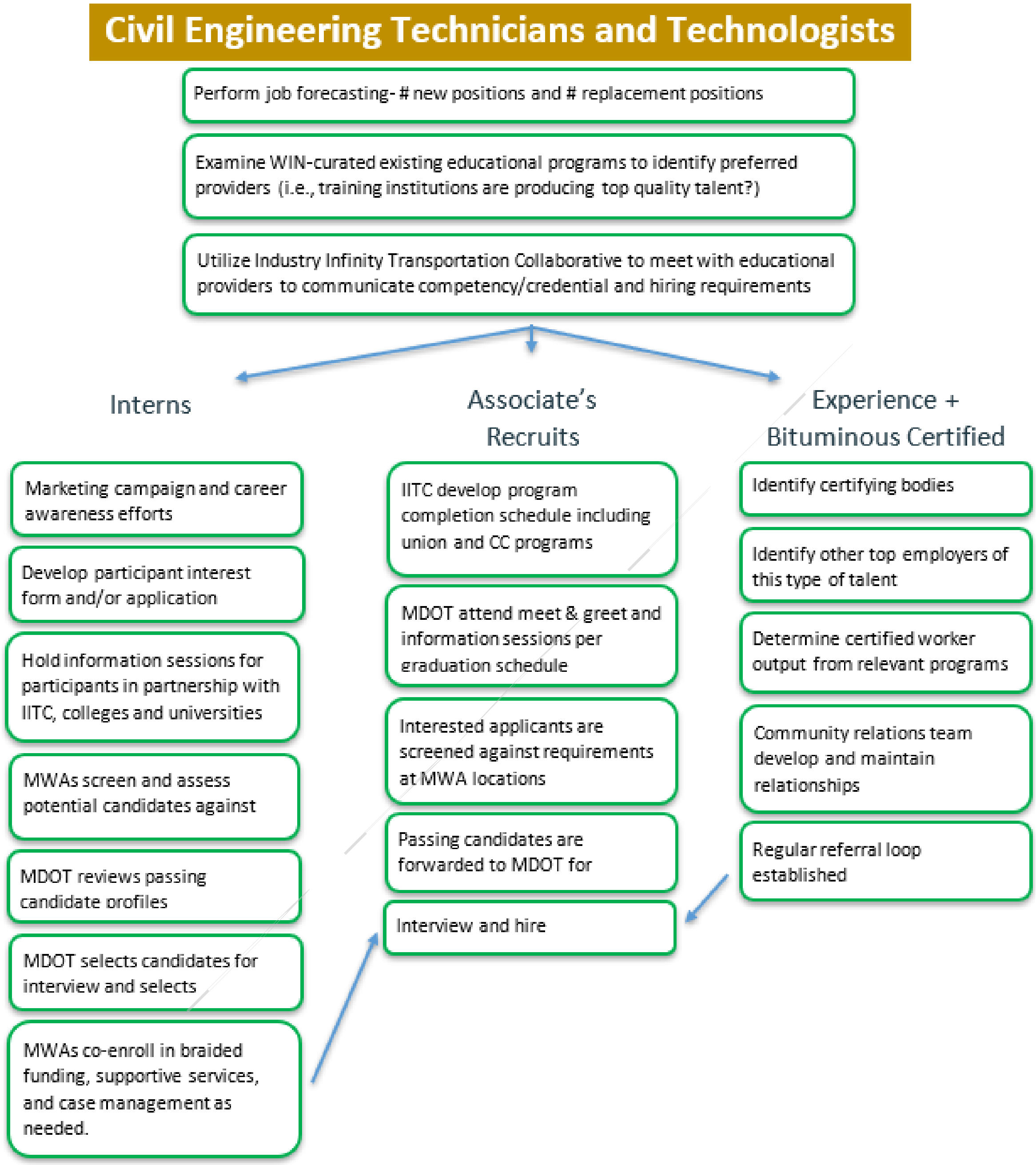
The following section provides recommendations for each occupation utilizing TPM stages for a recommended comprehensive recruitment flow.

5.12.1 Civil Engineers



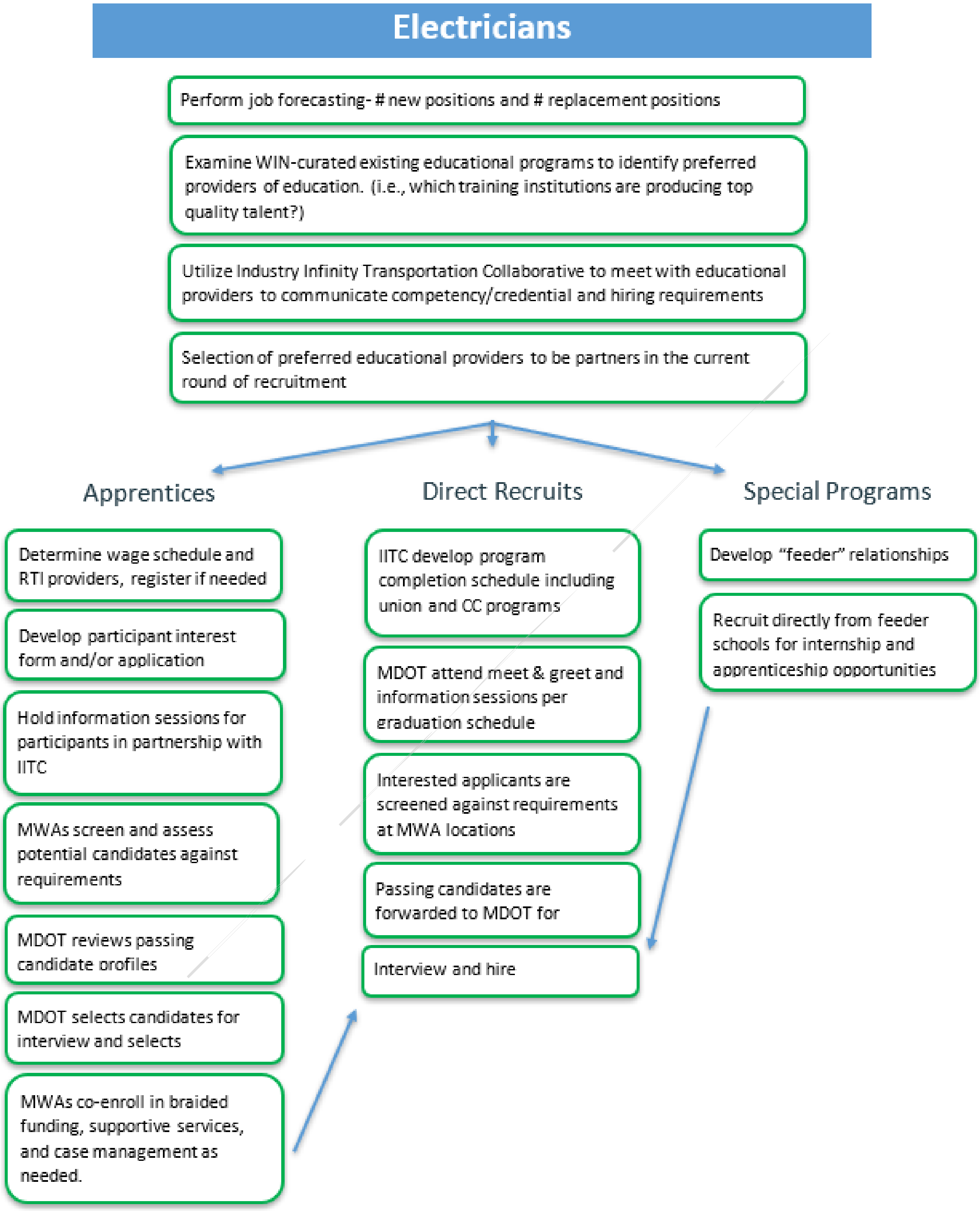
Source: U.S. Chamber of Commerce

5.12.2 Civil Engineering Technicians and Technologists



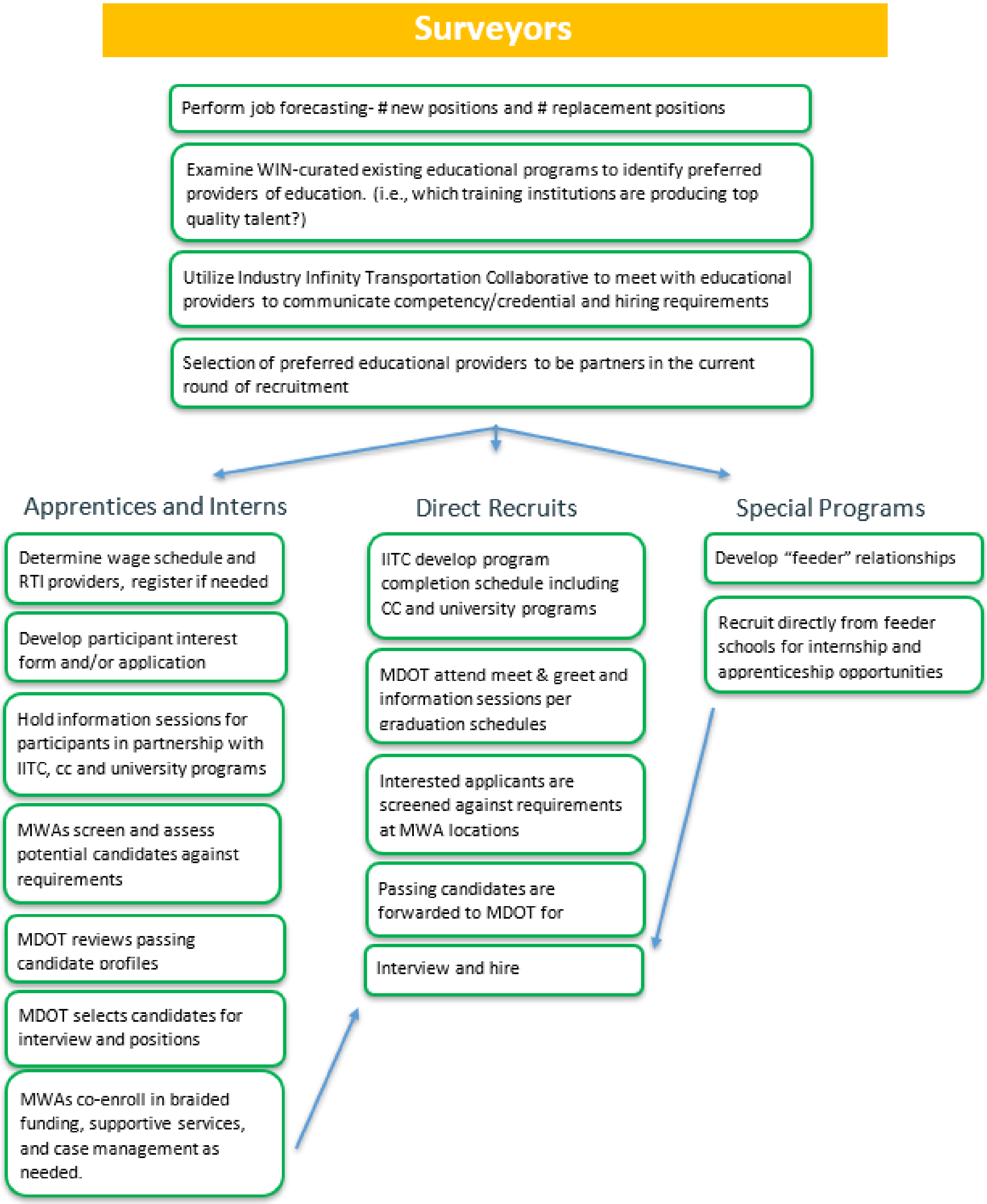
Source: U.S. Chamber of Commerce

5.12.3 Electricians



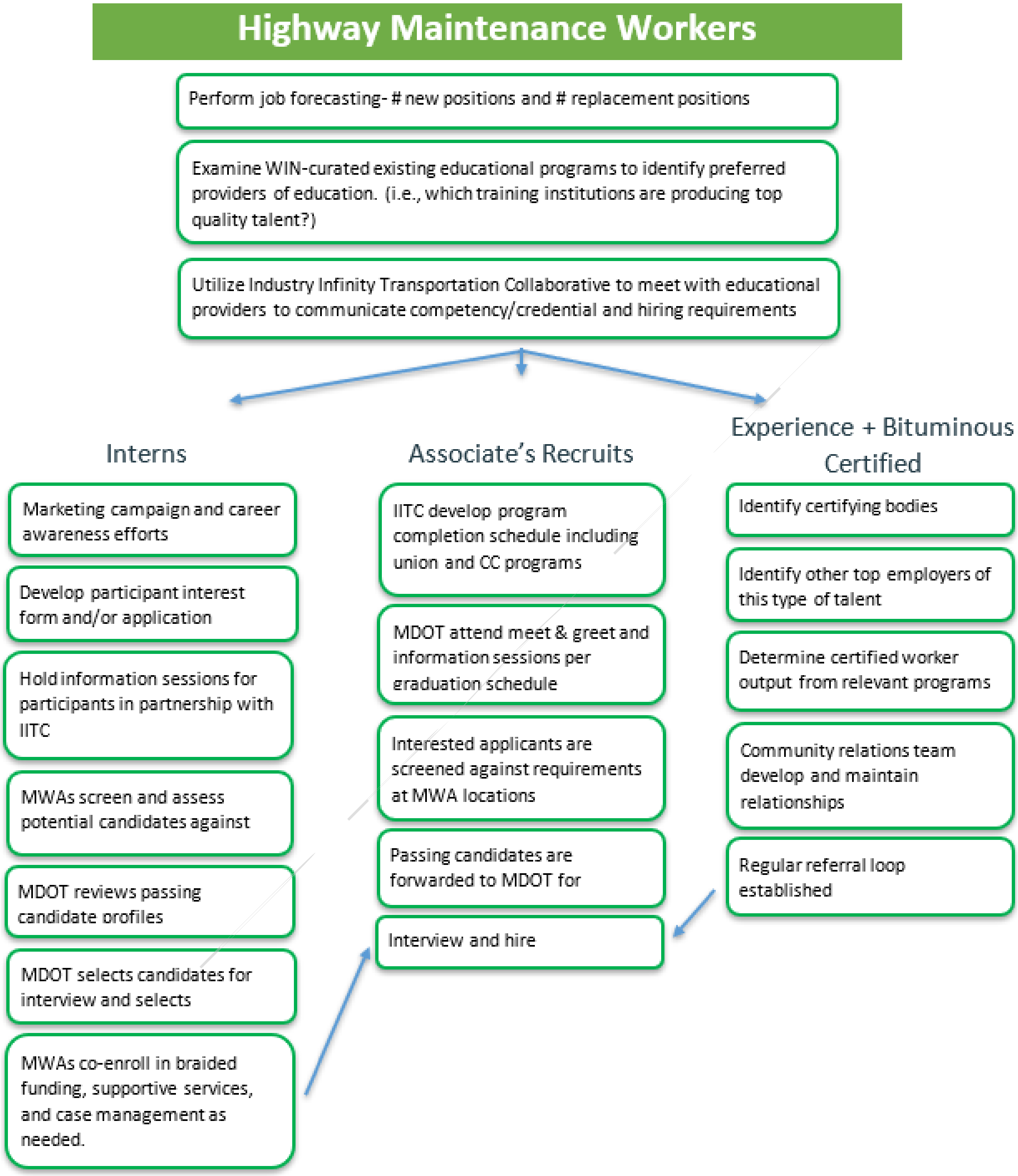
Source: U.S. Chamber of Commerce

5.12.4 Surveyors



Source: U.S. Chamber of Commerce

5.12.5 Highway Maintenance Workers



Source: U.S. Chamber of Commerce

5.13 Conclusion

To support MDOT's wide range of in-demand occupations and emerging skills, developing a broad recruitment strategy is necessary by leveraging existing regional resources. Achieving MDOT goals around workforce diversity and internal mobility will ultimately assist with employee turnover. Other recruitment recommendations are summarized below. The Industry Infinity Collaborative can assist in developing and implementing these recruitment strategies with MDOT and other stakeholders in the transportation employer community.

- Facilitate a focused workforce survey among primary contractors and consultants to understand the talent ecosystem better
- Ensure development of relationships with all 16 Michigan Works! Agencies, and develop a mechanism for continuous feedback loop on talent and occupations
- Participate as advisory board members at community colleges with robust transportation programs and K-12 advisory opportunities
- Continue to take advantage of virtual job fair opportunities, particularly with diverse audiences.
- Consider efforts supporting educational software programs and virtual career awareness opportunities
- Develop an internal mobility strategy with defined career pathways and training.
- Consider a broader marketing campaign targeting the transportation industry incorporating many events
- Plan to have consistent representation on the Industry Infinity Transportation Collaborative focused on workforce

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Appendix A: Outreach and Engagement

In addition to understanding MDOT's vision on emerging technologies, the importance of a technology-enabled workforce is also essential to capture internal units' vision. During this research effort, the team prepared a survey to engage leaders of MDOT units whose work is or could be relevant to emerging technologies. The input collected during this survey served as the basis for the strategic recommendation process provided in the next section. This section provides a summary of the survey results.

The survey included 23 questions categorized into four sections. The first section focused on capturing general information about the respondents. The second section aimed to capture information about the existing situation within the department. Section three sought to understand the leaders' vision for their group and staff regarding the goals and skillset they will need in the next five years. And finally, the fourth category included questions about the required actions to achieve the goals. In total, 113 MDOT employees responded to the survey, and some chose to skip some of the questions. The responders were associated with the following units:

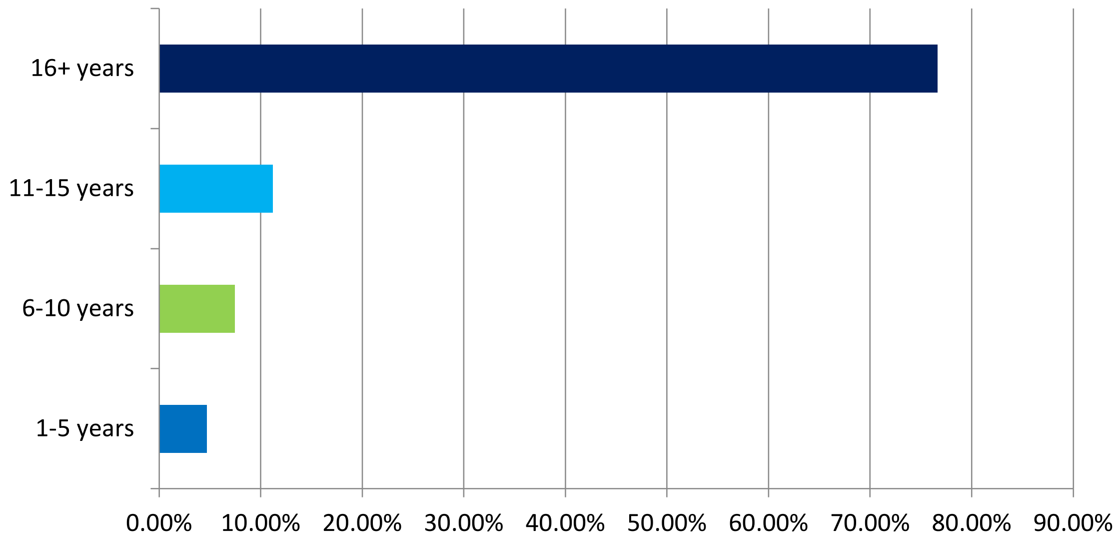
- Administration
- Blue Water Bridge
- Bureau of Finance and Administration
- Bureau of Transportation Planning
- Office of Business Development
- Connected and Automated Vehicle Program
- Congestion Mitigation and Air Quality
- Construction and Field Services
- Data Inventory & Integration Design Division
- Development Services Division
- Intermodal Services
- ITS Operations
- Mackinac Bridge
- Maintenance Services
- MDOT Bay Region
- MDOT Superior Region
- MDOT Metro Region
- MDOT North Region
- MDOT Southwest Region
- MDOT University Region
- North/Superior Bridge Unit
- Office of Development
- Office of Economic Development
- Office of Governmental Affairs

- Organizational Development
- Operation and Maintenance
- Pavement Management
- Research Administration
- Specifications and Estimates
- Statewide Model
- Statewide and Urban Travel Analysis
- System Evaluation and Program Development
- System Monitoring and Reporting
- Traffic and Safety
- Alpena Transportation Service Center
- Cadillac Transportation Service Center
- Crystal Falls Transportation Service Center
- Detroit Transportation Service Center
- Gaylord Transportation Service Center
- Huron Transportation Service Center
- Ishpeming Transportation Service Center
- Jackson Transportation Service Center
- Kalamazoo Transportation Service Center
- Macomb Transportation Service Center
- Marshall Transportation Service Center
- Muskegon Transportation Service Center
- Oakland Transportation Service Center

6.1 Years of Employment with MDOT

More than 76 percent of the respondents have been with MDOT for more than 16 years. Career Gevityity is common among DOT employees as many employees tend to stay with their agency until their retirement. Long-term employment with MDOT could also benefit the department as more experienced employees continue to remain, and their knowledge and experience will be available to the department. DOTs face a staffing dilemma. Losing years of knowledge and experience is a considerable resource loss for a state DOT. "When an employee leaves, state DOTs suffer negative impacts such as lost investments in training, loss of experience, critical skills loss, and costs corresponding to the replacement of leaving employees." (Harper, Bogus, Kommalapati, & Choe, 2018)

FIGURE 78.YEARS OF EMPLOYMENT WITH MDOT FOR THE CURRENT EMPLOYEE SURVEY PARTICIPANTS

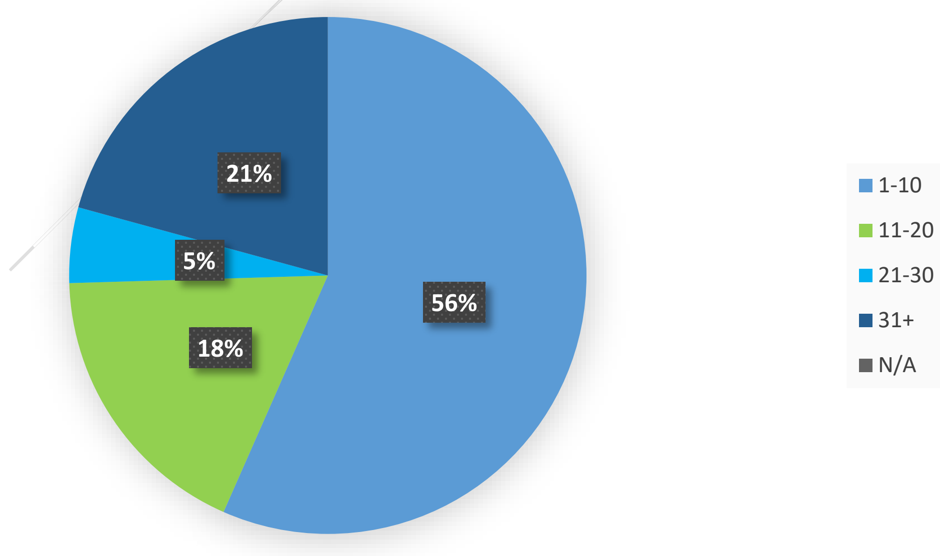


Source: CAR-WIN MDOT Staff Survey (2021)

6.2 Number of Associates

Based on the survey responses, all the participants have some degree of authority in supervising and managing teams of MDOT staff. Over half of the respondents manage a team of 21-30 employees.

FIGURE 79. NUMBER OF ASSOCIATES AMONG THE CURRENT EMPLOYEE SURVEY PARTICIPANTS



Source: CAR-WIN MDOT Staff Survey (2021)

6.3 Familiarity with Emerging Technology

In Task 1 of this research effort, our team identified five (5) major technology groups that will significantly impact MDOT practices in the short/mid/ and long term. These technology groups included:

- Mobile Robotics (examples: Automated vehicles, Drones, inspection robots (crawling, climbing, or aquatic robots)
- Advanced Traffic Management Systems (Examples: ITS, Advanced Signals)
- Big Data Structures, Analysis, and Applications (Examples: Artificial Intelligence, Machine Learning, Neural Networks, Deep Learning)
- Mechanistic-Empirical Design & Engineering
- Complete Streets Design & Context-Sensitive Solutions

As part of the effort to assess the existing situation within MDOT in terms of technology awareness and applications, we asked the respondents if they have any familiarity with the technologies mentioned above.

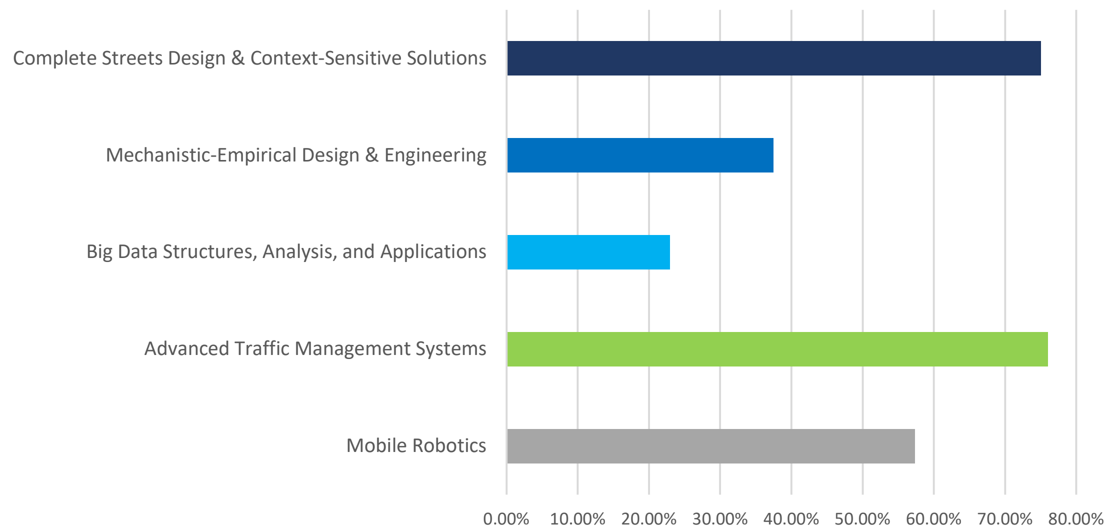
The technology group that survey respondents have had the most familiarity with is the "Advanced Traffic Management Systems (ATMS)" (76.04 percent). This finding is not surprising as MDOT has invested in implementing ITS and advanced signal technologies on Michigan roadways over the past decade. As a result, MDOT employees have had involvement in such projects.

Survey responses also indicate a good level of familiarity with "Complete Streets Designs and Context Sensitive Solution" within the staff. More than being a technology, these are mostly technology concepts that are constantly evolving and improving. The department needs to keep the team whose work is relevant to these technologies aware and informed of the updates.

The third-highest level of familiarity belongs to "Mobile Robotics." This group includes technologies such as AVs, UAVs, inspection robots, climbing, or aquatic robots. Over the past few years, MDOT has put lots of effort into establishing its position as a CAV technology leader by exploring the technology capabilities through pilots, demonstrations, working groups, and research activities.

While awareness is not equal to working with the technology, it is yet a good starting point. To expand the internal knowledge of the technologies, MDOT needs to offer professional development opportunities to the staff by involving them in related projects, sending them to the industry events and conferences, offering in-house lunch-and-learn opportunities, leveraging FHWA's Local Technical Assistance Program (LTAP) resources, and offering on-the-job training opportunities through partner educational institutions. Also, hiring technology-informed employees will eventually lead to expanded Department activities in relevant technology areas.

FIGURE 80. FAMILIARITY WITH EMERGING TECHNOLOGY AMONG THE CURRENT EMPLOYEE SURVEY PARTICIPANTS



Source: CAR-WIN MDOT Staff Survey (2021)

6.4 Existing Soft Skills

Based on the soft skills identified in Task 2 of this research effort, we asked the participants if they currently have any of those skills within their groups. Table 23 summarized the responses. According to the responses, MDOT employees show satisfactory soft skills levels, but there is still room for improvement. Skills related to diversity (e.g., cultural awareness), creativity and innovation, interpersonal relationships (e.g., emotional intelligence), and teamwork (e.g., communication and system thinking) are amongst those that need improvements.

TABLE 23. AVAILABILITY OF SOFT SKILLS WITHIN SURVEY RESPONDERS' TEAMS

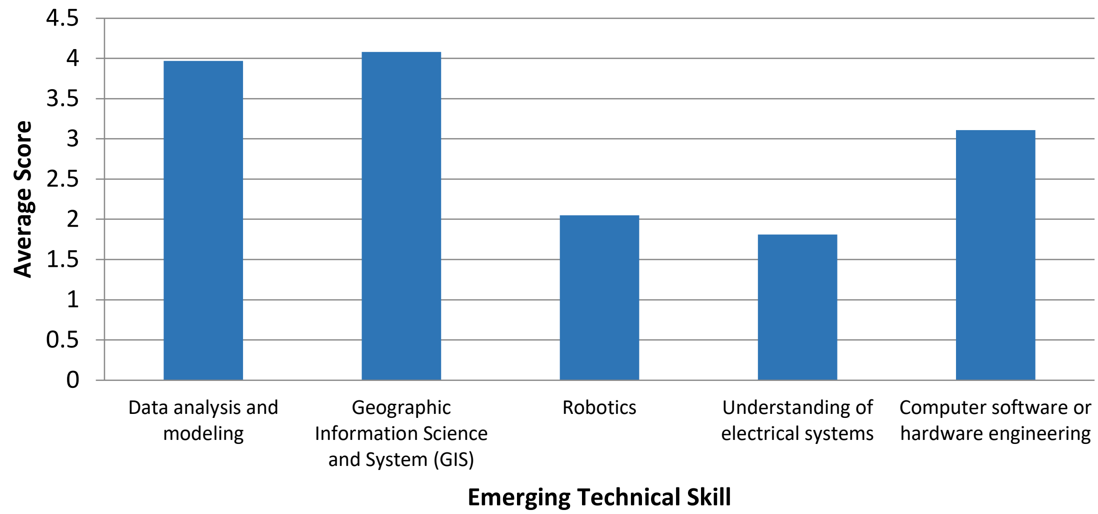
Answer Choices	Responses	
	Percent	Number
Creativity	80.0	76
Innovation	85.3	81
Growth mindset	57.9	55
Emotional intelligence	54.7	52
Cultural awareness	54.7	52
Decision making	92.6	88
Task management	94.7	90
Communication	90.5	86
Collaboration	93.7	89
System thinking	44.2	42
Other (please specify)	3.2	3

Source: CAR-WIN MDOT Staff Survey (2021)

6.5 Need for Technical skills

Task 2 of the report lists 18 primary emerging technical skills needed to accommodate this era of advancement in the industry. In the survey, we categorized the identified technical skills into five major categories. The survey asked participants to rank the technical skills they are looking to develop through upskilling (training) within your group (1 highest priority – 5 lowest). Survey responders ranked ArcGIS, Data Analysis, and Modeling as the highest priorities with an average score of 4.1 and 4.0. Surprisingly enough, respondents did not consider robotics and understanding electrical systems as one of the department's immediate skill needs. This finding could be due to a lack of understanding of emerging technologies' fundamentals or a lack of vision for applying the technologies in the department's practices.

FIGURE 81. RANKING OF EMERGING TECHNICAL SKILLS NEEDED IN MDOT UNITS IN THE NEXT FIVE YEARS



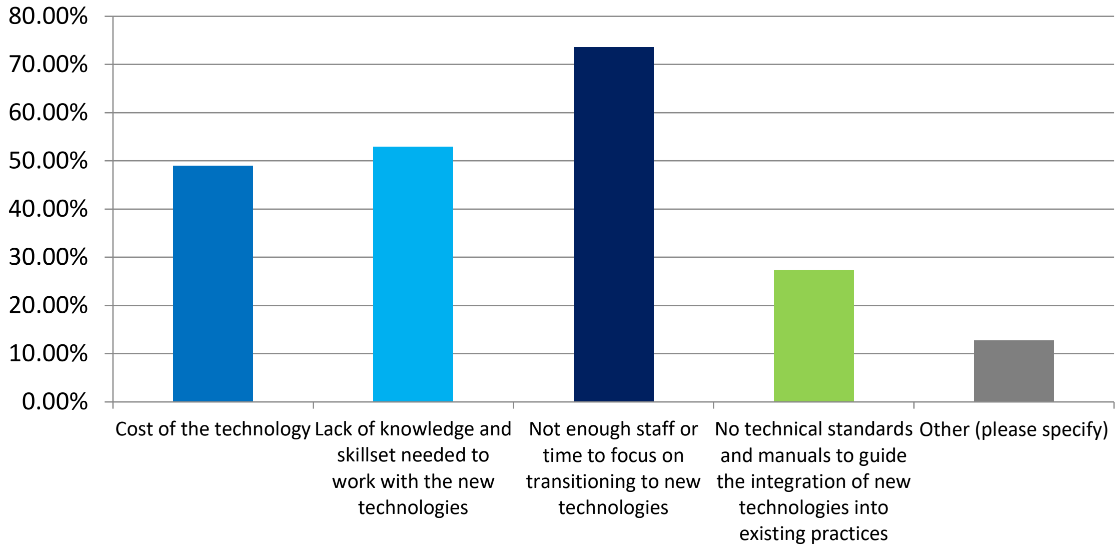
Source: CAR-WIN MDOT Staff Survey (2021)

6.6 Technology Adoption and Challenges

More than 73 percent of survey responders believe that limited staff or time to transition to new technologies is the biggest challenge to adopting emerging technologies into MDOT businesses. Participants ranked lack of knowledge and skill set needed to work with the new technologies and technology costs as the second and third most challenging factors. The respondents believe that MDOT units require more resources to explore the benefits of the technology, and then staff can acquire new talent or technology skills.

The other challenges mentioned include technology interoperability and internal processes, especially with the necessity of involving DTMB in technology-related processes, cybersecurity risks, and high employee turnover rates.

FIGURE 82. MAJOR CHALLENGES TOWARD EMERGING TECHNOLOGY ADOPTION INTO MDOT BUSINESSES



Source: CAR-WIN MDOT Staff Survey (2021)

6.7 Internal Goals for Technology Integration

The survey asked about the respondents' understanding of their unit supervisors' goals concerning technology integrations. Our team received 78 unique answers that could be categorized into three major categories as follows:

Technology as a tool: In this group of responses, the respondents mostly mentioned goals related to understanding the technology relevant to their work area and the applications and then using them in their work. Some examples include:

- Create and maintain a pro-technology mindset within the group
- Keep up with new, changing industry standards and technology.
- Incorporate technology into MDOT businesses to maintain the department's position as a leader in transportation technologies
- React to and implementing innovations in different areas.

Some of the technologies that participants mentioned in their responses include:

- Big data and data analytics
- Connected and Automated Vehicles
- Smart signal management system
- Central data integration and data management
- ArcGIS
- Surveying and data collection tools
- Road design tools

Skills and Talent: The second category is the need for new skills and talent to apply and use emerging technologies. The followings are some examples of survey respondents:

- Finding people trained and able to assist our region with integrating these technologies into our 5-year program.
- Getting staff up to a knowledgeable level of design software capabilities when technologies and requirements are often changing.
- Receiving more funds to move staff into more specialist positions within their disciplines.
- For the team to remain willing and ready to adapt to the technology.
- Staff prepared for complete digital delivery and modeling, including construction staff.

Benefits of The Technology: The final category of goals related to the advantages of applying emerging technologies into MDOT practices. Such benefits include:

- Inclusivity
- Accessibility
- Safety
- Efficiency
- Effectiveness
- Clarity of the processes
- Improved quality of customer services
- Improved communication and teamwork
- Improved competency
- Innovative solutions

6.8 Desired Skills in the next five years

In another survey question, the team asked the respondents to list a few technical and soft skills their group desires within the next five years. Among the responses, the participants listed GIS, surveying, leadership, adaptability, and effective communication as desired skills. Here is the complete list of the respondents' desired skills:

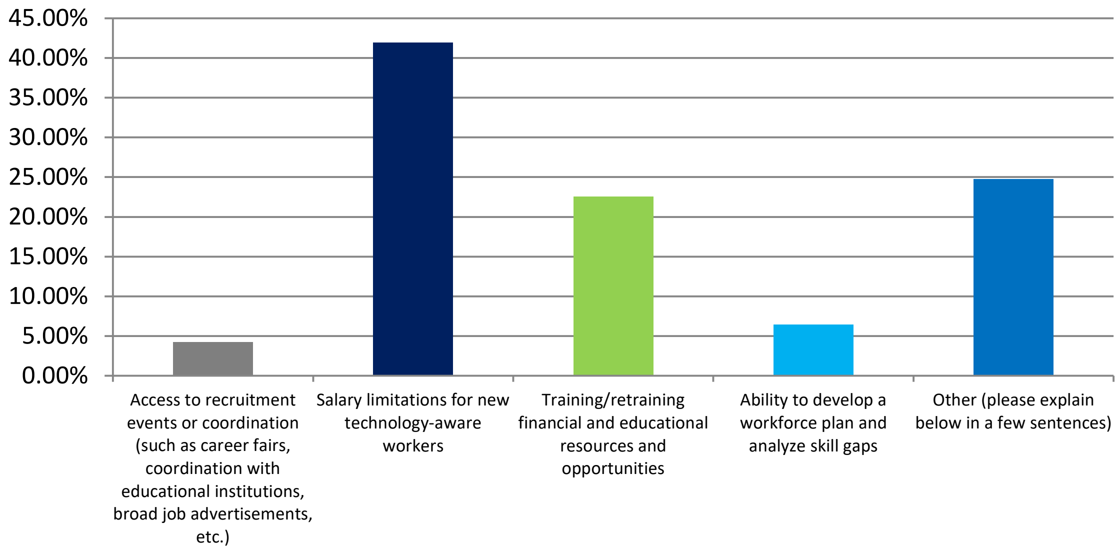
TABLE 24: SURVEY RESULTS: DESIRED SKILLS IN THE NEXT FIVE YEARS, 2021

Technical	Soft
• Artificial Intelligence and machine learning • Network Security • 3D modeling and digital design • GIS • GPS/Survey equipment in the field • Robotics and automation • Customer Service Management • Computer and Information Science • Data analytics, programming, modeling, and visualization • database management and reporting • Surveying skills in the construction unit with advanced equipment • Electrical circuits and wiring diagrams • Asset Management • Network communications • Software Development and Programming, Hardware Technician • Enterprise information management	• Innovation • leadership • Effective team building/teamwork • Effective communication • Customer Service • Growth mindset • Emotional Intelligence • Adaptability • Conflict resolution • Collaboration • Trust building • Inclusion and equity • Critical Thinking • Cultural awareness • Networking skill • Problem Solving • Time and resource management • Systems thinking • Proactive work attitude • Public speaking/presentations • Passion and work ethic • Decision Making

6.9 Most significant Challenges to Achieve Goals

To capture respondents' concerns regarding the goals mentioned above, we asked them to select the item representing the most significant challenge to achieve those goals. Here's a summary of the responses:

FIGURE 83. CHALLENGES FACING MDOT UNITS TO ADOPT EMERGING TECHNOLOGIES



Source: CAR-WIN MDOT Staff Survey (2021)

The majority of respondents (41.2 percent) chose "salary limitations for the new technology-aware workforce" as the most prominent challenge for technology adoption in the next five years. This issue is not limited to MDOT, but other DOTs across the country are suffering from not attracting or retaining talent due to highly competitive salaries offered by private sector companies. "*According to the 2012 salary survey conducted by the American Society of Civil Engineers (ASCE) and the American Society of Mechanical Engineers (ASME), state-employed engineers received less than the average income of engineers*". (Harper, Bogus, Kommalapati, & Choe, 2018)

6.10 Hard-To-Fill Positions

The organization-wide survey results represent a broad range of respondents from MDOT, particularly those in supervisory, managerial, engineering, administrative, and directorial positions. The identified hard-to-fill positions are categorized into six overarching occupation groups: Electrician, Engineering, Technician, Specialist, Analyst, and Other. The grouped occupations pulled from the survey results are below.

TABLE 25:SURVEY RESULTS: OCCUPATIONAL CATEGORIES, 2021

Analyst	Electrician	Specialist	Technician
• All Transportation-Related Analysts (Entry/Mid-level/Experienced) • Financial Analyst • Help Desk and Software Application Analyst • Predictive Analyst • System Analyst • Traffic Analyst	• All Transportation-Related Electricians (Entry/Mid-level/Experienced) • Electricians • Licensed Electricians • Master Licensed Electrician • Region Electrician • Traffic Signal Electrician	• All Transportation-Related Specialists (Entry/Mid-level/Experienced) • Area Density Specialist • Bridge Design Plan Review Specialist • Congestion Management Specialist • Data Specialist • Engineering Specialist • Freight Movement Specialist • GIS Specialist • Prevailing Wage Specialist • Property Specialist • Resource/Environmental Specialist • Statewide Model Specialist • Technician Specialists	• All Transportation-Related Technicians (Entry/Mid-level/Experienced) • Construction Field Technician 11 • Construction Office Technician 11 • Construction Technician • Construction Transportation Technician • Departmental Technician • Design Technician • Equipment Technician • Field Technician 11 (Entry/Mid-level) • Material Testing Technician • Office Technician • Permits Technician • Traffic & Safety Technician • Transportation Technician

TABLE 26:SURVEY RESULTS: OCCUPATIONAL CATEGORIES, 2021 CONT.

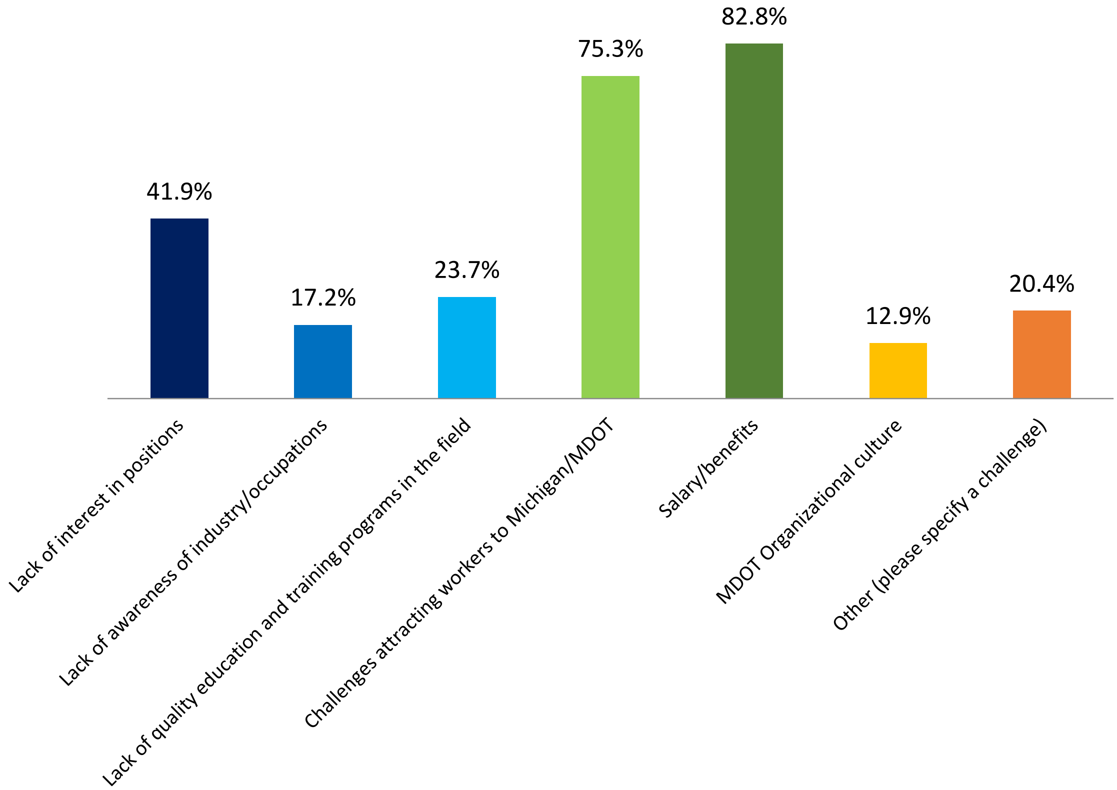
Engineering		**Other**	
• All Transportation-Related Engineers (Entry/Mid-level/Experienced) • Act 51 Engineer • All Engineers (Entry/Mid-level/Experienced) • Assistant Construction Engineer • Assistant Region Design Engineer • Bridge Design Plan Review Engineer • Bridge Engineers • Bridge Inspection Engineer • Civil Engineers (Geographic Location Issues) • Construction Engineer • Cost and Scheduling Engineer • Design Engineer (Entry/Experienced) • Design Staff Engineer • Documentation Engineer • Engineering Managers • ITS Engineer • Local Agency Construction Engineer • Local Agency Engineer	• Mid-level engineers (MDOT Level 12) • Municipal Utilities Engineer • Operations Engineer • PE Engineer • Qualified Engineers • Rail Design Engineer • SDE Database Engineer • Senior Engineers • Signal Operations Engineer • Specifications Review Engineer • Staff Engineer • Street Lighting Engineer • Technical/Journey Level Engineers • Traffic & Safety Engineer • Traffic Operations Engineer • Transportation Design Engineers • Transportation Engineer (Entry/Mid-level/Experienced) • Utility & Permit Engineer	• Bicycle & Pedestrian Coordinator • Bridge Maintenance Inspector • Bridge Safety Supervisor • CAV experts • Data Liaison • Data Scientist • Designer • Geologists • GIS Supervisor • Heavy Equipment Mechanics • HPMS • Intermodal Management System Administrator • Interns • Land Surveyor • Landscape Architect • Lead Maintenance Workers • Lead Workers • LTE 13 • Maintenance Employees • Part-Time TMW • PE Positions	• Permit Agent • Pilot • Project Manager (PE) • Python Scripter • Real Estate Professionals • Secretary • Senior Project Manager-Construction • Software Development • Soils crew member • State Workers (WC) • Steeplejacks • Supportive Outreach • Surveyor • TE 11 • TE 12 • Technical Hardware Expert • Technical Staff • TMW Positions • Transportation Maintenance Workers • Transportation Planner • Traveling Mix Inspector

6.11 Challenges for filling hard-to-fill positions

According to survey results, the most significant challenges MDOT faces in attracting and retaining highly skilled workers for their hard-to-fill positions are (1) salary and benefits (82.8 percent); (2) attracting workers to Michigan and MDOT (75.3 percent); and (3) lack of interest in positions posted (41.9 percent). Other talent attraction challenges include outdated State of Michigan Civil Service Job Specifications, uninterested or unqualified staff, specialized jobs requiring job and institutional specific knowledge, and higher salaries offered in the private sector. Below are the additional responses from

- “Expecting signal electricians to be technology experts and traffic engineering aware all while paying them less than a standard building electrician.”
- “Specifications are too narrow and only allow hire within. Current staff not interested or not qualified.”
- “Generally, recruiting can be difficult at Blue Water due to our location being fairly isolated and not a particularly easy commute for many.”
- “Geographic Locations at times create difficulties. We have had to hire non-civil engineers for positions that would normally be civil engineers.”
- “Competitive pay compared to the private sector. Lack of growth in a technical job - meaning someone wanting to become an industry expert designer is stopped at a 12-level engineer or one 13-level (Asst Design Eng). The structure at MDOT requires management to move up after that.”
- “Civil Service”
- “Hard to keep high performers in the areas of Information Technologies, ITS, Connected Vehicles. Civil Service classifications make it very hard to adjust pay scales, and staff acquires knowledge and experience. Too many rules.”
- “Work-loads are ever increasing; staffing is continuing to go down.”
- “Often get candidates with an engineering degree and no background or experience in transportation.”
- “Civil service not understanding [the] position and denying Position descriptions.”
- “Higher salaries in the private sector.”
- “Potential employees [are] drawn to other parts of the state.”
- “State of Michigan Civil Service Classifications are antiquated.”
- “Specialized training and education.”
- “Some hard-to-fill jobs are very specialized. It is the job-specific and institutional-specific knowledge that can be difficult to ramp up.”
- “State of Michigan Civil Service Job Specifications are outdated.”
- “Finding people with 21st-century job skills: Collaboration, Communication, Critical Thinking, Creativity.”

FIGURE 84. CHALLENGES FOR FILLING HARD-TO-FILL POSITIONS



Source: CAR-WIN MDOT Staff Survey (2021)

6.12 Desired Recruitment

Over half of respondents (60.7 percent) have added new technical or soft skill requirements to their job postings over the past three years. As mentioned in task 4, many of these new skills stem from emerging technologies and the changes needed to maintain current infrastructure. New skills are also required to close the gap in departmental vacancies by promoting from within. The technical and foundational skills currently requested in units around MDOT are below. GIS seems to be the most commonly requested technical skill from respondents.

- “Even a journey electrician is expected to know how to program a traffic signal controller, which is a highly complex computer set up to a communications network on which people's safety relies.”
- “Planisware, Jobnet, GIS.”
- ‘We try to incorporate items that refer to the Mission, Vision, and Values statements.”
- “I believe leadership type of items have been added to postings and interview questions.”
- “The ability to learn TAMS.”

- “Focus on leadership skills and competencies.”
- "Data analytics including Power BI, Google Analytics, Business Objects.)
- “LCPtracker”
- “Data analysis has been a skill, but task and project management to implement the results from the analysis has been added.”
- “Stressing communications skills of all staff members.”
- ‘Independent actions, teamwork, and communication skills.”
- “Redefined roles of assistant construction engineers. Dual role as construction engineer and designated rep for LAP projects based on geography then balance of workload.”
- ‘Yes, adding modeling/drafting software requirements.”
- "Creating a positive work environment.”
- “Knowledge of computer systems."
- “Utilization of excel for maintenance budget tracking.”
- “GIS duties, asset management, performance-based practical design awareness.”
- “GIS database management, Arc GIS Online management, Traffic data collection software specialties.”
- “Proficiency in survey technology to support 3 d model usage.”
- “Updated the software skills required to be consistent with our current needs.”
- “Use of GPS technology for Transportation Technicians.”
- “Many tied to new software programs or technology.”
- “Projects and Contracts focus.”
- “Drone and limited GIS.”
- ‘Project management skills.”
- “Use of TAMS software for lead maintenance workers.”
- “Experience or familiarity in use of geotechnical investigation methods and equipment.”
- “Visioning, Leadership, Group dynamics, leadership standards of excellence.”
- “GIS and collaboration.”
- "Leadership.”
- “Team Oriented."

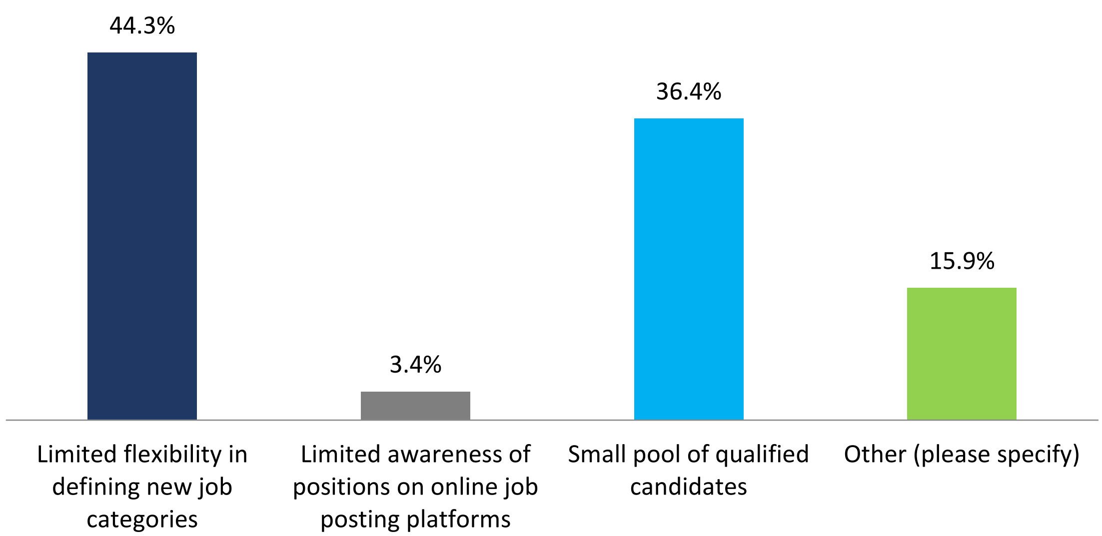
There are also many new industry certifications and external training programs that have been created over the past three years to meet the needs of the transportation field, with 38.8 percent of respondents identifying new certifications below. Again GIS, but also DISC, and bias and diversity training appear frequently in these responses.

- “Training provided by Engineering Support for design software. Design Basic Training.”
- “MDOT House, talent reviews.”
- "Training avail through OOD (soft skill).”
- “Plenty of technical training also available."
- “With the pandemic and greater availability of training and conferences virtually, these opportunities have been made available to more staff members.”
- “Drone pilot certification.”
- “Project PDF and Open Roads Designer.”
- “Certified Project Manager, a lot of Federal Training opportunities.”
- “State supplied implicit bias training and another group that targets Women in Engineering.”
- “Bias training.”
- “With conferences going virtual, this has opened up more opportunities for staff to attend and gain knowledge.”
- “TAMS and MDSS.”
- “DISC, MDOT House training, Diversity, Equity and Inclusion, IT Security, COVID, Implicit Bias.”
- “We’ve been intentional about making more leadership training available.”
- "Claims analysis.”
- “FHWA core curriculum.”
- “Innovative Contracting methods."
- “Access Database Training.”
- “Implicit bias training, cybersecurity.”
- “Connected vehicle/infrastructure, various computer training, great variety of training from IBTTA.”
- “GPS Training and Computer skills training (Bluebeam).”
- “Level 1 Multistrand Post-Tensioning Field Installation.”
- “Level 1 Multistrand and Grouted Post-Tensioning Inspector.”
- “GPS and total station training to assist field staff in inspection of construction work.”
- “New PM training that is specific to MDOT practices.”
- “IMSA.”
- “ArcGIS training.”
- “We administer a tiered GIS training program in partnership with a local university and ad hoc training of Traffic Data Management System to internal and external partners including other state agencies, local transportation agencies, consultants and the public.”
- “Available GIS training and training for Geopak Design software.”
- “ESRI MOOC, ESRI R&H, conferences, SOM classes, MSU, and Roadsoft classes.”
- “Yes, the current virtual training has created many new opportunities for staff.”
- “ITE-Road Safety Professional certification and PTOE certification (not currently encouraged by MDOT).”
- “DiSC certification; project management knowledge or certification (not necessarily a PMP - Project Management Professional).”
- “We offer the availability of workshops to staff to learn and upskill new technologies becoming available.”
- “Inspection of self-consolidating concrete, ArcGIS.”

6.13 Recruitment Challenges in Regards to HR Processes

There have been many challenges identified facing MDOT management. Other than wages, training, and recruitment, MDOT also has a very high turnover. This major challenge is a direct result of the challenges. Federal compliance and regulation, and flexibility hinder the organization from maintaining and growing, particularly during the COVID-19 pandemic. Uncertainty around employment and benefits is contributing to turnover factors, while heavy workloads, outdated schedules, and low wages promote an unyielding environment in which employees often part from MDOT.

FIGURE 85. RECRUITMENT CHALLENGES IN REGARDS TO HR PROCESSES



Source: CAR-WIN MDOT Staff Survey (2021)

Below are the internal responses on additional challenges and concerns facing MDOT management in both the short and long-term.

- “We need qualified electricians. To get them and keep them, you need to pay them what they are worth. They are worth quite a bit more than we are paying them now.”
- “Staffing levels in Superior seem adequate for the program we expect in coming years, although I'd like to hire few TMWs and then need fewer LT TMWs.”
- “It can be frustrating when you can’t hire outside of the current staff. We aren’t getting the right fit for the job.”
- “We have at times difficulty in classifying staff (with Civil Service) to higher levels based on their higher-level duties that would allow one to advance in their current role. Region Resource Analyst and Region Property Specialists come to mind.”

- “If help is needed, we have not been able to grow staff but become more reliant on consultants.”
- “I am a new supervisor (working out of class). Three months in the position.”
- “In my opinion and from what I have seen, the starting wage in the positions I’m trying to fill isn’t allowing employees to want to stay and make this a career like when I first started. The wages are not keeping up with the market. This is the biggest reason why employees are leaving.”
- “Flexibility with MDOT organizational structure and definition of roles, and rules with flexibility on overlapping duties during transitional periods, such as retirements, should be areas to focus on promoting knowledge transfer.”
- "It's all about the $ and benefits.”
- “Consultants pay twice as much, and now their benefits are the same or equal to MDOT. They also offer the same flexible schedule as MDOT. There really is no reason to stay anymore."
- "Other areas our unit would like to work on or obtain training on in the future.”
- “Use of survey data with GIS to document construction work and include in MDOT asset management system.”
- “New uses for drones to conduct quantity surveys and measurements of completed construction work.”
- “New ways to utilize software to develop working maps with photos and other information to help facilitate communication with contractor staff in the field."
- “Change is happening so quickly, hard to anticipate technical needs that will be critical in next five years, let alone 10 or 20 yrs.”
- “Federal and state reporting requirements typically dictate the knowledge, skills, and educational requirements of my workgroup. More recently, industry and public expectations have started to influence a change.”
- “The Office of Business Development is responsible for all regulatory Federal Civil Rights Compliance for MDOT.”
- “We need an increase a competitive, if not better, benefits and salary package than the private sector to get a better and more qualified pool of candidates.”
- “I am very concerned that there is not a long-term career path for individuals wanting to focus on design engineering. The typical design engineer is essentially topped out as a TE 12 after approximately five years. Our system practically requires individuals who seek higher-level positions to move into other areas of work focus.”

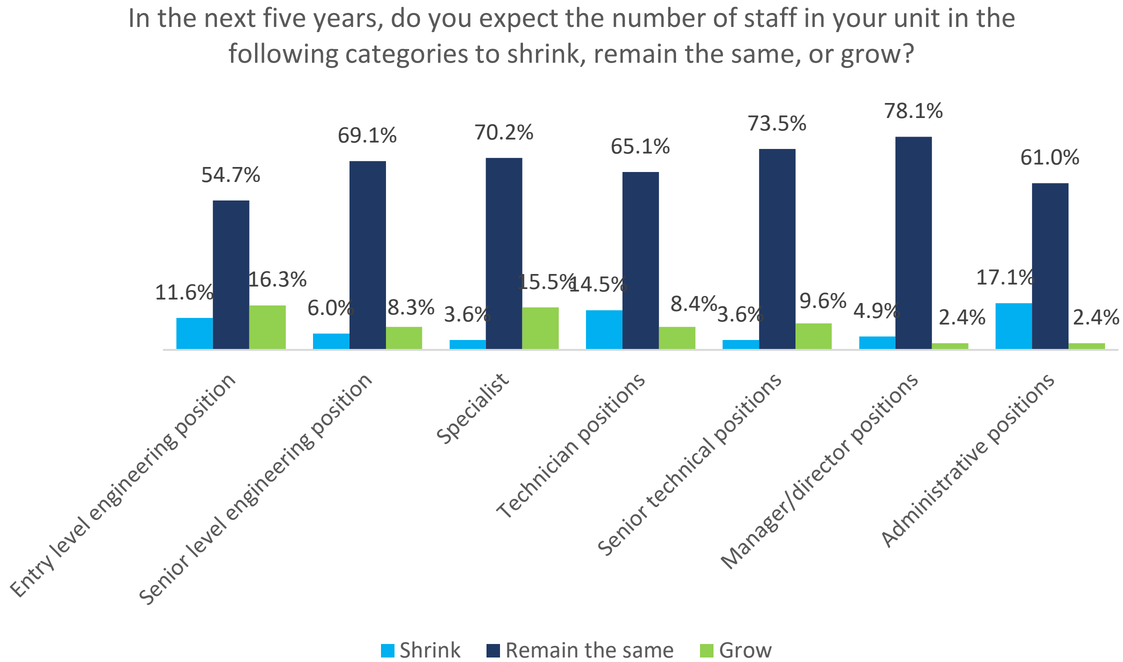
6.14 Other Factors Influencing Hiring

Over the next five years, MDOT management felt the staff in their department would remain the same, while others expect their staff to decrease. Respondents felt the growth or shrinkage would only be around an average of 1-3 workers per department, including employees receiving promotions or retiring. The greatest challenge expressed was the salary limitations for new technology-aware workers, with a 42.0 percent response rate. Other challenges include training and retraining financial and educational resources and opportunities (22.6 percent) and the ability to develop a workforce plan and analyze skill gaps (6.5 percent). Below are the specific challenges faced by respondents.

- “Rapid loss of knowledge in the signal electrician realm as employees leave MDOT.”
- “Retaining employees long enough to develop skills.”
- “Job specs are too narrow.”
- “Worker benefits.”
- “Funding to pilot and obtain the technology.”
- “Civil Service rules. Trying to fit positions into existing models and the extended time it takes to establish, recruit, and fill new positions.”
- “Creating tech positions that motivate/attract individuals with industry experience that will become a tech expert.”
- “Identifying technologies applicable to improving efficiency and level of service of work area and having funding available to implement new technologies.”
- “Support for initiatives and investments from upper management.”
- “Organization challenges to devote positions to new skills sets while not being ready to give up existing positions/task.”
- “The IT structure at the state of Michigan.”
- “Constant turnover and too many roadblocks on the path to implementation.”
- “MDOT organization can be "clunky" to prepare staff for next steps or allow for overlap/mentoring before known employee departure, as in retirement of key positions.”
- “Fear of change from known technologies. Government typically takes a risk avoidance or risk transfer approach to technology advancements and allows the private sector to set the pace and then demand the agency respond instead of taking the lead.”
- “Getting buy-in from staff. Often new tech is seen as a burden, adding more work to an already busy workload. The new tech must make life easier, not harder. If group can see the benefit to them and the overall benefit, they will be much more receptive to learning and using it.”
- “Limited resources and competing strategies.”
- “Too many duty and tasks across many areas.”
- “Lack of FTE's; cost of training.”
- “Ability to hire staff with the appropriate skill set. Will require staff with degrees outside the norm for transportation planners.”
- “Free time to focus on the goals with multiple competing priorities.”
- “Funding limitations within the department.”

“Knowing what technologies are available and matching them with the people with the skills to use them.”

FIGURE 86. EXPECTED CHANGES IN THE NUMBER OF STAFF WITHIN THE UNITS



Source: CAR-WIN MDOT Staff Survey (2021)

Most respondents, 81.3 percent, do not foresee any major construction, bridge, railway, or major infrastructure projects that would trigger a hiring event in their unit. However, units on such projects as the Plaza Expansion, Design Build, and Management of the Connected and Automated Vehicle Infrastructure would rather have increased support from temporary staff than consultants. Respondents fear increased funding would put more pressure on staff already working with heavy workloads, causing more turnover for MDOT.

Appendix B: Task 1 Background Research Results

The following sections describe the process through which the five core emerging technologies were selected.

7.1 MDOT Technology Strategic Planning

CAR has reviewed existing MDOT planning documents that guide the Department's integration of technology into transportation systems management and operations. This section summarizes the key aspects of each document.

A review of MDOT's most pertinent technology-related planning documents reaffirms MDOT's commitment to remaining informed of the advancements in transportation-related technology. Further, MDOT aspires to operate with sufficient flexibility and a culture of innovation to facilitate the efficient adoption and utilization of emerging technologies when appropriate. This collection of plans is often specific in describing technology innovations that MDOT has explored and adopted in the past but does not propose specific deployment plans or investment strategies for future years.

7.1.1 Transportation Systems Management and Operations Plan

Cambridge Systematics delivered MDOT's current (Version 4) Transportation Systems Management and Operations (TSMO) Plan in January 2020. The Plan documents Michigan's strategic direction, actions, and recommendations for operating and managing an optimized, integrated transportation network. MDOT employs TSMO strategies and solutions to provide more efficient use of existing transportation resources by implementing strategies, deploying technologies, and integrating systems to improve the safety and mobility of the transportation system sustainably.

Strategic Areas of Focus

The MDOT TSMO Plan emphasizes seven "strategic areas of focus" (Cambridge Systematics, January 2020, pp. 17-19). Most of these areas of focus somehow relate to technology, as described below:

- **Evaluate and Streamline Information Technology (IT) Processes.** Many MDOT's core IT-related activities are supported by the Michigan Department of Management and Budget (DTMB). DTMB's mission is to enable efficient state governance by centralizing services required by multiple agencies (Michigan Department of Technology, Management and Budget, n.d.). However, the strategy of providing common services to all state government agencies may impose barriers to addressing the unique needs of individual departments. This area of focus is intended to identify inefficient IT processes and pursue improvements.
- **Integrate Operations Across All Business Areas.** The TSMO Plan identifies ten business areas. These business areas often operate independently of each other (i.e., as 'silos') even when it would make sense to cooperate to share resources such as data and funding sources. This area

of focus is intended to break down these silos to enable the entire department to operate more

- **Integrate the Operations of Intelligent Transportation Systems (ITS) and Signals.** Breaking down current silos between ITS and signal operations is emphasized. MDOT considers it a priority to improve coherent operations between signals, ITS devices, and the Statewide Transportation Operations Center (STOC).
- **Adapt Processes, Products, and Training to Advances in Technology.** MDOT considers it a priority to remain engaged with the latest technologies to improve the management and operations of the transportation system.
- **Enhance Communications with Stakeholders.** This focus area is intended to assure that both internal and external stakeholders are sufficiently informed of MDOT's priorities and strategies.
- **Prioritize Resources to Meet Emerging Critical Needs.** This focus area may be better understood as an effort to identify activities that are not a critical need for MDOT's goal of improving system management and operations.
- **Drive Progress with Meaningful Performance Measures.** There is much potential for effective data-based decision support of TSMO efforts. This area of focus emphasizes selecting and utilizing meaningful metrics that do not unduly burden relevant business units.

TSMO Business Areas

MDOT has identified ten TSMO business areas and has assigned a lead for each area.[12] Several of these are technology-focused. The ten business areas are (Cambridge Systematics, January 2020, p. 12):

- Traffic Incident Management
- Work Zone Management
- Congestion (Recurring) Management
- Safety (All Modes)
- Modal Interaction and Integration
- Road Weather Management
- Field Equipment, Asset, and Functionality Management (ITS and Signals)
- Transportation Operations Centers and Traveler Information Systems
- Connected and Automated Vehicle Systems
- Data Collection, Storage, Utilization, Analytics, and Decision-support Systems

Business Area Recommendations

Each business area's leads were asked in summer 2017 to submit priority recommendations to the TSMO Core Team. Before the publication of this Plan, only the Field Equipment, Asset, and Functionality Management (ITS and Signals) business area had submitted a recommendation. The ITS/Signals business area recommends initiating an effort to determine how many electricians MDOT should have on staff to maintain signals at an appropriate level of service (Cambridge Systematics, January 2020, p. 25).

[12] The TSMO Plan does not explain how the ten business areas were selected.

7.1.2 Intelligent Transportation Systems Strategic Plan

HNTB Corporation delivered the MDOT Strategic Plan for Intelligent Transportation Systems in 2018. MDOT's ITS Program falls under MDOT's TSMO initiative, and thus this Plan is explicitly supportive of the TSMO Plan. The MDOT ITS Program Mission is to "Integrate MDOT's ITS Program into all TSMO business areas and leverage both proven and emerging transportation technologies to enhance safety sustainably, mobility, economic benefit, and support improved quality of life" (HTNB, 2018, pp. 5-6).

MDOT has seven ITS focus areas that align with the seven TSMO focus areas, as shown in Table 27 below. The plan uses a hierarchy in which the seven focus areas are broken down into a series of goals. These goals are associated with a series of actions intended to achieve the goals (HTNB, 2018, pp. 10-15). Many of these actions are very relevant to integrating technology into MDOT's core TSMO efforts, including:

- Maintain ITS system functionality during equipment upgrades and software updates
- Develop ITS network security plan
- Improve ITS data sharing with the public (e.g., via MI-Drive, traveler information systems)
- Minimize the negative impacts of work zones and traffic incidents.
- Improve data sharing across Department (e.g., via DUAP)
- Support traveler information systems and partner with private sector providers such as Waze, Google, HERE, etc.
- Utilize ITS Asset Management Database to improve system planning
- Define metrics describing effective ITS deployments and collect appropriate data on deployed assets to determine if anticipated benefits are being realized.

TABLE 27: TSMO – ITS FOCUS AREA ALIGNMENT

	TSMO STRATEGIC AREAS OF FOCUS		ITS FOCUS AREA
1	Evaluate and Streamline Information Technology Processes	→	Information Technology Processes
2	Integrate Operations across All Business Areas	→	TSMO Business Area Integration
3	Integrate the Operations of ITS and Signals	→	ITS/Signal Program Integration
4	Adapt Processes, Products, and Training to Advances in Technology	→	Emerging Technologies
5	Enhance Communications and Outreach to External and Internal Stakeholders	→	Partners and Outreach
6	Prioritize Resources to Meet Critical Emerging Needs	→	Workforce Development
7	Drive Progress with Meaningful Performance Measures	→	Performance-Based Priorities

Source: HTNB

7.1.3 Connected/Automated Vehicles (CAV) Strategic Plan

MDOT's CAV effort is a subset of the ITS Program and ultimately falls under MDOT's TSMO initiative. WSP delivered the CAV Program Plan in 2017. This plan's technology focuses primarily on connected vehicle technology using a family of standards collectively known as dedicated short-range communication (DSRC) (WSP, 2017, p. 4). The Plan states that connected *and* automated vehicle technology are considered together because "MDOT views Connected Vehicle (CV) technology as an enabling technology for Automated Vehicles (AV), and thus sees actions supporting CV technology development and deployment as also supportive of future AV operation on state roadways."[13]

The CAV Strategic Plan is framed around six CAV Program goals (WSP, 2017, p. 4):

- Serve as a national model to catalyze CAV deployment.
- Establish foundational systems to support wide-scale CAV deployment.
- Make Michigan the go-to state for CAV research and development.
- Accelerate CAV benefits to users.
- Exploit mutual benefit opportunities between CAV technologies and other department business processes and objectives.
- Use Michigan experience to lead dialog on national standards and best practices.

[13] Research has not identified any commercial efforts to deploy autonomous vehicles that are enabled by DSRC. Currently, autonomous vehicles are typically connected via 4G LTE commercial cellular network. (With the exception of Waymo, all autonomous vehicles remain in development phase and cannot operate on public roads without a safety driver.)

7.1.4 Transportation Asset Management Plan

Of the planning documents reviewed for this task, only the 2019 Transportation Asset Management Plan (TAMP) is federally required (Michigan Department of Transportation, 2019). The TAMP represents new state reporting requirements first introduced by the 2012 federal transportation funding bill, MAP-21. Michigan's 2019 TAMP is the second iteration of a planning document that will be updated annually from now on.

States are now required to provide an annual TAMP to describe the states' risk-based asset management plan for all National Highway System (NHS) routes within the state. While MDOT and many other DOTs have traditionally considered transportation asset management (TAM) as a strategy to maintain highway pavements and bridges, federal law defines TAM much more broadly. The federal definition is:

> *"a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the lifecycle of the assets at minimum practicable cost."*

In other words, FHWA envisions the TAMP as a document that encompasses both TSMO and programming activities within a state (U.S. Department of Transportation, Federal Highway Administration, 2018). States are required to address the NHS's pavement and bridge assets but are encouraged to include additional assets. The optional scope of state TAMP plans can consist of assets beyond pavement and bridges (e.g., ITS devices, signage, markings, etc.) and roads that are not part of the NHS.

State TAMPs are required to report, at minimum, a series of objective metrics reflecting nationally accepted best practices for pavement and bridge condition assessment for all NHS routes within the state. The intent of federal legislation and FHWA guidance is for states to utilize these best practice performance metrics for data-based decision support. However, MDOT reports that the department is unprepared to incorporate the required reporting metrics into the functional state TAM program. The 2019 TAMP describes MOT's current [non-compliant] asset management processes by which the Department makes planning and programming decisions.

Risk Management

A State DOT's TAM process should identify threats that can affect the condition of NHS pavements and bridges and the NHS's performance and determine the risk profile of such threats. This analysis should include risks associated with current and future environmental conditions (such as extreme weather events, climate change, and seismic activity), financial risks (such as budget uncertainty), operational risks (such as asset failure), and strategic risks (such as environmental compliance).

MDOT has developed a risk-assessment framework with two primary threat categories (agency threats and program threats) and eight sub-categories.

TABLE 28: MDOT AGENCY THREATS

Threat Category	Threat	Consequence Rating[14]
Labor	Staffing shortage	5
	Inability to attract needed talent	5
Technology	Inability to procure and manage new transportation system technologies	3
	Inability to procure state-of-practice technology support for day-to-day activities of staff	3
Financial	Federal and state funding levels	3
	Federal and state funding structure	3
	Changes in federal regulations	2
	Trust fund levels and potential "cliff"	1

Source: MDOT

Notably, MDOT includes an inability to attract needed talent among agency threats, and specifically staff who can understand and manage emerging technologies and support core operations staff.[15]

[14] 1 = minimal. 5 = most severe.

[15] There is an embedded assumption in this threat that core staff are unable to understand emerging technologies. MDOT should consider that experienced professionals may be in a better position to understand the utility of emerging technologies than external consultants who focus on the technologies but are not familiar with MDOT's practices.

TABLE 29: MDOT PROGRAM THREATS

Threat Category	Threat	Consequence Rating[16]
System Maintenance	Spikes in maintenance costs	3
	Needed support for severe winter weather events	3
Project Costs	Material Costs Spike	3
	Labor cost spike	2
	Recurring Congestion	2
Climate Change	Climate Change	2
System Disruption	Economic Downturn	2
	Failure to address critical functions	2
	Demographics	2
Project-level Disruptions	Extreme weather events	2
	Labor disputes	1

Source: MDOT

In addition to the *threats* listed in Table 28 and

[16] 1 = minimal. 5 = most severe.

Table 29, the MDOT TAMP discusses a series of *hazards* and assesses the risk of these hazards for each MDOT region. The most severe hazards include extreme heat, extreme cold, dam failures, snowstorms, and flooding (Michigan Department of Transportation, 2019, pp. 24-25). The TAMP does not detail precisely how these hazards impose risk.[17]

Financial Plan and Investment Strategies.

The Financial section of the 2019 Michigan TAMP estimates available revenue for the Highway Capital Program—which omits non-capital and routine maintenance expenses—from 2019 to 2028. MDOT's Investment Strategies section reports anticipated funding gaps for the next decade but did not use standard best practices in system condition forecasting. MDOT reports that it is not prepared to forecast pavement and bridge conditions using the methods required by federal regulation (Michigan Department of Transportation, 2019, pp. 44-53).

Performance Gap Analysis

MDOT is required to set pavement and bridge condition targets over a four-year performance period using standard objective metrics described in federal TAMP reporting regulations. The performance period covered in the 2019 TAMP is 1 January 2018 – 31 December 2021. The 2019 TAMP provides a GAP analysis using legacy metrics. MDOT reports that the Department is not yet ready to adopt best practices in forecasting as prescribed by federal regulation (Michigan Department of Transportation, 2019, pp. 54-65).

7.1.5 Michigan Transportation State Long-range Plan (SLRP)

States are federally required to produce a statewide long-range plan (SLRP) applying performance-based planning and programming (PBPP) to statewide transportation system planning at least 20 years into the future. Michigan is currently drafting a plan to look forward to 2045 (Michigan Department of Transportation, 2020). The State Transportation Commission officially adopted the current plan in 2016, and it looks out to 2040 (Michigan Department of Transportation, 2016). Similar to the federally required TAMP, the SLRP emphasizes linking objective performance metrics to specific goals.

The 2040 State Long-Range Transportation Plan (SLRTP) consists of an executive summary document and 23 individual white papers.[18] The most relevant white papers are reviewed below.

[17] For example, "extreme heat" is identified as "very high" risk in all regions. There are potential reasons why extreme heat would impose risk (e.g., accelerated degradation of asphalt pavement), but this is not made explicit. Without such detail, it cannot be known how to appropriately mitigate such risks.

[18] All 2040 SLRP white papers are available at https://www.michigan.gov/mdot/0,4616,7-151-9621_14807_14809_74454_74455---,00.html, accessed March 2020.

Vision White Paper

The white paper titled "Vision for an Integrated Transportation System" is a central supporting component of the 2040 Long-range Plan (Michigan Department of Transportation, 2016). The white paper elaborates on MDOT's desired vision for the statewide transportation system in 2040, emphasizing intelligent decision-making and improvements in operational efficiency. It is recognized that MDOT's ability to promote a culture of innovation that facilitates efficient adoption of emerging technologies—including "connected and autonomous vehicles"—and generally remain innovative is a critical component of this strategy (Michigan Department of Transportation, 2016, pp. 2, 4-5).

Connected and Automated Vehicles and New Technology White Paper

The CAV White Paper summarizes MDOT programs, initiatives, investments, and activities that MDOT has pursued regarding emerging technologies in the several years before the publication of the final draft in 2016 (Michigan Department of Transportation, 2016). The white paper does not propose specific future initiatives. However, it acknowledges the uncertainty of the direction of emerging technologies, stating, "whether mandated by the government or demanded by consumers, MDOT must be ready for the changes these technologies will bring to the use and maintenance of the road network" (Michigan Department of Transportation, 2016, p. 1).

New technologies that are identified as being actively pursued by MDOT include the following (Michigan Department of Transportation, 2016, pp. 4-7):

- E-Construction (i.e., automated and digital management of construction projects)
- Stringless Concrete Paving
- Intelligent Transportation Systems (ITS)
- Transportation Operations Centers (TOCs)
- Truck Parking Information Management System (TPIMS)
- Active Traffic Management (e.g., US-23 Flex Route)
- Road Weather Information System (RWIS)
- Transportation Systems Management and Operations (TSMO)
- Maintenance Decision Support System (i.e., live location tracking of MDOT winter maintenance vehicles)
- Smartphone Apps

In addition to the technologies listed above, the white paper notes MDOT support of CAV research projects and facilities such as Mcity and the American Center for Mobility.

While this white paper provides only a high-level summary of how MDOT has been involved with these technologies, it is noted that MDOT maintains a separate CAV Program Plan that includes more detailed information (Michigan Department of Transportation, 2016, p. 2).

Goals, Objectives, and Performance Measures White Paper

The Performance Measures white paper component of the 2040 SLRTP reaffirms the approach adopted in the initial 2030 SLRP released in 2006 (Michigan Department of Transportation, 2016). The 2030 SLRP included an extensive collaborative process involving many MDOT staff and stakeholders. The process resulted in the identification of several core performance metrics, including (Michigan Department of Transportation, 2016, pp. 23-28):

- Percentage of bridges and pavement lane miles in "good" or "fair" condition
- Percent of system meeting "acceptable" international roughness index (IRI)
- Fatality rates
- Crash rates
- Hours of delay

The 2040 SLRP is a corridor-based plan. MDOT has identified nineteen (19) "corridors of highest significance as a framework to evaluate performance metrics." The current and projected performance metrics of the 19 corridors are provided in the 2040 SLRP supporting document, *Corridors of Highest Significance – Performance Metrics* (Michigan Department of Transportation, 2016). Notably, this document includes some projections of future metrics but does not set long-range goals. The reason may be related to many MDOT's current performance metrics not being compliant with federal requirements.[19] Driven by the potential of putting funding at risk, MDOT will likely transition to best practices in performance-based metrics in the coming years in line with FHWA guidance.

7.2 Technologies

This section describes a series of basic technologies with potential implications for current or future MDOT activities. The technologies are listed in alphabetical order.

7.2.1 4G-LTE

4G-LTE describes a group of technology standards comprising a wireless communication stack enabling the fourth generation (4G) of cell-based wireless communication technology designed for long-term evolution (LTE) (ETSI, n.d.). 4G LTE communication has enabled many wireless internet connectivity advancements, enabling numerous valuable mobile applications and connected devices. Despite recent attention to 5G, 4G-LTE is currently the most ubiquitous and utilized cellular communication standard and will remain so for some time. Commercial telecommunication companies provide 4G LTE connectivity over proprietary networks, so there is rarely a need for an end-user to be familiar with the

[19] MDOT's pavement asset management program is based on a subjective open-source rating system called PASER. Such a rating system cannot be integrated into a performance-based approach because failure modes are not disaggregated. Further, there are important issues with data collection. Research indicates that data collection systems similar to MDOT's results in significant error—typically overestimated the budget required to maintain the system (Zimmerman, 2017).

communication stack and standards' details. More relevant to a transportation agency is the plethora of opportunities that 4G LTE communication can offer. 4G-LTE provides widely available mobile internet access with speeds able to accommodate many applications.

7.2.2 Additive Manufacturing (3D Printing)

Additive manufacturing, also known as 3D-printing, refers to a group of low-volume manufacturing technologies that create a physical object by sequentially depositing layers of material as specified by a digital model (Anker & James, 2017).

In the mid-2010s, there was a growing opinion that additive manufacturing technology had the potential to be so widely integrated into manufacturing processes that entire supply chains would be disrupted. The second-order effects of this could affect system-wide freight transportation patterns to the extent that they should be considered in mid- and long-term transportation planning (Bhasin & Bodia, 2014). While many specific industries have adopted additive printing for specific applications, 3D printing has not yet had an apparent impact on large supply chains or freight movements.

At the current technology stage, 3D printing can be beneficial for an organization that requires rapid prototyping or needs occasional parts that may be more efficiently manufactured on-site rather than held in inventory.

7.2.3 Advanced Signals

A standard traffic signal has a pre-determined cycle time no matter what the circumstances. It displays each phase—green, yellow, and red—in a pre-programmed time-sequence ad infinitum. A slightly more complicated system may allow for timing variations based on time of day; for example, extending the green phase for a corridor during rush hour or converting to a blinking red phase during late-night hours, but these phases are still pre-determined. Changing timing schemes generally requires manual re-programming of the device in the field.

In recent decades, state and local transportation departments have been upgrading signal systems with advanced signals that provide various means of more efficient traffic control. The most modern signals are essential intelligent connected devices capable of control and monitoring from remote TOCs and a dynamic response to real-time traffic conditions. Many agencies, including MDOT, have adopted standards that are extensible to allow for integrating future signal technologies (Descant, 2018).

Adaptive Signals

Intersection efficiency can be significantly improved if signals are connected to vehicle detection systems—either in the pavement or mounted on poles—and change timing in response to live traffic conditions. Adaptive/responsive signals can also respond to pedestrian requests to cross. Some signals are connected to an ITS network and can immediately adjust timing schemes to prioritize emergency and/or transit vehicles. The most advanced adaptive signals are connected to TMCs, where intersection performance can be measured and analyzed, and phase timing can be adjusted in real-time (Fehon & Peters).

V2I-based Adaptive Signals

Come concepts for adaptive signals do not use remote sensors to determine traffic patterns but respond to signals broadcast by the vehicles themselves. This concept is already common for transit vehicle signal priority and emergency vehicle signal preemption. These are mature commercial products that typically use a propriety optics-based communication system.

The USDOT and others have spent years investigating a system's potential based on some kind of quasi-ubiquitous connected vehicle network. Most research assumes the V2X network would be based on DSRC, but other technologies would work similarly (Aziz, Wang, Young, Sperling, & Beck, 2017).

Signal Phase and Timing (SPaT)

A related idea is that instead of signals being adaptive to vehicles, the signals would broadcast signal phase and timing (SPaT) information to drivers who would use that data to drive more efficiently. The USDOT and others have also researched this concept, again, typically assuming that DSRC would be the communication technology utilized. However, SPaT data could also be provided over other networks such as 4G/LTE, and some OEMs have already embedded such features into current consumer vehicles (District Department of Transportation, 2018).

The USDOT and the American Association of State Highway and Transportation Officials (AASHTO) are currently promoting a “SPaT Challenge” to encourage agencies to broadcast DSRC SPaT data from signals (National Operations Centers of Excellence). There is no commercial DSRC network at this time, so the use of the system is limited to research and pilot projects. This research may provide additional information regarding the efficacy of SPaT. Earlier studies have reached mixed conclusions. One issue is that SPaT can only work with fixed-timing (non-adaptive) signals. Having both the signals and the traffic responsive to each other creates an unbounded and unpredictable traffic system (Robinson & Dion, 2013). Considering the proven benefits provided by adaptive signals, the potential benefit of SPaT remains unclear.

Battery Backup

Another smart approach to signals is to provide battery backups to function in a power outage (Pitman, 2019). This usage implies additional device programming and system architecture considerations regarding timing strategies if connected systems lose contact with TOCs.

7.2.4 Distributed Ledger Technology

For many data-based applications, it is sufficient to store data in a spreadsheet (e.g., Microsoft Excel). When datasets become very large, complicated, or require multiple access levels, it may be necessary to work with a database program (e.g., Microsoft Access). Traditional databases can manage large amounts of various data types but often impose problems when sharing data between individuals or institutions. A traditional database is centralized and managed by a database administrator, and thus, sharing responsibilities and access requires establishing accounts for each user with appropriate permissions. In practice, this often results in messy data-access schemes where users are challenged to access accurate, current data, and data-entry errors are common and difficult to identify.

An alternative to a centralized database management system is available in distributed ledger technologies (DLT). Likely the best-known DLT is *Blockchain*, the DLT underpinning the popular cryptocurrency, Bitcoin. While Blockchain effectively provides decentralized access to accurate data, it has drawbacks relating to energy usage and scalability (Tabora, 2018). This alternative has led to a growing field of research to develop and evaluate different Blockchain types and other DLTs (Cao, et al., 2019).

There are not yet many examples of successful implementations of Blockchain in transportation, either within the government or industry (Zichichi, Ferretti, & D'Angelo, 2020). However, DLT will likely continue to evolve and slowly replace centralized database management systems for many future applications. Integrating DLT into “smart contracts” can improve oversight of contracted work with reduced oversight and administrative work (Roeck, Sternberg, & Hofmann, 2019). In addition to potential use as a general contract tracking and evaluation tool, DLT could become the basis for applications like tolling, use/congestion charges, or establishing trusted entities within a network (Carter & Koh, 2018).

At least one concerted effort iso establish standards for using Blockchain in transportation, the *Blockchain in Transport Alliance* (BiTA) (Blockchain in Transportation Alliance, 2020).

7.2.5 C-V2X and 5G

Cellular connectivity and mobile applications are currently built mainly on a series of industry-standardized technologies collectively known as 4G-LTE. LTE networks are likely to remain the primary communication technology for many years to come. However, they are also expected to be augmented by a novel communication stack representing the fifth-generation (5G) of cellular communication technology (GSMA, 2019).

Cellular V2X (C-V2X) communication is a recent concept describing a family of open standards intended to allow peer-to-peer networking and device interoperability regardless of any third-party cellular network provider. The C-V2X standards applications remain in development, but there is an emphasis on ensuring forward compatibility with evolving 5G standards, making C-V2X a compelling alternative to

DSRC for vehicle and infrastructure connectivity. The potential integration of 5G and C-V2X to transportation systems and public agencies remains an active research area.

7.2.6 Database Technology

In many transportation departments, an Excel spreadsheet is the default tool used to store and evaluate data. Spreadsheets are sufficient for many data storage and analysis needs. However, as dataset size grows, includes extensive temporal data, or needs to be used for multiple purposes, it is practically necessary to store data in a relational database (e.g., Microsoft Access).

Without an internal database and data management professionals, an agency can become over-reliant on outside contractors who deliver specific project solutions. However, these contractors are not in a position to rationalize the system of systems. It will become increasingly beneficial for organizations that collect, store, and manage a large amount of data to have in-house experts. These individuals can design and maintain an appropriate database architecture and coordinate data-sharing across the enterprise.

7.2.7 Neural Networks, Deep Learning, and Cognitive Computing

Many decades ago, computer science and artificial intelligence (AI) researchers were inspired by new neuroscience findings to design processing architectures and software algorithms that mimic the biological activity of neurons in the human brain. This approach to artificial intelligence has enjoyed a recent resurgence as evolving computer hardware, and the availability of large data sets have made it more viable. Such an approach is generally known as an *artificial neural network*. Multiple layers of artificial neurons (known as perceptrons) can be combined to process data in a process known as *deep learning*. The real-time implementation of deep learning is known as *cognitive computing* (Center for Automotive Research, 2018). This approach to AI and data analysis continues to find new and valuable uses.[20] There are potential uses for deep learning to be applied to transportation systems management. However, it is most likely that this will take the form of technology providers offering a mature product or service on a contractual basis. One new application of deep learning to transportation management is the potential for deep learning to be applied to adaptive traffic signals' timing across a grid road network.

7.2.8 Distributed Processing

Distributed processing, also known as *edge computing*, refers to the pre-processing of data by sensors integrated into a broader network. There is nothing revolutionary or new about distributed processing. However, it has become an increasingly important consideration in data management and communication network architecture. Recent advances in computer processing have resulted in the availability of low-cost, high-speed chips that can be integrated into connected devices. The ability to

[20] The contemporary approach to autonomous driving systems is predicated on object recognition and tracking algorithms that are highly dependent on deep learning.

embed complex data-processing at the device level can decrease the data transmission burdens on communications networks and make overall data management across a system more efficient.

7.2.9 Dedicated Short-range Communication

DSRC has become the common term applied to a family of technologies providing open, unencrypted, low-latency communication of a tractable series of messages enabling mobile connectivity or wireless access in a vehicular environment (WAVE). The concept of providing a radio communications network to support road transportation is nearly a century old. The modern incarnation of DSRC for connected vehicle applications was initiated in response to the U.S. federal transportation funding provisions described by the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 (U.S. Congress, 1991).

The research activities initiated in the early 1990s have evolved into a family of industry standards capable of supporting several transportation-related applications. While some of the standards remain unsettled, coordination between government and industry has culminated in a concept of operations sufficiently mature to support DSRC-based connected-vehicle pilot deployments in New York, Florida, and Wyoming. These pilots were initiated in 2015 and are nearing the completion of the operational phase. These projects are expected to result in data that will provide insight into DSRC communication technology and applications' efficacy.

European Union - Connected ITS

The approach that industry and government have taken towards adopting DSRC is relatively unique to the United States. Other transportation markets have imported elements of DSRC, but not the entire communications stack or concept of operations. The idea most similar to the U.S. connected vehicle architecture is the Connected ITS (C-ITS) concept adopted by the EU (European Commission and DG MOVE, 2016).

7.2.10 Geographic Information Systems

Transportation agencies have always been highly dependent on their ability to produce, maintain, and utilize data-rich maps of the transportation system. The modern incarnation of data-based mapping is known as geographic information systems (GIS) and has become a remarkably powerful tool for a multitude of public and private organizations. GIS software references a database that includes geographic information that allows digital elements to be dynamically rendered into a visual representation of the world (a map) and supports numerous approaches to data processing and analysis. While the potential applications of GIS are extensive, taking full advantage requires a skilled user familiar with not only GIS software but underlying database architecture, data management systems, and the relationships to the physical world (U.S. Department of Transportation, 2012).

7.2.11 Lidar

Lidar is a remote-sensing device that measures the distance from the device to an object by emitting electromagnetic radiation and capturing the photons reflected off of physical objects. Lidar works very similarly to radar, but radar typically uses lower-frequency microwaves. In contrast, lidar typically uses infrared light (Dennis, Buller, Xique, Bahrani Fard, & Hart, 2018). The root of the term lidar is in reference to radar, as it was originally a portmanteau of light + radar (National Oceanic and Atmospheric Administration, 2014). Lidar is conceptually a well-established technology, having been used for industrial (and even limited automotive applications) for decades. Lidar has recently enjoyed a resurgence in transportation research due to its use in autonomous driving systems, pioneered by Velodyne-produced units used in the DARPA Challenges.

Mobile Lidar Systems

As with other chip-based technologies, lidar has recently experienced a resurgence in interest due to recent hardware and processing capability advancements. Lidar is uniquely capable of creating a high-definition three-dimensional representation of the physical world. Contemporary lidar units can operate with sufficient reliability even when integrated into a mobile unit such as a road vehicle or UAV. There is substantial interest in utilizing mobile lidar systems (for various transportation system maintenance and operation applications) (Olsen, et al., 2013).

7.2.12 Machine Learning

Many confusing terms fall within the realms of the already confusing meta-term of artificial intelligence (AI). One of these confusing terms is *machine learning*. Machine learning is the process in which a specifically designed algorithm can derive insightful information from large datasets.

With machine-learning techniques, programmers establish general relationships between potential inputs and outputs concerning the program's end-goal (known as a fitness function). The operational details of the algorithm are initially left unresolved. Instead of specific operational rules, the AI is endowed with the ability to learn the relationships between inputs and outputs when presented with a set of training data. The training data includes previously validated input, output, and operational variables as necessary to allow the algorithm to establish functional relationships (at least within a degree of certainty). A basic machine-learning process is often similar to statistical regression. However, it may use advanced statistical methods or handle large inter-related datasets that would be difficult or impossible for humans to comprehend and manipulate with traditional regression approaches. Software developed with basic machine-learning techniques is now commonplace. But such AI is limited to applications in which data is structured, and critical parameters are known. One familiar machine-learning application is the Google search algorithm, which is continually evolving based on previous searches and links clicked by various users.

Deep learning is a sub-category of machine learning that utilizes artificial neural networks for data analysis that would be impractical with more straightforward approaches. Complex tasks such as object recognition and natural language recognition are typical of complex unconstrained tasks addressed with deep learning techniques.

As with other AI techniques, it is unlikely that a transportation agency would require in-house expertise on the topic of machine learning. However, many consultants and vendors already offer ITS systems that incorporate machine learning elements, so an agency would be advantaged to be familiar enough with such concepts to make intelligent purchasing decisions.

7.2.13 Machine Vision

Machine vision generally refers to any technology that uses an electronic sensor to capture and analyze an image. Many agencies already use machine vision for such applications as vehicle and pedestrian recognition for adaptive traffic signals and automated license plate recognition for tolling.

Machine vision has recently undergone a period of advancement due to the use of artificial neural networks and deep learning techniques applied to machine vision. Generally, a high-quality sensor is capable of capturing image details with higher fidelity than a human eye. However, the human brain is uniquely capable of making sense of the matrix of photons intercepting the human retina. Computers struggle to reach a human level of comprehension. However, in some specific areas where massive datasets are available to train the algorithm, machine vision is comparable to human-level object recognition.

One unique advantage of machine vision over human vision is that humans are limited to what we call the visible spectrum. Machine vision can potentially utilize photons from across the spectrum to create an image. Current applications often use the near-infrared part of the spectrum.

7.2.14 Radar

Radar sensors emit microwave radiation and capture the reflected photons to determine the distance between the sensor and the solid object. Due to the physics of microwave radiation, radar sensors are not well-suited for machine vision. However, they are very well suited to determine the distance and relative velocity of a relatively large, fairly solid object. Radar systems have been in use for nearly a century, but advancements in waveforms and signal processing frequently offer new capabilities (Dennis et al., 2018). Recently, transportation agencies have experimented with ground-penetrating radar (GPR) to survey underground utilities before earthworks and construction (Zeiss, 2018). Others have employed satellite-based interferometric synthetic aperture radar (InSAR) to assess geotechnical attributes such as slope stability (Bahrani Fard & Santiago, New Approaches in Data-driven Asset Management Practices, 2019, p. 32).

There isn't an obvious need for a transportation agency to have in-house expertise in radar technology and associated signal processing as with other sensor technologies. Radar is a mature technology, and many transportation technology suppliers offer radar-based ITS systems. For example, MDOT's ITS system widely incorporates microwave vehicle detection stations (MVDS) that use radar technology to measure vehicle count and traffic speed.

7.2.15 Simulation

Computer simulation describes any approach where a real-world system is abstracted into components, and its operation is simulated by applying simplified rules of operation. Computer simulation technology has been utilized for decades by transportation agencies for the long-term planning of system demands. More contemporary simulation approaches can account for much of the complexity in real-world systems to help predict system demands (Zheng, et al., 2013) (Bucci, Calley, & Green, 2018).

7.2.16 Unoccupied Aerial Vehicles (UAVs/Drones)

Unoccupied aerial vehicles (UAVs), more commonly referred to as drones, offer agencies the ability to have a small aerial platform that can carry a number of sensors to assist with the inspection of various assets. Inspection via UAVs has been substantially researched and shows much promise for implementation into routine operations (Bahrani Fard & Santiago, New Approaches in Data-driven Asset Management Practices, 2019, pp. 26-27). Transportation agencies have not extensively adopted UAVs for inspection purposes, possibly because it remains difficult to retain sufficient control over a drone to maintain safety and achieve high-quality images.

7.2.17 Engineering, Design, and Construction

The technologies that have previously been listed are most applicable to MDOT's TSMO activities. Additional technologies may have more applicability to MDOTs engineering, design, and construction activities.

- **Advanced Asphalt** (Asphalt Pavement Alliance, n.d.): Design and engineering approaches to improve asphalt performance and reduce lifecycle costs.
- **Advanced Excavation Equipment**: Equipment companies continually introducing new technologies and products to enable efficient staging and excavation. (E.g., Road-legal Excavation Vehicles)
- **Advanced Signage and Marking Materials**: Materials companies such as 3M have continued to improve and innovate materials to be highly visible, resilient to wear, and cost-effective.
- **Augmented Slope Stabilization (e.g., Polymer Binders):** Many new and emerging approaches to temporary and permanent slope stabilization.
- **Bridge Hydraulic Jacking:** Equipment and methods used to repair bridge and structural foundation settlement.
- **Computer-aided Drafting and modeling (3D CAD):** Integration with string less paving, also useful for engineering, design, and materials/cost estimation.

- **Conveyor Material Placement Technology:** Innovation in conveyor and materials placement technologies can speed up fast-tracked construction.
- **Crash Attenuation Technologies:** Devices and methods to safely diffuse the energy of unintended vehicle crashes**.**
- **Crack sealing and filling:** New methods and materials such as *hot-applied repair mastic sealant* have improved the cost performance of surface crack repairs and pavement preservation.
- **Dewatering Technologies:** Water removal during excavation and subgrade construction.
- **Energy-absorbing guardrails:** Previous decade has seen extensive innovation in cost and safety improvements for guardrail materials and design.
- **Extreme Temperature Concrete Construction**: Both PCC and asphalt pavements have optimal temperature ranges for construction. Researchers and contractors are continually innovating approaches to extend the range of construction season, times of day, and achieving higher quality when working in marginal conditions.
- **Fiber-reinforced Polymer Road Furniture:** Polymer reinforcement of construction materials is increasing in popularity, including in road furniture like cabinets and streetlight posts. Fiber-reinforced polymer is increasingly allowing light-weight, low-cost, durable products.
- **Finite Element Analysis:** Engineering and design approach, especially for bridges but other things, as well. New software packages may provide unique capabilities.
- **Foamed Asphalt:** New cold in-place asphalt recycling method.
- **Full-depth Patching:** Pavement patching typically involves only surface layers. Full-depth patching can be a money-saving approach in many instances and requires unique approaches to provide a high-quality outcome.
- **Geogrid:** Sheets of synthetic material to stabilize soil under pavements or retaining walls.
- **Geographic Information Systems, Survey, and GPS Technology:** In past decades, highway projects would involve printing out a plan on giant pieces of paper and the contractor using stringlines, sight levels, and similar to layout the project. All these tasks are now done chiefly with digital files with GPS-correcting base stations.
- **Gravel Stabilization Technology:** Technologies and methods to stabilize gravel roads and base courses. Includes both chemical (binders) and mechanical (geogrid) approaches.
- **High-density Foam (geofoam):** Technology for engineering pavements to be constructed in non-typical locations such as wetlands and unstable slopes.
- **Hydro-demolition:** High-pressure water jets for breaking and cutting things such as concrete or asphalt. It is often employed to minimize dust or other externalities associated with traditional demolition.
- **In-situ Sensors:** In-situ sensors can be designed-in to pavements and structures to replace inspection practices.
- **Job site Mobile Office (Trailers):** Do not underestimate the importance of modular and flexible mobile offices for job site management.
- **Lidar:** Lidar can be used to create a 3D digital model of anything. Useful for precision measurements, inspection, record keeping, and more. Not sure how well-adopted at this time.
- **Machine Vision:** The ability of a machine to “see” and perceive its environment through the use of visual sensors (cameras), processing software algorithms, and hardware.

- **Materials Testing Technologies:** Equipment and methods used to validate that construction materials conform to specifications.
- **Mill and Fill Innovations:** Mill & fill is a pavement rehabilitation approach involving removing and replacing only the top layer of pavement. Various elements of this process are subject to novel and innovative approaches to improve the cost-efficacy of the rehab approach.
- **Prefabricated Bridge Construction:** An alternative to time-consuming cast-in-place methods of bridge design and construction.
- **Prefabricated Pretensioned Bridge Construction:** Prefabricated members are constructed with steel members under tension.
- **Prefabricated Road Pavement:** Prefabricated bridge decks are now reasonably common for fast-tracked, high-quality construction. Such methods may be expanded to surface paving in challenging projects.
- **Radar:** Many uses, including grade compaction testing (GPR).
- **Real-time sensing of PCC concrete cure strength:** Traditionally, PCC cure is tested with invasive core sampling. There are new methods of doing this automatically with embedded sensors.
- **Rumble Strips:** Pavement surface treatments can provide safety benefits, and innovative approaches are an area of active research.
- **Slab jacking and repair:** Rehabilitation on unevenly settling PCC slabs.
- **Steel Bridge Corrosion Mitigation Strategies**: Design and material choices to reduce steel bridges and structures' lifecycle costs.
- **Steel-Tie Placement Innovations:** New research regarding the placement of load-transfer bars is leading to innovative engineering approaches.
- **Stingless Paving:** Paving with digital measurement and localization as opposed to string lines.
- **Supplementary Cementitious Materials**: PCC admixtures with binding properties. DOTs can achieve performance and cost savings advantages through using these supplemental materials.
- **Surface Sweeper and Cleaner Vehicles**: Vehicles that can clean the road either with brushes or air. Labor-saving automation of job site cleaning and maintenance.
- **Thin-Surface Overlay Technology:** Engineering, design, and construction of pavement surface rehabilitation using thin overlays.
- **Trenching Technology and Practices:** Like tunneling, trenching is difficult, dangerous work; new technologies and methods are frequently introduced to improve the safety and efficiency of construction.
- **Tunneling (Micro and Macro):** Tunneling technologies are always in the process of being upgraded and improved. Micro refers to, e.g., utility lines, culverts, and similar, Macro refers to vehicle tunnels.
- **Under-bridge inspection maintenance equipment:** Bridges are complicated, and inspecting them is hard. There are many unique solutions to this issue, and more are introduced all the time.
- **Unoccupied Aerial Vehicles (UAV, a.k.a Drones):** Small flying robots that can be used for inspections, deliveries, and also monitoring construction sites.
- **Utility Structures Advanced Design and Technology**: New designs make utility structures cheaper, easier to install, easier to maintain, etc.

7.3 Technology-based Concepts

This chapter reviews a series of technology-based concepts that are especially relevant to a transportation agency's operations. These concepts are distinct from the technologies introduced in the previous chapter because these concepts can include various specific technology approaches to achieve a similar objective.

7.3.1 Advanced Traffic Management Systems

An Advanced Traffic Management System (ATMS) is a concept for leveraging information technology for active traffic control interventions, typically focusing on urban and congested areas. ATMS was advanced as an element of an intelligent vehicle-highway system (IVHS) (later renamed intelligent transportation systems [ITS]) back in the 1990s (Euler, Jacobson, & McCasland, 1990). An ATMS can utilize many different technologies and approaches but is, at its core, a system that automates real-time traffic management decisions or at least provides decision-support for such decisions. ATMS uses sensors to surveil real-time traffic data, uses that data to estimate traffic conditions based on a model of the road network then takes some kind of action to manipulate traffic patterns (such as adjusting signal timing or providing information to drivers via dynamic message signs) (De Schutter, et al., 1999, pp. 42-51). Modern ATMS are typically centered around one or more transportation operations centers (TOCs) where professionals monitor and operate the ITS system as appropriate. ATMS functions may also be in response to temporary events and construction projects.[21] As in many otherwise established fields, emerging technologies and data sources are complicating practical ATMS but providing exciting new opportunities.

7.3.2 Artificial Intelligence

Even top experts in the field disagree about how to define artificial intelligence. Understood most broadly, AI includes all possible approaches to simulating a rational, intelligent agent's actions. This disagreement means AI is any algorithm designed to ingest data, process and characterize it, discover important features or patterns within it, and perform classification or decision-making based on what was discovered. Machine learning and deep learning are two AI approaches that are especially relevant today and are discussed in the previous section.

7.3.3 Autonomous Vehicles

The auto industry has been envisioning self-driving vehicles at least since General Motors presented its “Futurama” concept at the 1939 World’s Fair. GM’s self-driving Futurama road system used a combination of road-embedded magnets and radio communication to guide vehicles without driver control (Beiker, 2014). The current approach to autonomous vehicles was spun mainly out of the DARPA Challenges in the mid-2000s. Google was the first company to take commercial interest in furthering the

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[21]Work Zone Management is a common ITS concept that may be considered a subcategory of ATMS.

technology demonstrated in the DARPA Challenges, hiring several members of the most successful teams—notably from CMU and Stanford in 2009. Google's program, now spun out as an independent firm called Waymo, remains the leader in self-driving capability. Waymo is the only organization known to deploy vehicles on public roads entirely without a safety driver.

Progress of autonomous vehicle deployment has not met the hopes of many. It is now generally accepted that adopting fully self-driving autonomous vehicles into the transportation system will be a decades-long transition and may never be complete. Meanwhile, limited vehicle automation in the form of driver assistance systems is increasingly popular, and there is strong evidence that many systems provide a significant safety benefit.

The resources and investment in autonomous vehicle research and automated driving technology may provide an opportunity for transportation agencies. Driving automation technology may be incorporated into public fleets and municipal vehicles to improve safety and operational efficiency. One exciting possibility is the potential for automated transit busses. While the technology that would allow a bus to navigate an urban area entirely autonomously is likely decades away, there are near-term opportunities for driver performance augmentation and even fully self-driving busses within the dedicated infrastructure (Ainsalu, et al., 2018).

7.3.4 Cloud

The term "cloud" in reference to the internet describes a general approach to network architecture and business models where data and/or processing resources are hosted on an external one or more external servers. Third-party providers typically host servers; an agency under contract for cloud services would not know where in the physical world the servers are located that host their data, making it feel like the resource is somewhere 'in the cloud.' There can also be private clouds that provide data and processing resources to distributed users.

7.3.5 Connected/Automated Vehicles (CAVs)

Many in government and industry have adopted the term *connected/automated vehicle (CAV)* to refer to a broad collection of emerging automotive technologies. All modern consumer vehicles have multiple automated features, and most are now equipped with some kind of wireless connectivity. These terms can be further subdivided into a myriad of technologies and operational concepts, some more relevant to transportation agencies than others.

Per the MDOT CAV Strategic Plan, "MDOT views Connected Vehicle (CV) technology as an enabling technology for Automated Vehicles (AV), and thus sees actions supporting CV technology development and deployment as also supportive of future AV operation on state roadways" (WSP, 2017, p. 1). The CV technology type discussed in the CAV Plan is DSRC. It is very common for government transportation agencies to conceptualize emerging vehicle technologies as CAV. Many government-funded research projects propose that connectivity and automation are fundamentally integrated (Southwest Research

Institute, 2018). However, this framing has led to some confusion. At this time, there are no known projects that use DSRC or any similar communications technology as a functional component of vehicle automation. To the extent that autonomous vehicles are connected, they use a secure commercial 4G/LTE network. Many autonomous vehicle developers have taken steps to limit this degree of connectivity as it introduces risk (Berk, 2019).

7.3.6 Connected Vehicles

At a high level, the term “connected vehicle” may refer to any wireless communication method that brings data into a vehicle. MDOT has typically assumed a narrow definition of the term. According to the MDOT CAV Strategic Plan, “Connected vehicle (CV) technologies enable all types of vehicles, roadways, other infrastructure, and mobile devices to all communicate and share vital transportation information. The primary communications technologies used to support CV applications is dedicated short-range communications (DSRC).” DSRC Technology is described specifically elsewhere in this document.

It is relevant to recognize that DSRC-connected vehicles are not available as a commercial product. It is common for the industry to use the term connected vehicle to refer to cellular connectivity via 4G/LTE. Depending on the context and application, it could also refer to other standards, such as Bluetooth, WiFi, or the 2G cellular-based e-Call system in Europe. Other communication standards that may become relevant in the future include C-V2X and 5G.

7.3.7 Crowdsourced Data

Many organizations, including transportation agencies, are interested in obtaining existing datasets as a low-cost way to replace or augment internally collected data. One category of available data is crowdsourced data. Crowdsourcing refers to any method used to leverage a group of people's combined intelligence, knowledge, or experience to answer a question, solve a problem, or manage a process. An MDOT-funded study has identified several uses of crowdsourcing, falling under one of four categories (Dennis, Wallace, & Reed, Crowdsourcing Transportation Systems Data, 2015):

- Third-party Aggregated Crowdsourced Data
- Social Media for Public Engagement
- The Internet as a Sensor
- Dedicated Platforms for Transportation Systems Management

7.3.8 Cybersecurity

As transportation agencies increasingly utilize technology connected by various computer networks, they also become more reliant on these networks and can suffer operational efficiency losses if they are compromised. It is essential to have a cybersecurity plan in the process, including appropriate monitoring procedures to identify and mitigate risks (Dennis, Alibayev, Barbeau, & Ligatti, 2018).

7.3.9 [Big] Data Analytics

The term "Big Data" became popular about a decade ago but has declined in use in the last five years or so. Big data is just data but reflects an understanding that the cost of collecting and storing data had prompted the aggregation of massive datasets that were difficult to analyze using traditional methods. Huge and complex datasets are not easily evaluated with a spreadsheet. Often, traditional relational databases are not even up to the task of making sense of massive datasets, prompting many large organizations to develop proprietary data analysis software. The complexity of pavement management systems and associated data have led many transportation agencies to pursue such options (Zimmerman, 2017)

Transportation agencies typically work with fairly well-structured and standardized data, implying that common database approaches should be sufficient for most purposes. Data science professionals with a working knowledge of database management systems and other tools could provide additional value in identifying new ways to glean insight and integrate new information throughout the enterprise.

7.3.10 Data Management Systems

Large organizations that obtain, process, and report multiple large datasets should develop a coherent and logical data management system to avoid redundancy, assure quality, and facilitate the efficient use of data. Data management systems architecture and policies can become very complex. Investments and attention to the framework by which an organization manages data can provide operational benefits far above the costs (Bahrani Fard, Spulber, & Reed, 2018).

7.3.11 Intelligent Transportation Systems

MDOT's Intelligent Transportation Systems (ITS) program is now considered a subcomponent of MDOT's TSMO program. The statewide MDOT ITS system includes the following devices and approximate device counts Table 30.

In addition to the ITS devices listed in Table 30 MDOT is in the process of integrating signals operation with the ITS program. Many of these devices provide real-time data directly to MDOT TOCs through the statewide ITS network.

TABLE 30. MDOT Its Device Count as Of September 2019

Closed-circuit Television (CCTV) Camera	670
Microwave Vehicle Detection Station (MVDS)	717
Environmental Sensor	563
[DSRC] Roadside Unit (RSU)	251
Dynamic Message Sign (DMS)	235
Pavement Sensor	140
Lane Control Sign	93
Wireless Vehicle Detection Station (WVDS)	43

Dynamic Display Panel	68
Flasher Sign + Flashing Beacon	40
Travel Time Sign	12

Source: MDOT ITS Database as of September 2019. CAR performed additional data cleaning and interpretation.

7.3.12 Internet-of-Things

The "internet-of-things" is a moniker that was introduced in 1999 but has already become outdated. The original concept of the internet was a network of connected computer servers and terminals. But any *thing* can be connected to the internet as long as it speaks the correct language (TCP/IP) and has a unique IP address. While there are millions of unique networks globally, there is a common global network that we refer to as "the internet." By 2014, the number of devices connected to the internet outnumbered the number of human beings on the planet. These devices are part of the same internet we use to access websites, and it has overwhelmingly become an internet of things.

7.3.13 Remote Sensing

Traditionally, 'remote sensing' refers to technologies and approaches of data reconnaissance via satellite or high-flying aircraft. However, the definition is sometimes stretched to include any data-gathering approach where information about the physical world is obtained without physical contact; this could include sensors mounted on small UAVs or even hand-held devices (e.g., a camera).

Remote sensing technologies utilize the electromagnetic spectrum to obtain data. Typical devices are radar (microwave spectrum), lidar (infrared spectrum), and camera (visible spectrum). MDOT frequently funds research projects investigating remote sensing technologies for asset management (Dye Management Group, 2014) but hasn't shown much interest in integrating remote sensing techniques into core operations.

Non-destructive Testing and Evaluation

One general application of remote sensing techniques is the testing and evaluation of transportation asset conditions. Such approaches are increasingly commonplace but may be difficult to adopt if an organization does not have a sufficiently adaptive and extensible data management architecture to utilize previously uncollected data types (Hong, et al., 2012), (Bahrani Fard, Spulber, & Reed, 2018).

7.3.14 Smart Devices

The term "smart device" does not have any specific meaning but typically refers to some kind of device with some type of embedded processor or networking ability. As with some other terms that came of age in the early 2000s, *smart device* has lost much of its meaning and fallen out of vogue as a descriptive term. As computer hardware has now become so inexpensive and compact, most consumer products and devices include some kind of embedded technology even if it is not essential to the function of the product.[22]

7.3.15 Wireless Communication

Computer networks have become a ubiquitous element of daily life. The earliest networks were self-contained, typically in universities and research laboratories. With the development of TCP/IP communication standards, it became possible to begin connecting disparate networks by sending data through phone lines or other physical wires.

Wireless networks require similar standards as wired networks but impose additional complications involving connectivity, interoperability, security, and other issues. Commercial wireless telecommunications providers typically utilize networks, standards, and protocols that have been extensively tested, vetted, and piloted before placing the networks into service. If transportation agencies continue to pursue emerging research-grade technologies such as DSRC and C-V2X, it may be necessary to have the in-house skills to troubleshoot connectivity and other issues. Such expertise can also be outsourced, which may impose barriers if the third-party contractors are not sufficiently familiar with MDOT's internal networks and business processes.

7.3.16 Engineering, Design, and Construction

The technology concepts that have previously been listed are most applicable to MDOT's TSMO activities. Additional concepts may have more applicability to MDOTs engineering, design, and construction activities.

- **Autonomous Attenuator Vehicles**: Attenuator vehicles are placed at the rear of a moving road construction crew in case traffic crashes into them. The vehicles have integrated or trailer-mounted attenuation equipment to protect the truck driver, but the risk remains. Attenuator vehicles may be a near-term application of automated driving.
- **Automated Maintenance Scheduling of Construction Equipment:** As with connected vehicle applications that assist owners in complying with a maintenance schedule and fault triggers, connected construction equipment can do the same.
- **Augmented Reality (AR) and Virtual Reality (VR):** There is ongoing research to determine if there may be valuable applications of AR and VR to support the design, engineering, and construction of highway pavements and bridges.
- **Non-typical Intersection Design:** Most roadway and intersection geometries were introduced in previous decades where vehicles (i.e., size and speed), demand (i.e., traffic volume), and values (e.g., complete streets) were different from today. New geometry designs are being introduced to accommodate the changing world.
- **Inventory Control:** All organizations, including DOT maintenance divisions and construction companies, can benefit from modern inventory control software systems.

[22] E.g., a microwave that connects to Amazon's Alexa voice-control system and automatically orders popcorn when it thinks you're running low.

- **Grade Management Solutions:** Electronic topographic mapping using software and hardware such as GPS base stations.
- **Design Optimization:** Software-based approaches decision support for loosely constrained design problems. Approaches may include decision-support flowcharts, multi-criteria decision-making modeling tools, and fuzzy analytical hierarchical processes.
- **Soil Erosion and Sedimentation Control (SESC):** Methods and materials to prevent sedimentation and debris from leaving the job site and entering waterways or creating air pollution.
- **Pavement Condition Characterization:** Methods and metrics used to assess the condition of pavements and forecast lifecycle costs.
- **Self-healing pavement:** Asphalt Cement Concrete (ACC) pavement materials are a design that incorporates unique admixtures that allow for novel pavement remediation via induction heating.
- **Pavement Preservation:** Materials and methods for preserving the condition of existing pavement, delaying the need for reconstruction or rehabilitation, and decreasing lifecycle costs.

7.4 Technology-based Practices

Section 2 of this document introduced a series of specific technologies relevant to transportation systems maintenance and operations. Section 3 described a set of concepts that are not individual technologies but abstract concepts representing a broad family of related technologies. This section addresses concepts that are not technologies *per se* but are conceptual frameworks or practices that are becoming increasingly relevant to transportation agencies, mainly due to the development of foundational technologies that support them.

7.4.1 Civil Integrated Management

The term civil integrated management (CIM) refers to "an assortment of practices and tools entailing collection, organization, and management of information in digital formats about highway or other transportation construction projects" (O'Brien, et al., 2016). CIM is intended to be a holistic approach that includes contractual and legal elements. CIM is not so much a new way of doing things as it is a framework to track the myriad of simultaneous and inter-related activities required for any large civil works construction project. MDOT has not strongly adopted the CIM-framework language but already has many elements of CIM, including substantial experience with the e-construction initiative that emphasizes online and digital management of construction projects and contracts (O'Brien, et al., 2016, pp. 34-36).

7.4.2 Transportation Asset Management

MDOT was one of the earliest state DOTs to adopt a TAM Framework. Contemporary concepts of TAM are as a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the lifecycle of the assets at minimum practicable cost. Historically, Michigan's TAM program has focused exclusively on pavement and bridge assets. New federal requirements have forced MDOT to expand the scope of statewide TAM to include the statewide performance of the system. As described in Section 1, MDOT is currently engaged in modernizing TAM practices and associated data management practices to comply with federal reporting requirements.

7.4.3 Transportation Systems Management and Operations

TSMO is an integrated program to optimize the performance of existing multimodal infrastructure by implementing systems, services, and projects to maximize capacity and improve the transportation system's security, safety, and reliability. MDOT has adopted TSMO as a primary framework for managing operations across much of the department, as described in section 1.

7.4.4 Engineering, Design, and Construction

The three practices mentioned above are department-wide frameworks to achieve optimal cost-effective outcomes through systems integration. Many additional construction and contracting-focused practices can be integrated into these enterprise-focused approaches.

- **Construction Safety:** Incorporating best practices in safety assurance into the design, staging, and operation of construction sites.
- **Design/Build Contracting:** Method of project delivery in which one consultant works under a single contract with the project owner to provide design and construction services. (This removes the bidding component between design and build.)
- **Risk Assessment and Mitigation:** Incorporation of low-probability ("black swan") events such as natural disasters, pandemics, and terrorist attacks into planning and design of civil infrastructure projects and organizational practices.
- **Brownfield Development and Environmental Remediation:** Reuse of historical industrial sites such that the health and safety of the community are maintained.
- **Sustainability Certification:** Formal certifications that a project meets some measure of sustainability. Examples include LEED and GreenRoads.
- **In-place Material Recycling**: (E.g., technology, hot in-place asphalt recycling): Technologies, equipment, methods, and materials used to reconstruct new pavement using the old pavement as a construction material.
- **Complete Streets Design:** Engineering and design of rights-of-way with consideration for modes other than personal automobiles.
- **Collaborative Design and Community Engagement:** Planning and pre-planning methods to ensure that civil engineering and infrastructure projects reflect the community's needs and values.
- **Project Staging and Phasing:** Project management approaches, including design considerations, to minimize service disruption during construction.
- **Mechanistic-Empirical Design and Engineering**: Methods and tools to continually improve engineering and design using mechanistic models informed by empirical data.

- **Compliance Assurance Systems:** Software tools to assist in assuring compliance with regulatory requirements such as those regarding environmental, workforce, and safety compliance.
- **Climate Change Mitigation Design:** Design of civil infrastructure projects incorporation uncertainty of climatic impacts of increasing atmospheric levels of greenhouse gasses.

7.4.5 Summary of Technology-based Practices

Essentially every operational concept in this section describes some framework to use data and information to inform decisions that optimize management of the transportation system from long-term and strategic planning to daily tasks of MDOT staff and contractors. It can be overwhelming to make sense of the scopes and relationships between things like CIM, TAM, and TSMO. Additional concepts could be added to this list, such as rational risk assessment, contingency planning, enterprise data management, and so on. These concepts represent best practices as identified by researchers, engineers, academics, policy analysts, and others to encourage transportation agencies to utilize modern technology.

The core connection across these myriad concepts is that data is foundational. New technologies have made it possible to collect, store, transmit, analyze, and activate data in ways that were practically unimaginable only a decade ago. Organizations like AASHTO and FHWA have developed and promoted a series of frameworks to encourage transportation agencies to institutionalize some kind of coherent data-driven decision support framework. The language and taxonomy across these concepts may vary somewhat, but the end goal is the same: improved performance of the entire transportation system. The needed skill set is also essentially the same; agencies need staff who are comfortable working with data and computer systems, software, and networks that support such work.

Appendix C: Apprenticeship—Full Details by Occupations

Civil Engineering Technologists and Technicians

PUBLISHED

Competency-Based Apprenticeship

SPONSORING COMPANY:
O*NET Detailed Work Activities

Industries	
O*Net Code	17-3022.00
Rapids Code	
Req. Hours	0
State	DC
Created	Jul 16, 2021
Updated	Jul 16, 2021

Competency-Based Skills

13 skill sets | 14 total skills

Estimate technical or resource requirements for development or production projects

- Calculate dimensions, square footage, profile and component specifications, and material quantities using calculator or computer.
- Inspect project site and evaluate contractor work to detect design malfunctions and ensure conformance to design specifications and applicable codes.

Inspect facilities or sites to determine if they meet specifications or standards

- Evaluate facility to determine suitability for occupancy and square footage availability.

Review technical documents to plan work

- Read and review project blueprints and structural specifications to determine dimensions of structure or system and material requirements.

Create graphical representations of civil structures

Test characteristics of materials or structures
Conduct materials test and analysis using tools and equipment and applying engineering knowledge.
Estimate operational costs
Develop plans and estimate costs for installation of systems, utilization of facilities, or construction of structures.
Prepare detailed work plans
Develop plans and estimate costs for installation of systems, utilization of facilities, or construction of structures.
Confer with technical personnel to prepare designs or operational plans
Confer with supervisor to determine project details such as plan preparation, acceptance testing, and evaluation of field conditions.
Create maps
Analyze proposed site factors and design maps, graphs, tracings, and diagrams to illustrate findings.
Prepare operational reports
Prepare reports and document project activities and data.
Prepare project budgets
Develop project budgets by estimating the cost of project activities.
Survey land or bodies of water to measure or determine features
Plan and conduct field surveys to locate new sites and analyze details of project sites.
Negotiate prices or other sales terms
Negotiate prices for new contracts or for modifications to existing contracts with contractors.

Civil Engineers

PUBLISHED

Competency-Based Apprenticeship

SPONSORING COMPANY:
O*NET Detailed Work Activities

Industries	
O*Net Code	17-2051.00
Rapids Code	
Req. Hours	0
State	DC
Created	Jul 16, 2021
Updated	Jul 16, 2021

Competency-Based Skills

17 skill sets | 19 total skills

Inspect facilities or sites to determine if they meet specifications or standards.

- Inspect project sites to monitor progress and ensure conformance to design specifications and safety or sanitation standards.

Estimate technical or resource requirements for development or production projects.

- Compute load and grade requirements, water flow rates, or material stress factors to determine design specifications.

Recommend technical design or process changes to improve efficiency, quality, or performance.

- Provide technical advice to industrial or managerial personnel regarding design, construction, program modifications, or structural repairs.

Design systems to reduce harmful emissions.

- Design or engineer systems to efficiently dispose of chemical, biological, or other toxic wastes.

Test characteristics of materials or structures.

- Test soils or materials to determine the adequacy and strength of foundations, concrete, asphalt, or steel.

Direct construction activities

- Manage and direct the construction, operations, or maintenance activities at project site.

- Estimate operational costs.
  - Estimate quantities and cost of materials, equipment, or labor to determine project feasibility.
- Survey land or bodies of water to measure or determine features.
  - Direct or participate in surveying to lay out installations or establish reference points, grades, or elevations to guide construction.
- Create graphical representations of civil structures.
  - Plan and design transportation or hydraulic systems or structures, using computer-assisted design or drawing tools.
- Develop technical methods or processes.
  - Identify environmental risks and develop risk management strategies for civil engineering projects.
  - Develop or implement engineering solutions to clean up industrial accidents or other contaminated sites.
- Investigate the environmental impact of projects.
  - Identify environmental risks and develop risk management strategies for civil engineering projects.
  - Conduct studies of traffic patterns or environmental conditions to identify engineering problems and assess potential project impact.
- Explain project details to the general public.
  - Prepare or present public reports on topics such as bid proposals, deeds, environmental impact statements, or property and right-of-way descriptions.
- Incorporate green features into the design of structures or facilities.
  - Design energy-efficient or environmentally sound civil structures.
- Prepare proposal documents.
  - Prepare or present public reports on topics such as bid proposals, deeds, environmental impact statements, or property and right-of-way descriptions.
- Coordinate safety or regulatory compliance activities.
  - Direct engineering activities, ensuring compliance with environmental, safety, or other governmental regulations.
- Evaluate technical data to determine effect on designs or plans.
  - Analyze survey reports, maps, drawings, blueprints, aerial photography, or other topographical or geologic data.
- Implement design or process improvements.
  - Develop or implement engineering solutions to clean up industrial accidents or other contaminated sites.

Engineering Assistant (Civil Engineering and Architecture)

PUBLISHED

Competency-Based Apprenticeship

SPONSORING COMPANY:
Project Lead the Way

Industries	
O*Net Code	17-3013.00
Rapids Code	0764CB
Req. Hours	0
State	DC
Created	Jul 16, 2021
Updated	Jul 16, 2021

Competency-Based Skills

3 skill sets | 64 total skills

Overview of Civil Engineering and Architecture
Connect modern structural and architectural designs to historical architectural and civil engineering achievements
Identify three general categories of structural systems used in historical buildings
Explain how historical innovations have contributed to the evolution of civil engineering and architecture
Identify and explain the application of principles and elements of design to architectural buildings
Determine architectural style through identification of building features, components, and materials
Create a mock-up model depicting an architectural style or feature using a variety of materials
Identify the primary duties, and attributes of a civil engineer and an architect along with the traditional path for becoming a civil engineer or architect

Identify various specialty disciplines associated with civil engineering
Participate in a design charrette and recognize the value of using a charrette to develop innovative solutions to support whole building design
Understand the relationship among the stakeholders involved in the design and construction of a building project
Residential Design
Identify typical components of a residential framing system
Recognize conventional residential roof designs
Model a common residential roof design and detail advantages and disadvantages of that style
Use 3D architectural software to create a small building
Apply basic math skills to calculate the quantity and cost of concrete needed to pour the pad for a small building
Create a cost estimate for a small construction project, including a detailed cost break-down
Calculate the heat loss through one wall of a conditioned building
Calculate the heat loss for a building envelope with given conditions appropriate for the project
Apply principles of sustainable design to a small project
Apply elements of good residential design to the design of a basic house to meet the needs of a client
Design a home design that complies with applicable codes and requirements
Incorporate sustainable building principles and universal design concepts into a residential design
Create bubble diagrams and sketch a floor plan
Identify residential foundation types and choose an appropriate foundation for a residential application
Calculate the head loss and estimate the water pressure for a given water supply system
Create sketches to document a preliminary plumbing and a preliminary electrical system layout for a residence that comply with applicable codes
Design an appropriate sewer lateral for wastewater management for a building that complies with applicable codes
Create a site opportunities map and sketch a project site
Choose an appropriate building location on a site based on orientation and other site-specific information
Calculate the storm water runoff from a site before and after development
Document the design of a home using 3D architectural design software and construction drawings
Commercial Applications
Identify applicable building codes and regulations that apply to a given development
Classify a building according to its use, occupancy, and construction type using the International Building Code

Research and Use regulations to identify zoning designations and allowable uses of property
Comply with specifications, regulations, and codes during a design process
Compare a variety of commercial wall systems and select an appropriate system for a given commercial application based on materials, strength, aesthetics, durability, and cost
Compare a variety of commercial low-slope roof systems and select an appropriate system for a given commercial application based on materials, strength, durability, and cost
Incorporate sustainable building practices, especially a green roof, into the design of a commercial building
Use 3D architectural design software to incorporate revisions for the redesign of a building
Use 3D architectural design software to create appropriate documentation to communicate a commercial building design
Calculate the structural efficiency of a structure
Use load-span tables to design structural elements
Identify the work of a structural engineer
Use building codes and other resources to calculate roof loading to a structure and select appropriate roof beams to safely carry the load.
Analyze a simply supported beam subjected to a given loading condition to determine reaction forces, sketch shear and moment diagrams, and determine the maximum moment resulting in the beam
Use beam formula to calculate end reactions and the maximum moments of a simply supported beam subjected to a given loading condition
Use structural analysis software to create shear and moment diagrams of simply supported beams subjected to a given loading condition
Calculate the deflection of a simply supported beam subjected to a given loading condition
Use building codes and other resources to determine the required floor loading and design a structural steel floor framing system (beams and girders) for a given building occupancy
Identify and describe the typical usage of foundation systems commonly used in commercial construction.
Determine the loads transferred from a steel framed structure to the ground through a foundation
Size a spread footing for a given loading condition
Check structural calculations created by others for correctness
Interpret and apply code requirements and constraints as they pertain to the installation of services and utilities
Read and understand HVAC construction drawings for a commercial project
Apply criteria and constraints to size and locate the new utility service connections for a commercial facility
Modify system designs to incorporate energy conservation techniques
Use differential leveling to complete a control survey to establish a point of known elevation for a project

Design appropriate pedestrian access, vehicular access and a parking lot for a commercial facility
Analyze a site soil sample to determine the United Soil Classification System designation and predict soil characteristics important to the design and construction of a building on the site
Estimate the increase in storm water runoff from a commercial site and create a preliminary design for a storm water storage facility
Apply Low Impact Development techniques to a commercial site design reduce the impact of development on storm water runoff quantity and quality
Follow specifications and codes during a design process
Given 3D architectural design software, document a commercial site design

Technical Instruction

Engineering Assistant (2+2 Engineer Pathway) - 405 req. hrs
Introduction to Engineering/Computer Graphics
College Algebra
College Chemistry I
College Trigonometry
Introduction to Engineering
Analytic Geometry and Calculus I
University Physics I
English Composition I
English Composition II

CAD Drafter

PUBLISHED

Competency-Based Apprenticeship

SPONSORING COMPANY:
CareerWise Colorado

Industries	
O*Net Code	17-3013.00
Rapids Code	
Req. Hours	0
State	CO
Created	Jul 16, 2021
Updated	Jul 16, 2021

Competency-Based Skills

12 skill sets | 12 total skills

Applied Mathematics

Applies basic concepts in geometry, trigonometry, and algebra to design.

Project Management

Plans, documents, and completes personal work activities to meet drafting project objectives and deadlines. Communicates effectively with supervisor regarding personal work activity plans.

Technical Drawings

Reads and interprets technical drawings.

Primary Drafting Software

Uses company's primary drafting software to create technical drawings.

Business Context

Incorporates knowledge of related business activities (ie. upstream or downstream) to drafting work and decisions.

General Engineering

Understands the relevant engineering discipline(s), such as mechanical engineering, civil engineering, electrical engineering, or structural engineering.

Industry and Company Design Standards

Understands and adheres to the relevant design standards.

Business Technology Applications

Uses Microsoft Office and/or G-Suite business applications to accomplish work functions.

Secondary Drafting Software

Uses company's secondary or more specialized drafting software to create technical drawings.

Modeling Software

Uses software to create models.

Mechanical, Electrical, and Plumbing (MEP) Systems

Understands the structure and operation of heating, ventilation, air conditioning, electrical, and plumbing systems.

Manufacturing Equipment & Processes

Understands manufacturing equipment and the manufacturing processes used to create finished products.

Technical Instruction

Sketchup

Introduces techniques and common practices of 3D modeling using Sketchup software. Focuses on the creation and editing of virtual three-dimensional forms and volumes.

Computer Aided Drafting

Focuses on construction of three-dimensional objects using the AutoCAD software.

Inventor I/Autodesk

Introduces basic Inventor applications of non-parametric modeling, three-dimensional parametric modeling and visualization & animation of 3D modeling. The student learns to construct, modify, and manage models.

Solidworks/Mechanical

Introduces parametric feature-based solid modeling 3D concepts to build confidence in 3D thinking and progresses to three-dimensional parameters.

Advanced Solidworks

Advanced applications of the 3D software SolidWorks. Management of design data, advanced assembly, analysis of models, documentation materials/parts lists, rendering, animation, and dynamic simulation and testing.

Solidworks Associate Certificate (Mechanical Drafter)

A Solidworks Certification is proof of your cutting-edge skills in the Solidworks platform. Aside from proving your proficiency with the software, the certification also sets you apart from the rest of the crowd as a highly skilled designer or design engineer.

Drafter, Civil

PUBLISHED

Time-Based Apprenticeship

SPONSORING COMPANY:
Unknown

Industries	
O*Net Code	17-3011.00
Rapids Code	0128
Req. Hours	6400
State	DC
Created	Jul 16, 2021
Updated	Jul 16, 2021

Time-Based Skills

4 skill sets | 29 total skills

Fundamentals of Drafting - 1650 req. hrs
Use and Care of Drafting Equipment
Lettering and Titling
Blueprint and Map Reading
Tracing
Plotting and Mapping
Filing of Plans
Basic Surveying and Care of Surveying Equipment
Preparation of Charts and Graphs
Model Making

Operation of Office Machines - Calculator, Planimeter, Pantograph, Drafting Machines
Highway Drafting - 1650 req. hrs
Orientation
Roads, Curbs, and Drainage Structures (plan, elevation, profile and sections)
Estimating of Quantities and Costs
Computation of Horizontal and Vertical Curve
Detailing of Bridges
Field Surveying and Investigations
Ozalid printing
Assessment Rolls
Land Work Drafting - 1600 req. hrs
Orientation
Layout and Preparation of Land Maps and Gathering Survey Data from other Agencies
Computation of Land Areas
Traverse and Triangulation Computations
Field Surveying and Investigations including Procuring of Land Maps and Other Information
Waterworks Drafts - 1500 req. hrs
Orientation
Preparation of Piping and Electrical Layouts and Diagrams
Waterline Plans and Profiles
Detailing of Special Waterworks Structures
Estimating of Quantities and Costs
Field Surveying and Investigations

Electrician

PUBLISHED

Time-Based Apprenticeship

SPONSORING COMPANY:
Power Design, Inc

Industries	
O*Net Code	47-2111.00
Rapids Code	0159
Req. Hours	28500
State	DC
Created	Jul 29, 2021
Updated	Jul 29, 2021

Time-Based Skills

17 skill sets | 59 total skills

Preliminary Work: Learn names and uses of equipment in the trade - 480 req. hrs	
Commodity electrical material	160 hrs
Quotable electrical material	160 hrs
HVAC and plumbing equipment	160 hrs
Preliminary Work: Learn Basic material handling skills - 1440 req. hrs	
Loading Trucks	480 hrs
Securing Loads	480 hrs
Safe Work Practices	480 hrs
Preliminary Work: Learn Proper Job Etiquette - 80 req. hrs	
Jobsite entry and exit	40 hrs

Preliminary Work: Learn Basic Electrical Terminology - 120 req. hrs	
Terms	40 hrs
Definitions	40 hrs
Theories	40 hrs
Preliminary Work: Learn Names and Uses of - 2080 req. hrs	
Power Tools	520 hrs
Hand Tools	520 hrs
Layout Aids	520 hrs
Material Assembly Aids	520 hrs
Preliminary Work: Learn Basic Installation Methods - 2400 req. hrs	
Distribution	600 hrs
Structure	600 hrs
Rough	600 hrs
Trim	600 hrs
Preliminary Work: Learn Basic Safety for - 640 req. hrs	
Electricity	160 hrs
Construction Equipment	160 hrs
Tools	160 hrs
Construction Sites	160 hrs
Residential & Commercial Rough Wiring : Assist in - 4640 req. hrs	
Material Handling	1160 hrs
Stockroom Management	1160 hrs
Component and Material Layout	1160 hrs
Cut and Install Wires, Cable, Conduit, and Raceways	1160 hrs
Residential & Commercial Rough Wiring : Learn to - 2900 req. hrs	
Connect Conductors to Devices and Appliances	580 hrs
Install Service Equipment and Load Centers	580 hrs
Create Material Lists	580 hrs
Clean Up Job Site	580 hrs
Pull Wire	580 hrs

Residential & Commercial Rough Wiring : Assist in - 1040 req. hrs	
Connect Conductors to Devices and Appliances	260 hrs
Install Service Devices and Load Centers	260 hrs
Preparing Material Lists	260 hrs
Pull Wire	260 hrs
Residential & Commercial Finish Work: Connect and set - 4800 req. hrs	
Residential & Commercial Finish Work: Install proper size and type - 600 req. hrs	
Fuses	200 hrs
Breakers	200 hrs
Overload Devices	200 hrs
Residential & Commercial Finish Work: Install and connect various types of - 1200 req. hrs	
Line Voltage Luminaires	400 hrs
Low Voltage Luminaires	400 hrs
Exterior Lighting	400 hrs
Residential & Commercial Finish Work: Learn to check polarity of - 240 req. hrs	
Circuit Conductors	120 hrs
Devices	120 hrs
Residential & Commercial Finish Work: Test the circuit for - 240 req. hrs	
Overloads	80 hrs
Overcurrent	80 hrs
Short Circuits	80 hrs
Troubleshooting: Learn proper troubleshooting techniques for - 800 req. hrs	
Electrical Wiring	200 hrs
Electrical Equipment	200 hrs
Electrical Lighting	200 hrs
Low Voltage systems	200 hrs
Troubleshooting: Check out troubles and make repairs (supervised) of - 4800 req. hrs	
Electrical Wiring	1200 hrs
Electrical Equipment	1200 hrs
Electrical Lighting	1200 hrs
Low Voltage systems	1200 hrs

Technical Instruction

First Year - 5586 req. hrs	
Introduction | Orientation | Tools Year 1	147 hrs
Electrical Safety and PPE	147 hrs
Falls | Ladders | Scaffolds	147 hrs
Matter	147 hrs
Electron Theory	147 hrs
Magnetism	147 hrs
Electricity	147 hrs
Digital Multimeter Principles Chapters 1 through 4	147 hrs
Digital Multimeter Principles Chapters 5 through 9	147 hrs
Digital Multimeter Principles Chapter 10	147 hrs
Review & Testing	147 hrs
Electromagnetism	147 hrs
Uses of Electromagnetism	147 hrs
The Electrical Circuit	147 hrs
Math	147 hrs
Electrical Formulas	147 hrs
Series Circuits	147 hrs
Parallel Circuits	147 hrs
Series-Parallel Circuits	147 hrs
Multi wire Circuits	147 hrs
3-Way/4-Way Switching	147 hrs
Testing	147 hrs
The Electrical System	147 hrs
Protection Devices	147 hrs
Alternating Current	147 hrs

Capacitance	147 hrs
Inductance	147 hrs
Power Factor and Efficiency	147 hrs
Motors	147 hrs
Generators	147 hrs
Transformers	147 hrs
Box Fill	147 hrs
Testing	147 hrs
How to Use the NEC (Video)	147 hrs
AC/DC Fundamentals Review	147 hrs
Grounding and Bonding	147 hrs
Conductor Ampacity	147 hrs
Review and Testing	147 hrs
Second Year - 6192 req. hrs	
Introduction | Orientation | Tools Year 2	144 hrs
Electrical Safety and PPE 2	144 hrs
Confined Space, Emergency Response, and Lockout/Tagout	144 hrs
NEC—General Introduction	144 hrs
NEC—General Definitions	144 hrs
Requirements for Electrical Installations 1	144 hrs
Requirements for Electrical Installations 2	144 hrs
NEC—Wiring and Protection Grounded [Neutral] Conductors	144 hrs
Branch Circuits 1	144 hrs
Branch Circuits 2	144 hrs
Branch Circuits 3	144 hrs
Testing	144 hrs
Feeders	144 hrs
Branch-Circuit, Feeder, and Service Calculations 1	144 hrs

Outside Branch Circuits and Feeders	144 hrs
NEC—Wiring and Protection Services 1	144 hrs
Services 2	144 hrs
Overcurrent Protection 1	144 hrs
Overcurrent Protection 2	144 hrs
Grounding and Bonding	144 hrs
GFCI Devices	144 hrs
Review and testing	144 hrs
Surge-Protective Devices (SPDs)	144 hrs
General Requirements for Wiring Methods and Materials 1	144 hrs
General Requirements for Wiring Methods and Materials 2	144 hrs
Conductors for General Wiring 1	144 hrs
Conductors for General Wiring 2	144 hrs
Cabinets, Cutout Boxes, and Meter Socket Enclosures	144 hrs
Outlet, Device, Pull, and J-Boxes;	144 hrs
Conduit Bodies; and Hand hole Enclosures	144 hrs
Nonmetallic-Sheathed/Service-Entrance Cables	144 hrs
Voltage-Drop Calculations	144 hrs
Review and Testing	144 hrs
UF Cable and PVC	144 hrs
AC and MC Cable	144 hrs
FMC, LFMC, and LFNC	144 hrs
EMT, IMC, and RMC	144 hrs
ENT and Metal Wire ways	144 hrs
Multi-outlet Assemblies, Surface Metal Raceways, and Cable Trays	144 hrs
Conduit Bending	144 hrs
Raceway Sizing Calculations	144 hrs
Review and Testing	144 hrs

Third Year - 7050 req. hrs	
Introduction | Orientation | Tools Year 3	141 hrs
Electrical Safety and PPE	141 hrs
Excavation/Motor Vehicles/Tool Safety	141 hrs
Introduction/Theory/Alternating Current/Neutral Conductor	141 hrs
Harmonics/Voltage Disturbances/Voltage Window	141 hrs
Electrical Noise/Grounding and Bonding/Power Quality Issues	141 hrs
Lighting—Ballasts and Transformers	141 hrs
Flexible Cords and Cables, and Fixture Wires	141 hrs
Switches and Receptacles	141 hrs
Switchboards, Switchgear, and Panel boards	141 hrs
Luminaires and Low-Voltage Lighting Systems	141 hrs
Testing	141 hrs
Appliances	141 hrs
Fixed Electric Space-Heating Equipment	141 hrs
Motors, Motor Circuits, and Controllers 1	141 hrs
Motors, Motor Circuits, and Controllers 2	141 hrs
Air-Conditioning/Refrigeration Equipment and Transformers	141 hrs
Bonding and Grounding 1	141 hrs
Bonding and Grounding 2	141 hrs
Bonding and Grounding 3	141 hrs
Bonding and Grounding 4	141 hrs
Code Article Report	141 hrs
Testing	141 hrs
Hazardous Locations, Commercial Garages, and	141 hrs
Motor Fuel Dispensing	141 hrs
Health Care Facilities, Assembly Occupancies,	141 hrs
Mobile/Manufactured Homes, and Temporary Installations	141 hrs

Electric Signs, Manufactured Wiring Systems, and Elevators	141 hrs
Electric Vehicle Charging System and Electric Welders	141 hrs
Audio Signal Processing and Information Technology Equipment	141 hrs
Swimming Pools, Spas, Hot Tubs, Fountains, and	141 hrs
Similar Installations	141 hrs
Emergency, Legally Required, and Optional Standby Systems	141 hrs
Remote-Control, Signaling, and Power-Limited Circuits	141 hrs
Fire Alarm Systems, Optical Fiber Cables and Raceways,	141 hrs
Communications Circuits, Radio and Television Equipment, CATV	141 hrs
and Radio Distribution Systems	141 hrs
Solar Photovoltaic (PV) Systems 1	141 hrs
Solar Photovoltaic (PV) Systems 2	141 hrs
Testing	141 hrs
Introduction to Motor Controls	141 hrs
Motor Controls and Schematics 1	141 hrs
Motor Controls and Schematics 2	141 hrs
Reversing Controls 1	141 hrs
Reversing Controls 2	141 hrs
Controls for Multiple Motors	141 hrs
Miscellaneous Requirements	141 hrs
Variable Speed Drives	141 hrs
VFD Lab	141 hrs
Review and Testing	141 hrs

Electrician, Maintenance

PUBLISHED

Time-Based Apprenticeship

SPONSORING COMPANY:
General Dynamics Ordnance and Tactical Systems, Inc.

Industries	
O*Net Code	47-2111.00
Rapids Code	0643
Req. Hours	19900
State	DC
Created	Jul 29, 2021
Updated	Jul 29, 2021

Time-Based Skills

8 skill sets | 19 total skills

Electrical Measuring Instruments - 300 req. hrs	
	300 hrs
Transformers, storage masteries, etc. - 300 req. hrs	
	300 hrs
Electrical Wiring - 1500 req. hrs	
	1500 hrs
Rebuild and repair electrical equipment - 4800 req. hrs	
D.C. motors and generators	1200 hrs
A.C. motors	1200 hrs
Generators and rectifiers	1200 hrs
Solenoids	1200 hrs

Construction and installation of conduit and pipe, machines and equipment, light and power distribution - 1200 req. hrs	
	1200 hrs
General building maintenance - 3000 req. hrs	
Substations (Secondary circuits)	1000 hrs
Light and power circuits	1000 hrs
Elevators, cranes, hoists, etc.	1000 hrs
General machine and equipment maintenance - 7200 req. hrs	
Control systems	1200 hrs
Venting	1200 hrs
Induction heating	1200 hrs
Machine tools,	1200 hrs
Welding equipment	1200 hrs
Electrical equipment	1200 hrs
Electronic equipment and controls - 1600 req. hrs	
Construction and installation	800 hrs
Troubleshooting and repair	800 hrs

Technical Instruction

First Year - 1350 req. hrs	
Safety Instruction	150 hrs
History	150 hrs
Present and Future of Trade	150 hrs
Trade Jargon	150 hrs
Tools and Equipment	150 hrs
Mathematics	150 hrs
Applied Science	150 hrs
Introduction to Electricity and Electronics	150 hrs
Blueprint Reading and Specifications	150 hrs
Second Year - 900 req. hrs	
Mathematics for Electricians	150 hrs

Electrical Wiring Residential	150 hrs
Residential Blueprint	150 hrs
Reading	150 hrs
D.C. Fundamentals and Circuits	150 hrs
Technical Communications	150 hrs
Third Year - 900 req. hrs	
Geometry and Trigonometry	150 hrs
Applied Physics	150 hrs
Mathematics for Electricians II	150 hrs
Meters and Generators	150 hrs
Commercial and Industrial Blueprint Reading	150 hrs
Electrical Wiring - Commercial	150 hrs

Surveyor Assistant Instrument

PUBLISHED

Time-Based Apprenticeship

SPONSORING COMPANY:
International Union of Operating Engineers

Industries	
O*Net Code	17-3031.00
Rapids Code	0551
Req. Hours	3298
State	DC
Created	Jul 16, 2021
Updated	Jul 16, 2021

Time-Based Skills

7 skill sets | 7 total skills

Use and care for hand tools (other than survey equipment) - 340 req. hrs
Use and care for survey hand tools - 500 req. hrs
Use and care for rods, chains and related equipment - 1000 req. hrs
Hand signals, land surveying terms and definitions - 100 req. hrs
Marker Stakes - 350 req. hrs
Bench marks and turning points - 1000 req. hrs
First Aid - 8 req. hrs

Technical Instruction

- Surveying Equipment and Techniques - 108 req. hrs
  - Overview of the Survey Industry
  - Basic Field Operations and Setting Survey Points
  - Basic Measurement Techniques in Surveying
  - Introduction to Angle Measuring and Field Instruments
  - Introduction to Leveling
  - Introduction To Topographic Surveys
  - Apprentice Skills Evaluation – Field Final
- Supplemental Math - 18 req. hrs
  - Basic Mathematics Related To Surveying
  - Algebra And Geometry Related To Surveying
  - Direction And Location Measuring Systems
- Surveying Procedures - 108 req. hrs
  - Apprentice Responsibilities and Public Relations
  - Field Notes
  - Identification of Monuments: Review Metric and English Measuring Systems
  - Linear Measurements
  - Introduction to Station and Location Systems
  - Review of Angles, Bearings, and Instruments
  - Leveling Methods
  - Global Positioning System (GPS)
  - Plan Reading and Grade Sheets
  - Introduction to Construction Surveys
- Surveying Practices - 100 req. hrs
  - Review of Measuring Systems
  - Review of Angles, Bearings, and Location Systems
  - Trigonometry
  - Slope Staking
  - Electronic Distance Measuring and Recording

GPS Basics and Field Procedures
Surveying Computations - 102 req. hrs
Coordinate Geometry
GPS Coordinate Systems
Oblique Triangle Solutions
Horizontal and Vertical Curves
Traverse Surveys