Stony Brook University

Identification of Workforce Skills Sought in Transportation Industry: What do job ads look for?

A Technical Report Submitted to the Rural Safe Efficient Advanced Transportation (R-SEAT) Center and United States Department of Transportation

FINAL REPORT

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16. Abstract

This paper provides insights into the sought-after transportation workforce skills by analyzing more than 8,000 job advertisements. The required skillsets for various job titles were extracted by using text mining tools and compared with O*NET database that documents the workforce skill expectations of the transportation industry professionals. Then, the emerging transportation job titles were searched in the job market to see if the transportation industry is actively recruiting the future generation of workforce. Overall, the transportation jobs generally require a mix of soft and hard skill requirements, reflecting the industry's diverse demands. The findings agree with the literature about the high percentage of opportunities for middle-skill jobs that require post-secondary training but not necessarily a college degree. The required skills generally align with the O*NET database. Some transportation job ads include technology-related skills such as Python and SQL, however many emerging jobs for the transportation industry such as Transportation Data Ethicist, Connected and Automated Vehicle Program Manager, AI Scientist are yet to appear in job ads. Some emerging jobs, such as Traffic Data Scientist, Computer Engineer, System Engineer are advertised in the transportation industry, however, corresponding salaries offer are found to be not competitive when compared with other industries. This suggests that the transportation industry needs to follow the job market trends to offer competitive salaries for the emerging job titles that are also sought-after in other industries.

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EXECUTIVE SUMMARY

This report evaluates whether current transportation job advertisements (ads) align with the sector's rapid technological transformation, driven by advancements such as autonomous vehicles, AI, and data-driven systems. Through analysis of **8,193 job ads** (collected via web scraping from Indeed, LinkedIn, and state DOT websites) and comparisons with industry benchmarks (O*NET), this study identifies workforce trends, skill gaps, and challenges in recruiting talent for emerging roles. Key objectives include assessing alignment between job requirements and industry transformation, identifying critical skills and gaps in current workforce recruitment, and providing actionable recommendations to enhance hiring practices.

Key Findings:

1. **Workforce Composition and Middle-Skill Dominance**: Middle-skill jobs (requiring post-secondary training but not a college degree) dominate transportation job ads (40% of roles), including CDL drivers, construction laborers, and maintenance technicians. Recruitment challenges arise from competition with higher-paying industries and declining trade school enrollment, exacerbating workforce shortages in operational roles.
2. **Skillset Requirements**: Hard skills, such as technical proficiencies (e.g., GIS, CAD, Microsoft Office), are emphasized, with **CDL licenses** as the most frequently cited requirement. Soft skills, including communication, problem-solving, and teamwork, are critical but often generically described, limiting clarity for applicants. Emerging tech skills, such as Python, SQL, and TCP programming, appear in a minority of ads, signaling slow adoption of tech-driven roles.
3. **Emerging Job Titles Are Underrepresented**: Only **30% of 2,870 analyzed emerging job ads** (e.g., Systems Engineer, Data Analyst) were transportation-specific. Critical future roles (e.g., **AI Scientist, CAV Program Manager, Transportation Data Ethicist**) were absent, indicating a gap between industry needs and recruitment practices.
4. **Salary Competitiveness**: Transportation salaries lag behind other sectors for comparable roles (**10% lower median salaries** for emerging jobs). Government roles (e.g., DOTs) offer lower pay than private sector positions, hindering talent acquisition.
5. **Job Ad Specificity and Structure**: DOT job descriptions are more structured but often generic (e.g., vague "problem-solving" requirements). Ads lack specification, complicating applicant assessments.
6. **Alignment with Industry Benchmarks (O*NET)**: There is overlap in technical skills (GIS, CAD) and soft skills (communication) with O*NET expectations. However, gaps exist, as O*NET emphasizes critical thinking, active listening, and specialized tools (e.g., SAP, SQL), which are underrepresented in job ads.
7. **Geographic and Employer Trends**: High-demand states, such as California, Texas, New York, and Florida, account for the most job postings. Top employers include state DOTs (e.g., CALTRANS, TXDOT) and consulting firms (e.g., AECOM, Stantec).

8. **Educational and Experience Requirements**: 60% of roles require degrees, with Bachelor's degrees being the most common (e.g., Transportation Planner, Engineer). Additionally, 71% of ads mandate work experience, typically 1–5 years for entry-level roles.

Recommendations:

1. **Prioritize In-House Expertise for Emerging Roles**: Develop training programs to upskill current employees in **AI, data ethics, and cybersecurity**. Reduce reliance on consultants by hiring full-time specialists for critical roles (e.g., TSMO Program Manager).
2. **Enhance Salary Competitiveness**: Adjust pay scales for high-demand emerging roles (e.g., Data Scientist, AI Engineer) to match private-sector benchmarks. Offer incentives (e.g., professional development, remote work) to attract tech talent.
3. **Improve Job Ad Clarity and Outreach**: Standardize job descriptions with **specific skill requirements** (e.g., "Python for traffic modeling"). Advertise roles on job search platforms (e.g., Indeed, LinkedIn) to reach non-traditional candidates.
4. **Monitor Emerging Workforce Trends**: Track adoption of emerging job titles and technologies to refine recruitment strategies. Regularly benchmark salaries and skills against O*NET and competitor industries.

While transportation job ads reflect foundational industry needs, they lag in addressing technological transformation. Bridging this gap requires competitive compensation, strategic recruitment, and partnerships to cultivate a future-ready workforce. By implementing these recommendations, DOTs and private firms can better align with industry evolution and secure skilled talent.

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1. INTRODUCTION

The transportation industry employs about 16 million workers under 75 job titles that correspond to a vast range of jobs categories based on the SOC coding scheme [50]. Literature commonly agree that attracting, recruiting, and retaining talented workforce is particularly challenging for DOTs, with reasons ranging from the image of public work to lack of advancement opportunities, work environment concerns and perception of bureaucracy. In addition, emerging technologies (such as autonomous and connected vehicles, new sensing technologies, emerging micro- and shared-mobility modes) have been transforming the transportation industry in a rapid manner, prompting USDOT to prioritize transformation as one of the five focus points of 2022-2026 Strategic Plan [51]. In this technology driven transformation, transportation agencies compete with more resourceful technology and start-up companies to recruit and/or employ workforce that are well-versed in emerging topics such as autonomous systems, sensors, machine learning, and artificial intelligence. Hence, transportation industry in general, but public transportation agencies, are mostly not in the job search radar of the workforce from fields such as computer science and electrical engineering who happen to possess the sought-after skills. Thus, it is important to 1) understand how to recruit and retain skilled workforce, 2) educate the students from fields that DOTs traditionally recruit from (e.g., civil engineering, planning) to possess the sought-after skills and 3) train the existing workforce not to fall back in the technological advancement trend. The transformative potential of technology towards an accessible, multimodal transportation system can only be realized if the gap between the state-of-the-art and the state-of-the-practice is reduced. In the mid- to long-term, this can be achieved most effectively by educating the future generation of researchers and practitioners through training and education programs that build workforce skills that align with the transformation of the transportation industry. In the shorter term, transportation agencies need to recruit workforce with necessary skills to start building up the in-house expertise to meet the workforce skills demands related to the transformation. This project is the first installment of the envisioned REAT Center projects that aims to fill this gap. Specifically, this project documents the sought-after skills by transportation industry (focusing on DOTs) by analyzing the job ads (obtained via DOTs directly or through job ad sites) with text mining tools to extract the common skills and qualifications. Accordingly, strategies for more effective hiring practices are formulated.

First, transportation related job ads are collected through web scraping the employment websites (e.g., Indeed.com, Linkedin.com) by using transportation related keywords such as "transportation," "transportation engineer," "transportation planner, " "transportation maintenance " etc. The collected job data is analyzed in terms of the employer (i.e., DOT vs Non-DOT), and major job details (e.g., job location and title, required level of education, pay range if available, and so on). Then the job descriptions are further analyzed by data mining to document the required and preferred qualification. In terms of transformation in the transportation industry,

Transportation Systems Management and Operations (TSMO) Workforce Guidebook52 [3] identifies new and emerging job titles. TSMO is sub-category of transportation technical expertise, hence the emerging job titles in [3] do not apply to the whole transportation industry. Nevertheless, given that there are no similar studies for other categories of transportation job, the identified job titles are used as a proxy to examine whether emerging jobs are already being searched for. For this purpose, additional job ad data were collected from Indeed website by using the emerging job titles as keywords.

The outline of this report is as follows: First a literature review on the transportation industry workforce with a focus on the necessary workforce skills are provided. Second, the data collection methodology is summarized, followed by the overall descriptive statistics related to the collected job ads. Then, the text analysis of the job ad descriptions is provided to document both the "hard" (e.g., education level, required experience, etc.) and "soft" (e.g., problem solving, teamwork, etc.) skills that are commonly indicated in the job ads. These identified skills are discussed further within the related information collected by O*NET Program, and then the recommendations are presented.

2. LITERATURE REVIEW

The transportation industry is a crucial component of the U.S. economy, with its significance reflected in both employment numbers and economic contribution. As of 2022, approximately 15.8 million people, accounting for 10.4% of the U.S. labor force, were employed in the transportation and warehousing sector and related industries, marking the highest level of transportation employment since 1990 [50]. The trucking, as the largest employer within transportation and transportation-related industries, employed 1.2 million workers in 2022 [50]. The transportation services were responsible for the 6.7% of the GDP in the U.S. in 2022 [53] and transportation costs accounted for 16.9% of housing expenditures in 2022, second largest cost item after housing [54]. Reflecting the diversity of industries, the workforce in transportation spans from vehicle operators and support workers to professionals in engineering, planning, and administration. The broad range of transportation related occupations makes it challenging to tally the total number of workers, to the point that there are specific studies just to tally the number of transportation workforce. For instance, it is a challenge to account for employees that perform transportation-related functions in industries whose primary activity is not transportation, e.g., grocery chains or school districts employing drivers [54]. Per U.S. Bureau of Labor Statistics', The North American Industry Classification System (NAICS) system, the Transportation and Warehousing (NAICS 48-49) consists of 11 subsectors that employ more than 6.5 million people as of 2023 [53]. A joint data report from the U.S. Departments of Education, Transportation and Labor [54] utilizes the Bureau of Labor Statistics' Standard Occupational Classification (SOC) (which classifies the workers by the function they perform, regardless of where they may work) to address the workforce challenges under the six subsectors of transportation industry, i.e., Trucking Transportation, Transit and

Ground Passenger Transportation, Air Transportation, Highway Construction and Maintenance, Rail Transportation and Maritime Transportation. This report excludes the transportation related sectors of 1) Warehousing and logistics, 2) Manufacturers and suppliers of transportation vehicles and equipment such as aircraft manufacturing, shipbuilding, and bus and rail vehicle manufacturing, and 3) Sightseeing transportation, postal service, couriers, pipeline transportation, and other support activities for transportation. On the other hand, to have the complete workforce count, [55] also utilizes the Standard Industrial Classification (SIC) to include transportation related industries such as for-hire transportation services (SIC 40–47 and 492). An overview of the employment classifications for the transportation-related industries and the corresponding SIC, SOC and NAICS codes are provided in Table 4.

2.1. Transportation Workforce Challenges

The variety of job titles and descriptions across multiple industries also implies a large range of education and skillset requirements for the transportation workforce. Accordingly, the transportation workforce studies tend to focus on certain aspects of workforce development (e.g., attracting-recruiting-developing-retaining-training-education [5255,56,57,58,59,60]), specific operations (such as transit [61], Transportation Systems Management and Operations (TSMO) [52]), or local workforce needs of states/regions/cities [62,63,64,65,66,67]. Despite different scope, the studies point out several cross-cutting workforce challenges as summarized below.

2.1.1. Impact of age-demographics

The impact of age demographics is generally discussed under two main topics: 1) Aging workforce, and 2) The difficulty of attracting/recruiting new generation of professionals. Almost all workforce studies state the aging workforce (particularly pronounced for transit) as an important challenge for transportation workforce – please see Figure 1 for the 2022 numbers related to 55+ employees across transportation sector. Aging workforce introduces the challenges of potential worker shortages after retirement of existing workers, in addition to the loss of knowledge/know-how without the adequate procedures for knowledge retention [68,69,7970]. Around 10,000 retire each day, a trend expected to continue through 2031. This demographic shift is particularly impactful in transportation, where over 50% of workers will be eligible to retire in the next decade, double the retirement rate of the national workforce. This looming wave of retirements poses a significant challenge in terms of knowledge transfer and maintaining operational efficiency. [71]

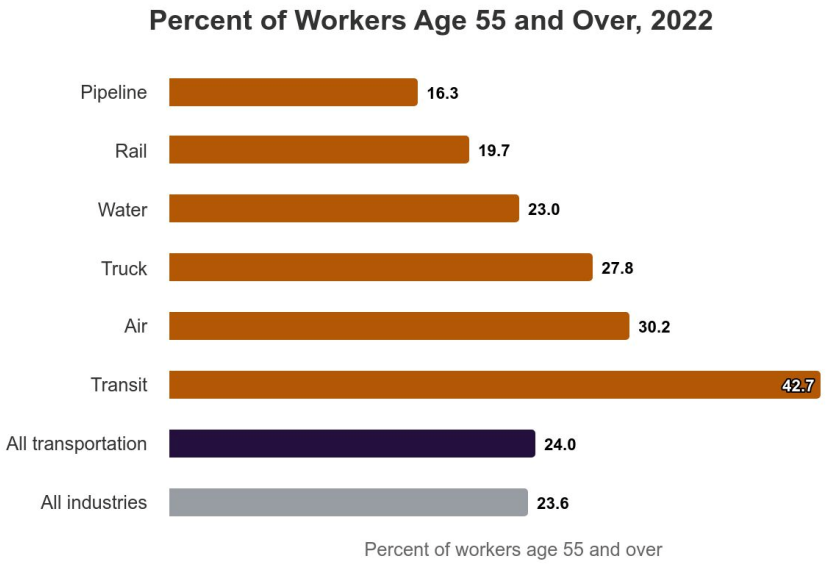


Figure 1- Distribution of 55+ Workforce Across Transportation Industries [50]

In this picture, attracting and recruiting younger generation of transportation professionals become crucial; however, literature cites various factors ranging from the image of public transportation agencies to employment expectations of younger generations as a barrier to replace the soon-to-retire workforce. The image and reputation of an industry significantly impact its ability to attract younger workers. Sectors like public transportation and manufacturing often struggle due to perceptions of outdated technology, limited career growth, and less appealing work environments. Modernizing the image of these industries through branding and demonstrating technological advancements can help improve their attractiveness. A significant area of discrepancy in the literature concerns what younger generations prioritize in their employment. Some studies emphasize that Millennials and Generation Z place a high value on work-life balance, flexible working hours, and remote work opportunities. For instance, a survey by Deloitte highlighted that work-life balance was a top priority for young professionals when choosing a job. Conversely, other research indicates that competitive compensation remains a critical factor for many young job seekers. A study found that while work-life balance is important, salary and financial incentives often take precedence when it comes to actual job decisions [70]. These conflicting findings suggest both factors play significant roles, varying with individual preferences and economic conditions.

Young workers often seek clear career paths, professional development, and opportunities for advancement. Industries perceived as offering stagnant roles with limited growth prospects tend to struggle in attracting young talent [72]. Companies that invest in training programs, mentorship, and clear progression routes are generally more successful in recruiting younger employees. The younger generation is generally more tech-savvy and prefers working in environments that embrace technological advancements and innovation. Industries that lag in adopting new

technologies can be seen as less attractive to potential young employees . On the other hand, sectors that are perceived as innovative and forward-thinking tend to draw more interest from tech-oriented young professionals. Corporate culture and values are also critical in attracting the younger workforce. Millennials and Generation Z often look for employers whose values align with their own, particularly regarding social responsibility, diversity, and environmental sustainability [73]. Discrepancies arise here as well, with some studies suggesting that while these values are important, they do not outweigh practical considerations such as job stability and benefits [74]. The literature reveals several discrepancies and conflicting findings regarding what the younger generation prioritizes in their employment decisions:

1. **Work-Life Balance vs. Compensation**:
    - **Pro Work-Life Balance**: Studies that emphasize that younger generations prioritize work-life balance over salary, seeking jobs that offer flexibility and remote working options [70].
    - **Pro Compensation**: Other studies argue that competitive compensation packages are still the most critical factor for many young professionals, especially in high-cost living areas [71].
2. **Values and Organizational Culture vs. Practical Benefits**:
    - **Values-Oriented**: Research from Cone Communications indicates a strong preference among young workers for employers who demonstrate a commitment to social and environmental issues [73].
    - **Practical Benefits**: Meister notes that while younger employees do value corporate ethics, they are not willing to sacrifice essential benefits such as healthcare, job security, and competitive salaries [74].
3. **Career Growth vs. Job Stability**:
    - **Career Growth**: Studies highlight that young workers seek roles with clear career progression and professional development opportunities [74].
    - **Job Stability**: In contrast, during economic uncertainties, younger generations may prioritize job stability and long-term security over rapid career advancement [74].

2.1.2. Middle-Skill Gap

Middle-skill jobs are the jobs that require some postsecondary training or education but not a college degree [75]. The impacts of shortage in middle-skill workforce (not only for transportation industry but for all industries) has been emphasized for more than a decade as an impending issue, along with estimates that middle-skill jobs account for 53% of the United States' labor market, whereas 43% of the country's workers are trained to the required level [75,76].

An NCHRP report [55] underlines that fewer people are enrolling in trade schools compared to traditional four-year schools that lead to job placements at white collar or service-based industries instead of production-based industries, like construction or factory work. The joint

data report from the U.S. Departments of Education, Transportation and Labor also emphasizes that the highest demand jobs are the semi-skilled and skilled jobs in operations and maintenance, and those type of positions are listed as one of the most difficult positions to fill based on State DOT Human Resources (HR) staff interviews [60]. Based on past research [77], Cronin and Goldstein [78] confirm the difficulty of recruiting talent with specialized skills and emphasize the competition with other industries as a factor that worsens the situation for transportation agencies, i.e., commercial sectors can offer better compensation packages for may transportation trades jobs such as electricians, mechanics, HVAC technicians. Adams et. al [75] argue that many critical highway maintenance occupations fall into this category that requires specialized knowledge, skills, and competencies (Please see Figure 2). Lemer [79] underline the lack of technical expertise in construction industry, i.e., *"contractors and construction managers found that 91% of respondents reported having a difficult or moderately difficult time finding skilled workers"*. Adams et. al [75] further argue that there is a lack of formal training and national recognition for middle-skill highway maintenance jobs that are also echoed in other studies (including a FHWA study on transportation workforce in Europe [80]). Multiple reports and studies emphasize the need for outreach efforts, development of apprenticeship programs and clear career paths to encourage younger generation to follow trades careers for transportation industry employment [67,]. Figure 3 provides the large % shortfalls (68% on the average) between projected annual job openings and related educational program annual completions between 2012-2022 [67] and underlines the importance of such educational initiatives.

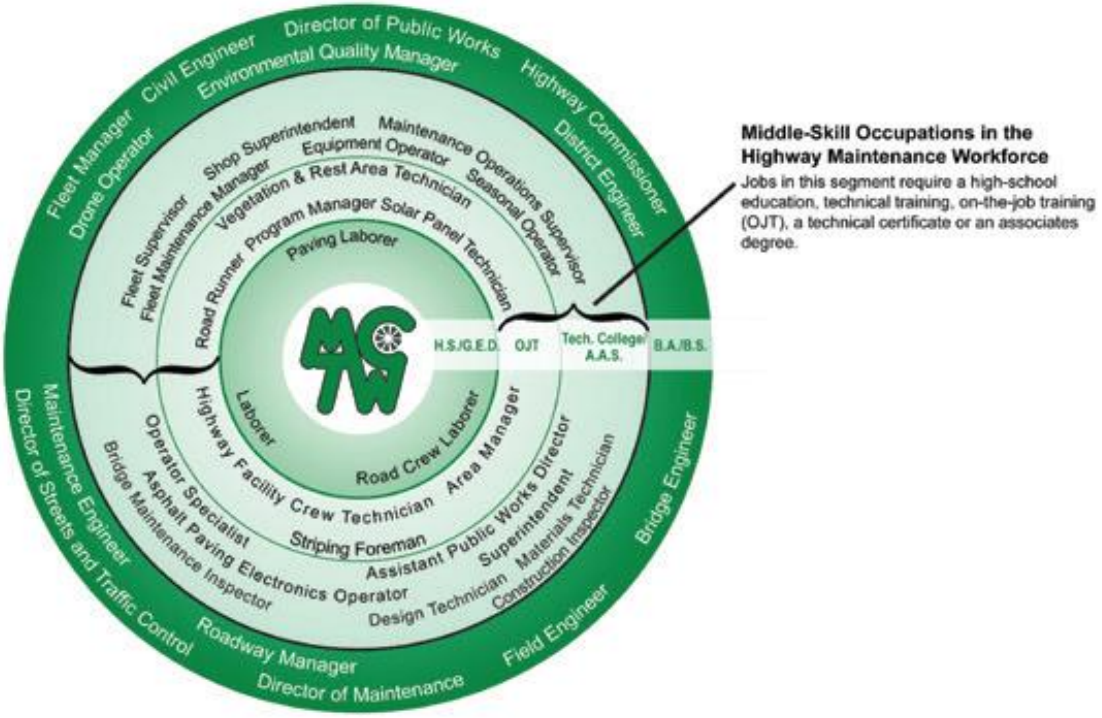


Figure 2- Typical Job Titles in Highway Maintenance with Corresponding Education Requirements [75]

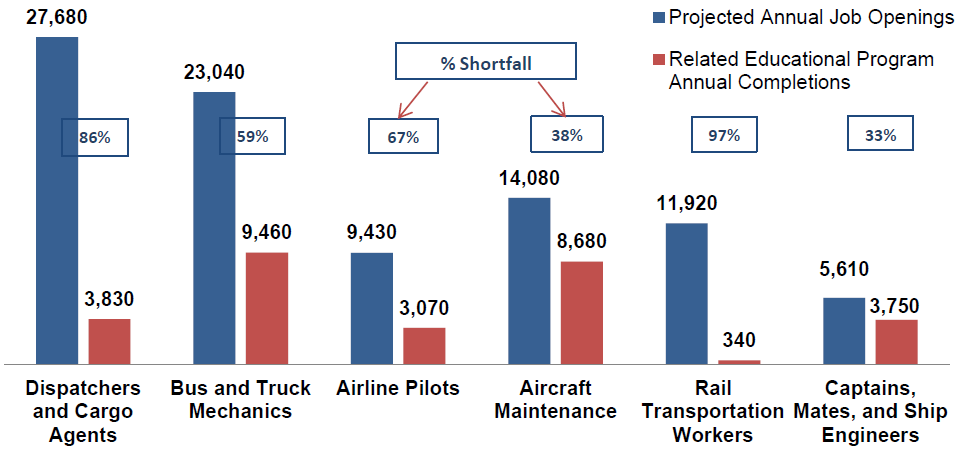


Figure 3-Projected Annual Job Openings (2012–2022) vs. Related Educational Program Completions [75]

2.1.3. Workforce Skillset Implications of Technology-Driven Transformation in Transportation Industry

Transformational impact of emerging technologies on transportation industry is also reflected on the skillsets that are necessary for the transportation workforce. Pomoni et. al [81] argue that digitalization and autonomy fueled by the technology innovation will transform the transportation

workforce both in numbers and new necessary skills (i.e., *"digitalization literate workforce"*). Adams et. al [75] exemplifies the technology driven new skill requirements for the middle-skill occupations by referring to increasing utilization of automated equipment and tablets by transportation workers. Szymkowski and Ivey [76] looks at the same issue from the perspective of transportation systems management and operations (TSMO), and point out the increasing role of connected and automated vehicle technologies, big-data analytics and sophisticated decision support systems that will transform how the transportation infrastructure is monitored and maintained. In addition to impending challenges related to connected and automated vehicles, shared mobility and electric vehicles, Harrison and Park [82] underline the impact of new information technologies on all aspects of transportation agency management, ranging from planning to engineering design.

Simkins and Mahjabeen [83] confirm that many of transportation job vacancies require new the information-communication-technology skills (such as traffic management, driver assistance, and car-to-infrastructure system operation skills) to match the technological developments in the industry, or as coined by PWC [71], the "e-skills". Pomoni et. al [81] further argue that integration of transport services the other sectorial services will require an inter-disciplinary workforce, and digitalization skills is not only relevant to employees but also for employers due to necessary upskilling of the potential workforce. Similar to the difficulty of filling up middle-skill positions, Harrison and Park [82] state that positions that require technical expertise in information technology and data analytics are difficult to fill. They also emphasize that an increasingly stretched workforce can face difficulties absorbing the changes due to quick-paced development of new technologies. Cronin and Goldstein [78] also underlines that the need for strong technology-focused skills is not unique to transportation, leading to fierce competition with other industries, like the case for middle-skill positions.

The objective of this project is to identify the sought-after skills in the current transportation job market, through analysis of recent job advertisements. In this respect, it is important to identify whether the job ads require the transportation workforce skills that align with the technology-driven transformation of transportation industry. The next section delves into the sought-after skills aspect of the transportation workforce.

2.2. Necessary Skillset for the Transportation Workforce

The diversity of job titles and responsibilities in the transportation industry make it difficult to list a master set of necessary skills for the whole workforce. One of the most comprehensive sources on that matter is the O*NET Program. O*NET Program is sponsored by the U.S. Department of Labor/Employment and Training Administration (USDOL/ETA) through a grant to the North Carolina Department of Commerce. Publicly available O*NET database includes worker attributes and job characteristics for various industries in the U.S., including transportation industry. O*NET Program collects information by first identifying a statistically random sample of businesses

expected to employ workers in the targeted occupations and selecting a random sample of workers in those occupations within those businesses. O*NET categorizes the jobs under the 2018 Standard Occupational Classification (SOC) system which is used by federal agencies to classify workers into occupational categories. For each job title, the following information are aggregated under main categories and listed under subcategories (i.e., the subsections in parentheses below) are:

- Occupation-Specific Information (Tasks, Technology Skills, Tools Used)
- Occupational Requirements (Work Activities, Detailed Work Activities, Work Activities Outline, Work Context)
- Experience Requirements (Job Zone, Training & Credentials, Apprenticeship Opportunities)
- Worker Requirements (Skills, Knowledge, Education)
- Worker Characteristics (Abilities, Interests, Work Values, Work Styles)
- Workforce Characteristics (Wages & Employment Trends, Job Openings on the Web)
- More Information (Related Occupations, Crosswalk, Professional Associations)

The job titles are aggregated under industry, job family or career cluster for the users. Table 1 provides the education requirements, general and technological skills for maintenance workers, transportation engineers and transportation planners. The technology skills commonly list the basic communication software packages (e.g., MS Office Suite) tools in addition to standard job specific software such as micro-macro simulation software, GIS tools, etc. Considering that these skills are based on the input from managers and supervisors, the required industries sought after skills do not explicitly include the skills related to emerging technologies such as sensors, autonomous vehicles, and so on. Such aspects are generally included in generic forms under the "Knowledge" category, e.g., transportation engineering knowledge categories of Engineering and Technology (Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.) and Computers and Electronics (Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming). In terms of this project's objectives, it is important to distinguish the expected general knowledge that is relatively more difficult to assess, and the specific technology skills that can be assessed more rationally. This distinction is also underlines in [84] which utilizes employer surveys to understand the so-called skill gaps (i.e., *"A shortfall in the aggregate supply of a certain skill or set of skills broadly sought by employers"* [85]*)* in transportation industry. Study states that *"employers reported more concerns over the workers' skill gaps, as opposed to the knowledge gaps"*.

*Table 1-Education, Skills and Technology Skills for Highway Maintenance Worker, Transportation Engineer and Transportation Planner based on O*NET Database [77]*

	Highway Maintenance Worker		Transportation Engineer		Transportation Planner	
EDUCATION	• 88% High school diploma or equivalent required • 5% Less than high school diploma required • 5% Associate's degree required		• 77% Bachelor's degree required • 9% Associate's degree required • 9% Post-baccalaureate certificate required		• 55% Bachelor's degree required • 45% Master's degree required	
SKILLS	Categories	Examples	Categories	Examples	Categories	Examples
	Operation and Control	Controlling operations of equipment or systems.	Critical Thinking	Using logic and reasoning to identify the strengths and weaknesses of alternative solutions	Active Listening	Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times
	Operations Monitoring	Watching gauges, dials, or other indicators to make sure a machine is working properly.	Reading Comprehension	Understanding written sentences and paragraphs in work-related documents	Complex Problem Solving	Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions
	Monitoring	Monitoring/Assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.	Speaking	Talking to others to convey information effectively.	Critical Thinking	Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions, or

						approaches to problems
	Coordination	Adjusting actions in relation to others' actions.	Writing	Communicating effectively in writing as appropriate for the needs of the audience	Reading Comprehension	Understanding written sentences and paragraphs in work-related documents
	Active Listening	Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times.	Complex Problem Solving	Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions	Speaking	Talking to others to convey information effectively
	Speaking	Talking to others to convey information effectively.	Judgment and Decision Making	Considering the relative costs and benefits of potential actions to choose the most appropriate one	Writing	Communicating effectively in writing as appropriate for the needs of the audience
	Complex Problem Solving	Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.	Mathematics	Using mathematics to solve problems	Judgment and Decision Making	Considering the relative costs and benefits of potential actions to choose the most appropriate one
			Time Management	Managing one's own time and the time of others	Active Learning	Understanding the implications of new information for both current and future problem-solving and decision-making
			Active Listening	giving full attention to what other people are saying, taking time to understand the points	Systems Evaluation	Identifying measures or indicators of system performance and the actions needed to

				being made, asking questions as appropriate, and not interrupting at inappropriate times		improve or correct performance, relative to the goals of the system
TECHNOLOGY	Data base user interface and query software	Database software	Analytical or scientific software	Citilabs Cube; McTrans Center TSIS-CORSIM; SIDRA INTERSECTION; Trafficware SynchroGreen	Analytical or scientific software	Citilabs Cube; McTrans Center TSIS-CORSIM; SIDRA INTERSECTION; Trafficware SynchroGreen
	Electronic mail software	Microsoft Outlook	Computer aided design CAD software	Autodesk AutoCAD, Bentley MicroStation ,Computer aided design and drafting software CADD	Computer aided design CAD software	Autodesk AutoCAD, Bentley MicroStation ,Computer aided design and drafting software CADD
	Internet browser software	Web browser software	Data base user interface and query software	Structured query language SQL	Data base user interface and query software	Structured query language SQL
	Office suite software	Microsoft Office software	Electronic mail software	Microsoft Outlook	Desktop publishing software	Adobe InDesign
	Presentation software	Microsoft PowerPoint	Geographic information system	ESRI ArcGIS software	Development environment software	Microsoft Visual Basic
	Spreadsheet software	Microsoft Excel	Internet browser software	Web browser software	Document management software	Adobe Acrobat
	Word processing software	Microsoft Word	Materials requirements planning logistics and supply chain software	Materials requirements planning logistics and supply chain software	Electronic mail software	Microsoft Outlook

KNOWLEDGE	Public Safety and Security	Knowledge of relevant equipment, policies, procedures, and strategies to promote effective local, state, or national security operations for the protection of people, data, property, and institutions.	Engineering and Technology	Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.	Transportation	Knowledge of principles and methods for moving people or goods by air, rail, sea, or road, including the relative costs and benefits
	English Language	Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition, and grammar.	Design	Knowledge of design techniques, tools, and principles involved in production of precision technical plans, blueprints, drawings, and models	English Language	Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition, and grammar
	Transportation	Knowledge of principles and methods for moving people or goods by air, rail, sea, or road, including the relative costs and benefits.	Transportation	Knowledge of principles and methods for moving people or goods by air, rail, sea, or road, including the relative costs and benefits	Mathematics	Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications
	Building and Construction	Knowledge of materials, methods, and the tools involved in the construction or repair of houses, buildings, or other structures such as highways and roads.	Building and Construction	Knowledge of materials, methods, and the tools involved in the construction or repair of houses, buildings, or other structures such as highways and roads.	Geography	Knowledge of principles and methods for describing the features of land, sea, and air masses, including their physical characteristics, locations, interrelationships, and

						distribution of plant, animal, and human life
	Education and Training	Knowledge of principles and methods for curriculum and training design, teaching and instruction for individuals and groups, and the measurement of training effects.	Mathematics	Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications	Law and Government	Knowledge of laws, legal codes, court procedures, precedents, government regulations, executive orders, agency rules, and the democratic political process
	Administration and Management	Knowledge of business and management principles involved in strategic planning, resource allocation, human resources modeling, leadership technique, production methods, and coordination of people and resources.	English Language	Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition, and grammar	Computers and Electronics	Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming
	Mechanical	Knowledge of machines and tools, including their designs, uses, repair, and maintenance.	Physics	Knowledge and prediction of physical principles, laws, their interrelationships, and applications to understanding fluid, material, and atmospheric dynamics, and mechanical, electrical, atomic and sub-atomic structures and processes	Administration and Management	Knowledge of business and management principles involved in strategic planning, resource allocation, human resources modeling, leadership technique, production methods, and coordination of people and resources

There are a few studies that identify the skill gaps in the transportation industry. Simkins and Mahjabeen [83] utilize a survey of transportation workers and employers to measure the knowledge, skills, and abilities (KSAs) required by employers and those held by workers. They report extensive KSA mismatch between the transportation and materials moving employers and workers in the areas of:

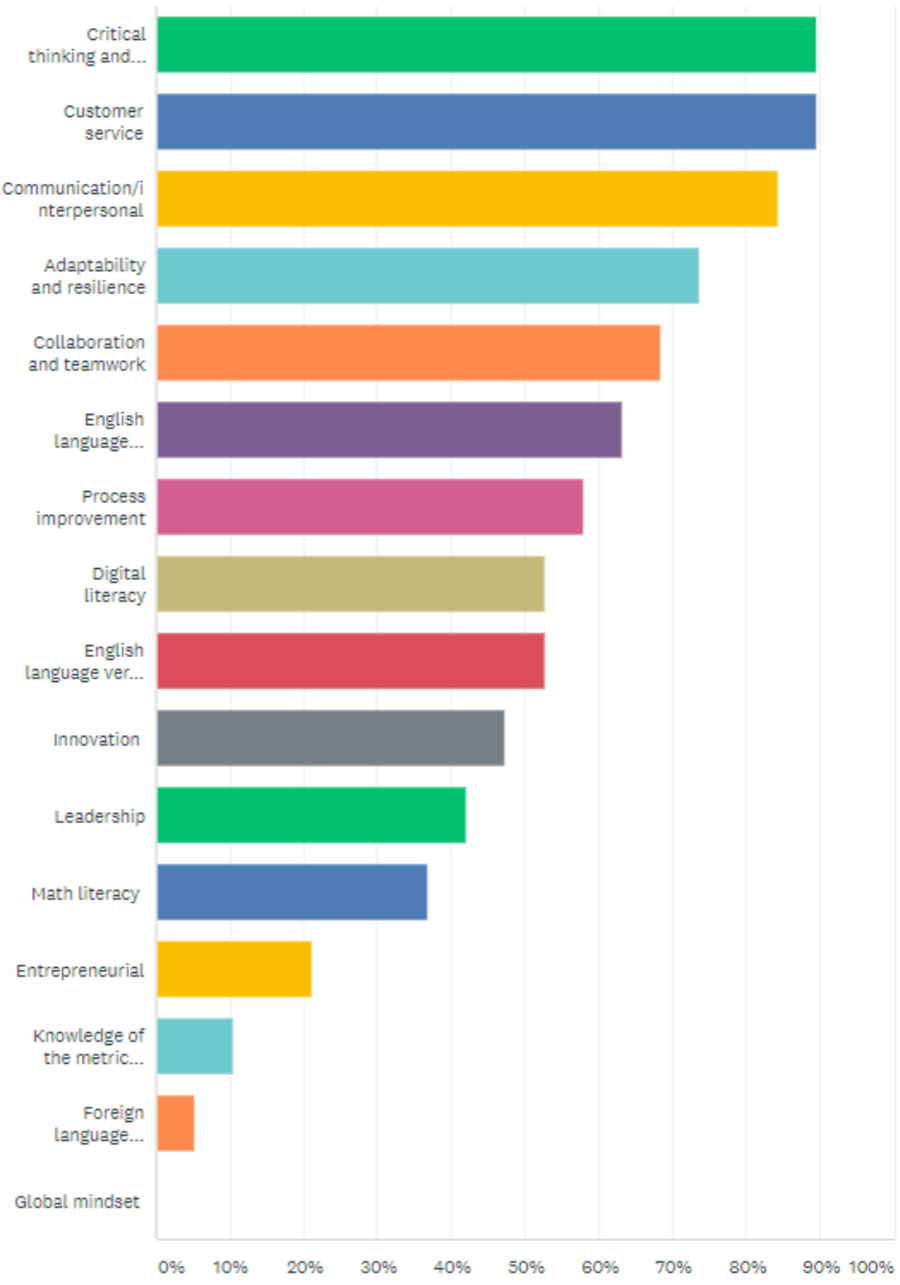
- knowledge of transportation, distribution, and logistics.
- knowledge of machines, tools, and equipment.
- equipment operation, maintenance, repair, and troubleshooting skills.
- critical thinking and problem-solving skills.
- work prioritization and resource-management skills; and
- ability to apply knowledge.

The overall finding of the study is the misalignment between KSAs that employers are looking for and the KSAs workers think they need for a given job. For example, employer report that 38% of the vacancies were difficult to fill due to major and severe gaps in equipment operation skills, however the workers reported having no gaps in this specific skill set. The study [83] concludes that this mismatch in perceptions can explain why the workers develop competencies that are not necessarily sought by employers and contribute to employers' complaints about skills gap. In addition to differentiation between skill and knowledge gaps, these findings point out the importance of job ads that can be one of the ways to reduce the gap/misalignment between sought-after and perceived required skills.

Another skills-gap study [84] focuses on the transportation, warehousing and logistics industry workforce in Pierce County, WA. The main finding of the study is the overall satisfaction of employers about the technical skills while concern for the lack of soft skills, e.g., resume writing proficiency, punctuality, and communication skills. "Soft" skills were once considered complementary but now are central to effectiveness.

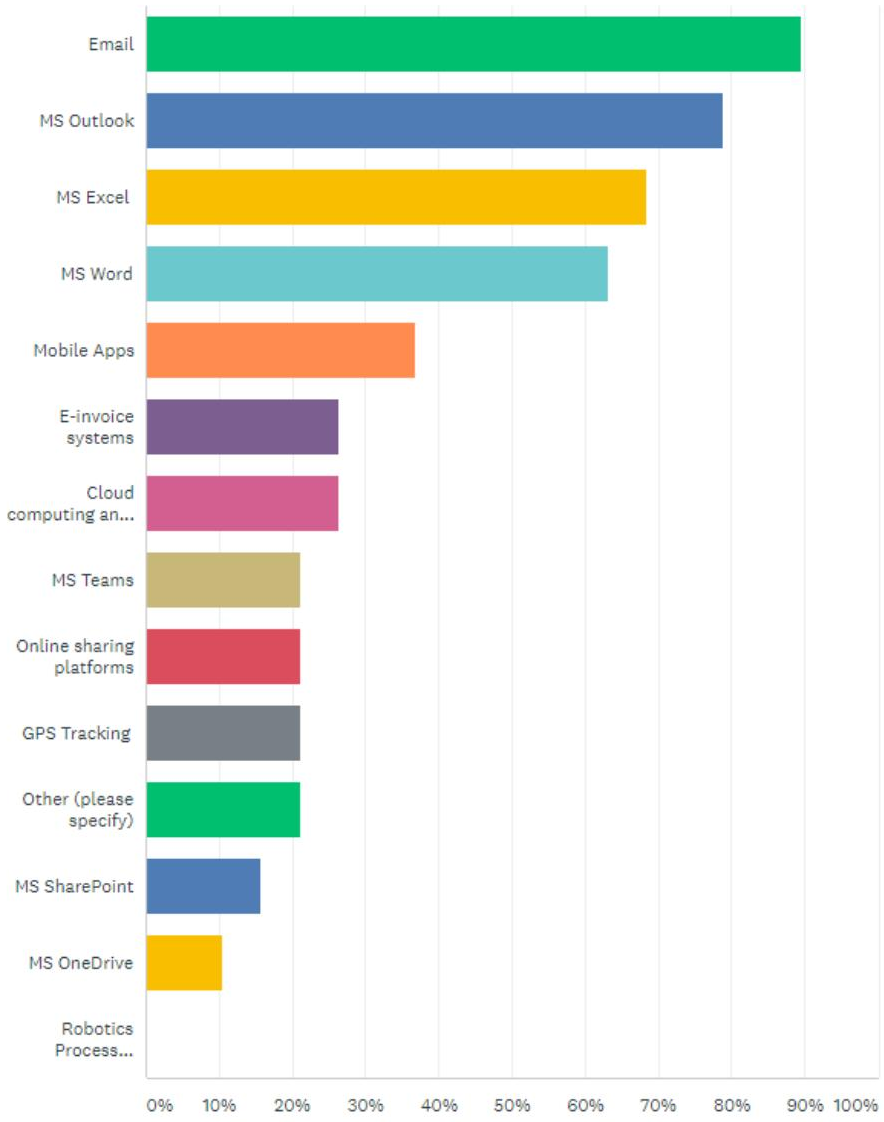
It is worth mentioning that both studies do not include skill gap discussions related to emerging technologies, or "e-skills". This aspect is partially addressed in a digital skills study [85] that is not specific to transportation industry but provides info on the broad category of "construction, transportation and storage" industry. The study defines "no" digital skills by assessing 1) prior computer use, 2) Willingness to take the computer-based assessment, and 3) Ability to complete 4 out of 6 basic computer tasks such as using a mouse, highlighting a text. The "limited" digital skills are assessed by completion of simple digital tasks (such as sorting emails) by taking a few steps on a generic interface. Their results indicate that 22% of the construction, transportation and storage industry workers have "no" digital skills, and 28% have "limited" digital skills. O'Brien et. al [63] investigates the transportation and supply chain industry sector workforce development needs in Southern California. Figure 4 shows the responses to the question about employability skills for the middle-skill employees. Besides the fact that data digital literacy does not rank very high (8^{th} among 16) in the list of answers, Figure 5 shows that the implied digital skills relate to basic communication software such MS Office tools. On the other hand, as the job

category or the job duties are presented more specifically, the list of skills starts reflecting the need for expertise in technology related tools and applications. For example, the most critical middle-skill workforce needs for data management lists automated data collection (3rd out of 18), data visualization (5th), inventory and network optimization (6th), predictive analysis (9th). For the most critical middle-skill workforce needs for operations& maintenance, zero-emissions technology ranks 2nd out of 18, followed by cyber security (5th), use of sensors (6th), fleet electrification (7th), Industrial Internet of Things (9th), Mechatronics (Mechanical/electrical/software aptitudes - 11th), 3D printing (12th), and Wearable and mobile technology (13th). Despite being the sought-after skills for the middle-skill workers, some of these listed skills are also college level course titles under engineering programs. This discrepancy is arguably due to rapidly evolving technology disrupting the traditional transportation jobs, where the continuing value of traditional skills conflict with the needs for emerging skills. Accordingly, some researchers envision new employment types that break from the tradition with new job titles and/or descriptions.



Critical thinking and data-driven problem-solving
English language literacy (reading and writing)
English language verbal communication
Knowledge of the metric system
Foreign language knowledge

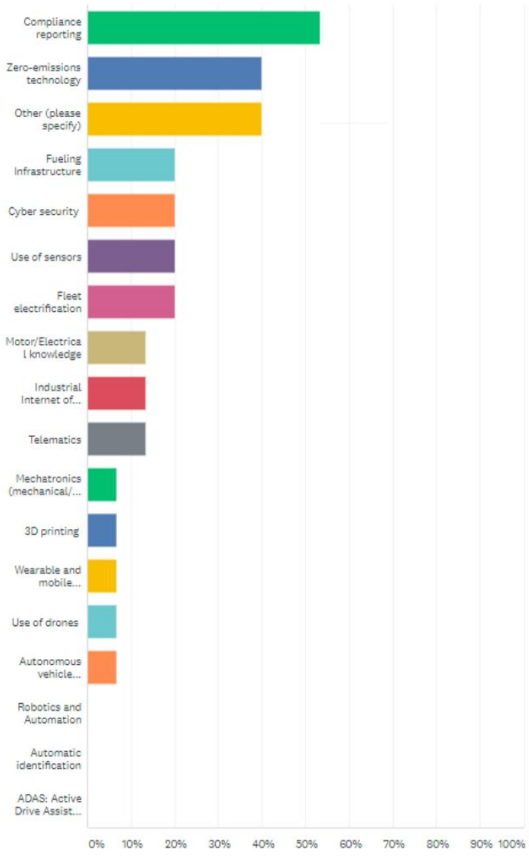
Figure 4-Top Employability Skills Transportation and Supply Chain Industry Sector in Southern California [63]



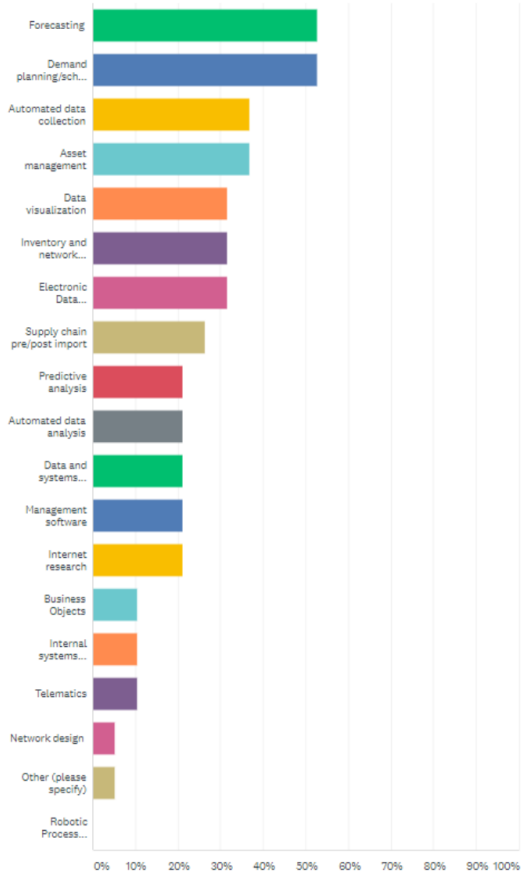
Cloud computing and storage

Robotics Process Automation

Figure 5-Most Critical Digital Literacy Skills for Transportation and Supply Chain Industry Sector in Southern California [63]



Industrial Internet of Things
Mechatronics (Mechanical/electrical/software aptitudes)
Wearable and mobile technology
Autonomous vehicle technology including cargo handling equipment
ADAS: Active Drive Assist Systems



Demand planning/scheduling
Inventory and network optimization
Electronic Data Interchange (EDI)
Data and systems security
Internal systems adaptability

Figure 6-Most Critical Middle-skill Workforce Needs for Data Management (left) Operations & Maintenance (right) [63]

2.3. Emerging Jobs for the Transportation Workforce

Szymkowski and Ivey [76] argue that government transportation agencies historically have been organized to expand and deliver infrastructure capacity, but using technology and sharing information quickly has become more appealing as society begins to place more value on system performance and reliability. Accordingly, they emphasize evolution of roles and responsibilities of traditional positions (please see Table 2).

Table 2-Evolution of Existing Positions in Transportation Industry [76]

JOB TITLE	FUTURE ROLES AND RESPONSIBILITIES
Traffic Engineer	• Use spatial data, such as GIS and relevant spatial analyses and statistics, for data-driven decision-making. • Advocate for the appropriate TSMO countermeasures during the planning, design, and construction of highway projects as appropriate. • Consider CAV impacts on traffic operations.
Traffic Signal Engineer	• Incorporate ICM techniques into the operations of traffic signals. • Consider CAV impacts on traffic signal operations. • Effectively use GIS and other analytical tools such as SPSS/STATA and traffic simulation and signal timing software (e.g., VISSIM, CORSIM, and Synchro) to create information that enhances operational decision-making.
Freeway Operations Engineer	• Incorporate ICM and other demand-management techniques into the operations of freeway facilities. • Consider CAV impacts on freeway operations. Consider and manage new techniques such as automated vehicle–only lanes. • Take a multimodal approach to freeway operations. • Use real-time data to make real-time operational decisions. Implement and use prediction software to make operational decisions.
Arterial Operations Engineer	• Incorporate ICM techniques into the operations of arterial facilities. • Consider CAV impacts on arterial operations. • Take a multimodal approach to arterial operations. • Use real-time data to make real-time operational decisions. Implement and use prediction software to make operational decisions. • Identify, analyze, and interpret trends or patterns in complex data sets.
ITS Design Engineer	• Integrate connected vehicles into ITS design. For example, add DRSC or 5G connectivity as needed. • Use modern technology in ITS design including CIM.
ITS Planner	• Use big data to analyze benefits of TSMO strategies and implement if feasible. • Mainstream TSMO into the project-planning process. • Implement modeling for analysis, visualization, planning, and training related to TSMO programs. • Perform scenario planning to plan for CAV.
Transportation Planner	• Mainstream TSMO into the project planning process. • Integrate management and operations strategies into the metropolitan transportation planning process to maximize the performance of the existing and planned transportation system. • Implement modeling for analysis, visualization, planning, and training related to TSMO programs. • Take a multimodal approach to transportation planning.

NOTE: GIS = geographic information systems; TSMO = transportation systems management and operations; CAV = connected and automated vehicles; ICM = integrated corridor management; DRSC = dedicated short-range communications; CIM = civil information modeling.

In addition, referring to the part of NCHRP Project 20-07(408) [52] on Transportation Systems Management and Operations (TSMO), they identify 19 new and emerging positions along with their rationale.

Table 3- Emerging Positions under Transportation Systems Management and Operations (TSMO) Domain [76]

Position	Rationale
Traffic Data Scientist/Statistician	An added emphasis on data science is required as very large amounts of data become more important.
TSMO Manager/Chief/Bureau Director	As TSMO is elevated in government agencies, the roles and responsibilities of higher-level executive management are necessary.

TSMO Program Manager	Several early adopters of TSMO have created program manager positions to coordinate across the wide array of functional areas and to implement activities that call for a broad range of internal and external stakeholders.
Computer Engineer	Specialized computer engineering is required as processing becomes more distributed and as more and more operational decisions are made through edge computing in the field as opposed to a centralized model.
Artificial Intelligence (AI) Scientist	Government agencies currently have very little experience with AI, but this will rapidly change as cooperative automated transportation becomes more broadly deployed.
Telecommunications Engineer	As private and public communication networks become ubiquitous and more bandwidth is required for emerging technologies, staff who can design the best ways to communicate with fixed and mobile assets will become more critical.
Data Management Specialist	As a complement to computer engineers and data scientists, data management specialists are responsible for curating data in a way that ensures a high level of reliability and accuracy.
Visualization Specialist	Along with analysis performed by data scientists, visualization of large amounts of data in an easy-to-understand way becomes important. The information is used to make better operational decisions and to demonstrate the benefits of TSMO.
Connected and Automated Vehicle (CAV) Program Manager	Many government agencies have hired program managers to work on issues related to developing the capacity to support CAV technologies through research, testing, and partnerships with industry
Traffic Incident Management Program Manager	Working with partners to improve responses to traffic incidents is crucial to driving down clearance times and secondary crashes. The best programs around the country have varying levels of participation from local and statewide agencies.
Cybersecurity Engineer	Cybersecurity is a growing concern as the internet of things, smart communities, and CAV technologies spread along transportation networks.
Transportation Data Ethicist	The most forward-looking of all the positions, this job is dedicated to making sure data is being used for the right reasons and that all data is properly anonymized.
Surface Weather Specialist	As climate change continues to affect the transportation network, engaging weather specialists within a traffic

	management center (TMC) environment will aid in understanding the impacts and improving responses.
Systems Engineer	As software, hardware, and communications networks become more complicated, it will become even more vital to have expertise on how all the pieces interact with one another.
TSMO Modeling Specialist	As integrated corridor management strategies become more prevalent, agencies will need staff with advanced modeling and simulation skillsets for planning for operations and assessing impacts.
Emerging Technologies Industry Liaison	Several organizations have identified a need for an industry liaison to facilitate collaboration among local private-sector technology companies and government agencies, recognizing the direct benefits of new approaches to solving problems and a less-direct economic development impact.
Transportation Systems Performance Manager	Telling the story of how the transportation system is functioning, both in real time and over a longer period, has been critical to demonstrating the benefits of TSMO. A performance manager sees the big picture and can demonstrate the collective benefits of the various functions of TSMO.
Integrated Corridor Management Manager	As management of freeways and arterial networks converge, it is important to have dedicated staff overseeing the strategies across facilities that promote safety while improving corridor wide mobility.
TMC Manager	Although many government agencies have TMC managers that oversee staff in daily operations reacting to incidents and other events, the growth of CAV and other technologies within a control room environment will require an added level of sophistication and understanding of how different actions affect network operations.

Szymkowski and Ivey [76] suggest that some of those new positions (such as cybersecurity engineer and AI scientist) can fit into a transportation organization's overall information system and technology strategy and help make the case for the position. They also underline the potential difficulties in recruiting for these non-traditional positions and recommend leveraging the use of professional organizations outside the typical transportation space. This recommendation has important implications for this project that focuses on job ads. About one-half of the state transportation agencies depend significantly on consultants for key technical positions such as systems engineering, information technology, and intelligent transportation systems (ITS) device maintenance, because agencies face difficulty in filling those positions.[76] Due to this lack of in-house expertise, states may face difficulties in assessing the candidate skills even when they

overcome the challenges (e.g., financial source, organizational structure) to open the position. In other words, the job ads that reflect the necessary workforce skills do not address the effective and optimal hiring of workforce with appropriate skills.

Table 4- The Classification and Types of Occupations in Transportation Workforce Studies

Source	Classification	Classification Code (SIC/SOC/NAICS)	Occupation Types	Description
Bureau of Labor Statistics [86]	Air Transportation	NAICS 481	• Aircraft mechanics and service technicians • Airline pilots, copilots, and flight engineers • Cargo and freight agents • Reservation and transportation ticket agents and travel clerks	The subsector distinguishes scheduled from nonscheduled air transportation. Scheduled air carriers fly regular routes on regular schedules and operate even if flights are only partially loaded. Nonscheduled carriers often operate during nonpeak time slots at busy airports. These establishments have more flexibility with respect to choice of airport, hours of operation, load factors, and similar operational characteristics. Nonscheduled carriers provide chartered air transportation of passengers, cargo, or specialty flying services. Specialty flying services establishments use general-

				purpose aircraft to provide a variety of specialized flying services.
	Rail Transportation	NAICS 482	• Locomotive engineers • Rail car repairers • Rail-track laying and maintenance equipment operators • Railroad brake, signal, and switch operators • Railroad conductors and yardmasters	The railroads in this subsector primarily either operate on networks, with physical facilities, labor force, and equipment spread over an extensive geographic area, or operate over a short distance on a local rail line.
	Water Transportation	NAICS 483	• Captains, mates, and pilots of water vessels • General and operations managers • Laborers and freight, stock, and material movers, hand • Sailors and marine oilers • Ship engineers	Industries in the Water Transportation subsector provide water transportation of passengers and cargo using watercraft, such as ships, barges, and boats. The subsector is composed of two industry groups: (1) one for deep sea, coastal, and Great Lakes; and (2) one for inland water transportation. This split typically reflects the difference in equipment used.

	Truck Transportation	NAICS 484	• Bus and truck mechanics and diesel engine specialists • First-line supervisors/managers of transportation and material-moving machine and vehicle operators • Laborers and freight, stock, and material movers, hand • Truck drivers, heavy and tractor-trailer • Truck drivers, light or delivery services	Industries in the Truck Transportation subsector provide over-the-road transportation of cargo using motor vehicles, such as trucks and tractor trailers. The subsector is subdivided into general freight trucking and specialized freight trucking. This distinction reflects differences in equipment used, type of load carried, scheduling, terminal, and other networking services. General freight transportation establishments handle a wide variety of general commodities, generally palletized, and transported in a container or van trailer. Specialized freight transportation is the transportation of cargo that, because of size, weight, shape, or other inherent characteristics

				require specialized equipment for transportation.
	Transit and Ground Passenger Transportation	NAICS 485	• Bus and truck mechanics and diesel engine specialists • Bus drivers, school • Bus drivers, transit and intercity • Dispatchers, except police, fire, and ambulance • Taxi drivers and chauffeurs	Industries in the Transit and Ground Passenger Transportation subsector include a variety of passenger transportation activities, such as urban transit systems; chartered bus, school bus, and interurban bus transportation; and taxis. These activities are distinguished based primarily on such production process factors as vehicle types, routes, and schedules.
	Pipeline Transportation	NAICS 486	• Control and valve installers and repairers, except mechanical door • Gas compressor and gas pumping station operators • Gas plant operators • Industrial machinery mechanics	Industries in the Pipeline Transportation subsector use transmission pipelines to transport products, such as crude oil, natural gas, refined petroleum products, and slurry. Industries are identified based on the products transported (i.e., pipeline

			• Petroleum pump system operators, refinery operators, and gaugers	transportation of crude oil, natural gas, refined petroleum products, and other products). The Pipeline Transportation of Natural Gas industry includes the storage of natural gas because the storage is usually done by the pipeline establishment and because a pipeline is inherently a network in which all the nodes are interdependent.
	Scenic and Sightseeing Transportation	NAICS 487	• Bus drivers, transit and intercity • Captains, mates, and pilots of water vessels • Reservation and transportation ticket agents and travel clerks • Sailors and marine oilers	Industries in the Scenic and Sightseeing Transportation subsector utilize transportation equipment to provide recreation and entertainment. These activities have a production process distinct from passenger transportation carried out for the purpose of other types of for-hire

				transportation. This process does not emphasize efficient transportation; in fact, such activities often use obsolete vehicles, such as steam trains, to provide some extra ambience. The activity is local in nature, usually involving a same-day return to the point of departure.
	Support Activities for Transportation	NAICS 488	• Aircraft mechanics and service technicians • Cargo and freight agents • Dispatchers, except police, fire, and ambulance • Laborers and freight, stock, and material movers, hand • Truck drivers, heavy and tractor-trailer	Industries in the Support Activities for Transportation subsector provide services which support transportation. These services may be provided to transportation carrier establishments or to the general public. This subsector includes a wide array of establishments, including air traffic control services, marine cargo handling, and motor vehicle towing.
	Postal Service	NAICS 491	• First-line supervisors/managers of	The Postal Service subsector includes the

			transportation and material-moving machine and vehicle operators • Postal service clerks • Postal service mail carriers • Postal service mail sorters, processors, and processing machine operators • Postmasters and mail superintendents	activities of the National Post Office and its subcontractors operating under a universal service obligation to provide mail services, and using the infrastructure required to fulfill that obligation. These services include delivering letters and small parcels. These articles can be described as those that can be handled by one person without using special equipment. This allows the collection, pick-up, and delivery operations to be done with limited labor costs and minimal equipment. Sorting and transportation activities, where necessary, are generally mechanized. The restriction to small parcels distinguishes these establishments from those in the transportation industries. These establishments may also

				provide express delivery services using the infrastructure established for provision of basic mail services.
	Couriers and Messengers	NAICS 492	• Couriers and messengers • Customer service representatives • Dispatchers, except police, fire, and ambulance • First-line supervisors/managers of transportation and material-moving machine and vehicle operators • Truck drivers, light or delivery services	Industries in the Couriers and Messengers subsector provide intercity and/or local delivery of parcels and documents (including express delivery services) without operating under a universal service obligation. These articles can be described as those that may be handled by one person without using special equipment. This allows the collection, pick-up, and delivery operations to be done with limited labor costs and minimal equipment. Sorting and transportation activities, where necessary, are generally mechanized. The restriction to small parcels partly distinguishes these establishments from those

				in the transportation industries. The complete network of courier services establishments also distinguishes these transportation services from local messenger and delivery establishments in this subsector. This includes the establishments that perform intercity transportation as well as establishments that, under contract to them, perform local pick-up and delivery. Messengers, which usually deliver within a metropolitan or single urban area, may use bicycle, foot, small truck, or van.
	Warehousing and Storage	NAICS 493	• Industrial truck and tractor operators • Laborers and freight, stock, and material movers, hand • Shipping, receiving, and traffic clerks • Stock clerks and order fillers	Industries in the Warehousing and Storage subsector are primarily engaged in operating warehousing and storage facilities for general merchandise, refrigerated goods, and other

			Transportation, storage, and distribution managers	warehouse products. These establishments provide facilities to store goods. They do not sell the goods they handle. These establishments take responsibility for storing the goods and keeping them secure. They may also provide a range of services, often referred to as logistics services, related to the distribution of goods. Logistics services can include labeling, breaking bulk, inventory control and management, light assembly, order entry and fulfillment, packaging, pick and pack, price marking and ticketing, and transportation arrangement. However, establishments in this industry group always provide warehousing or storage services in addition to any logistic services.

				Furthermore, the warehousing or storage of goods must be more than incidental to the performance of services, such as price marking.
Strengthening Skills Training and Career Pathways Across the Transportation Industry [87]	Trucking	NAICS 48411	General Freight Truck, Local	The subsector is subdivided into general freight trucking and specialized freight trucking. This distinction reflects differences in equipment used, type of load carried, scheduling, terminal, and other networking services. General freight transportation establishments handle a wide variety of commodities, generally palletized, and transported in a container or van trailer. Specialized freight transportation is the transportation of cargo that, because of size, weight, shape, or other inherent characteristics
		NAICS 48412	General Freight Trucking, Long-Distance	
		NAICS 48421	Used Household and Office Goods Moving	
		NAICS 48422	Specialized Freight (except Used Goods) Trucking, Local	
		NAICS 48423	Specialized Freight (except Used Goods) Trucking, Long-Distance	
		NAICS 48841	Motor Vehicle Towing	
		NAICS 48849	Other Support Activities for Road Transportation	

				require specialized equipment for transportation. Each of these industry groups is further subdivided based on distance traveled. Local trucking establishments primarily carry goods within a single metropolitan area and its adjacent nonurban areas. Long distance trucking establishments carry goods between metropolitan areas.
	Transit	NAICS 48511	Urban Transit Systems	The scheduled transportation industry groups are Urban Transit Systems, Interurban and Rural Bus Transportation, and School and Employee Bus Transportation. The nonscheduled industry groups are the Charter Bus Industry and Taxi and Limousine Service. The Other Transit and Ground Passenger
		NAICS 48521	Interurban and Rural Bus Transportation	
		NAICS 48531	Taxi Service	
		NAICS 48532	Limousine Service	
		NAICS 48541	School and Employee Bus Transportation	
		NAICS 48551	Charter Bus Industry	
		NAICS 48599	Other Transit and Ground Passenger Transportation	

				Transportation industry group includes both scheduled and nonscheduled transportation
	Air	NAICS 48111	Scheduled Air Transportation	Scheduled air carriers fly regular routes on regular schedules and operate even if flights are only partially loaded. Nonscheduled carriers often operate during nonpeak time slots at busy airports. These establishments have more flexibility with respect to choice of airport, hours of operation, load factors, and similar operational characteristics. Nonscheduled carriers provide chartered air transportation of passengers, cargo, or specialty flying services. Specialty flying services establishments use general-purpose aircraft to provide a variety of specialized flying
		NAICS 48121	Nonscheduled Air Transportation	
		NAICS 48811	Airport Operations	
		NAICS 48819	Other Support Activities for Air Transportation	

				services.
	Highway construction and maintenance	NAICS	Highway, Street, and Bridge Construction	This industry comprises establishments primarily engaged in the construction of highways (including elevated), streets, roads, airport runways, public sidewalks, and bridges. The work performed may include new work, reconstruction, rehabilitation, and repairs. Specialty trade contractors are included in this group if they are engaged in activities primarily related to highway, street, and bridge construction (e.g., installing guardrails on highways).
		SOC 47-4051	Highway Maintenance Workers	
	Rail	NAICS 48211	Rail Transportation	Industries in the Rail Transportation subsector provide rail transportation of passengers and/or cargo using railroad rolling stock. The railroads in this subsector primarily either operate on networks
		NAICS 48821	Support Activities for Rail Transportation	

				with physical facilities, labor force, and equipment spread over an extensive geographic area, or operate over a short distance on a local rail line.
	Maritime	NAICS 48311	Deep Sea, Coastal, and Great Lakes Water Transportation	Industries in the Water Transportation subsector provide water transportation of passengers and cargo using watercraft such as ships, barges, and boats. The subsector is composed of two industry groups: (1) one for deep sea, coastal, and Great Lakes; and (2) one for inland water transportation. This split typically reflects the difference in equipment used. The following Support Activities for Water Transportation were also included in our analysis. Port and Harbor Operation
		NAICS 48321	Inland Water Transportation	
		NAICS 48831	Port and Harbor Operations	
		NAICS 48832	Marine Cargo Handling	
		NAICS 48833	Navigational Services to Shipping	
		NAICS 48839	Other Support Activities for Water Transportation	

				comprises establishments primarily engaged in operating ports, harbors (including docking and pier facilities), or canals. Marine Cargo Handling comprises establishments primarily engaged in providing stevedoring and other marine cargo handling services (except warehousing). Navigational Services to Shipping comprise establishments primarily engaged in providing navigational services to shipping. Marine salvage establishments are included in this industry

3. METHODOLOGY

The methodology can be divided into two main categories: 1) Web scraping for job advertisement data and 2) Text mining for job qualifications and skills. Web scraping tools (such as Octoparse) are used to gather the job ad data from the employment websites, in addition to search for state DOT websites for jobs. Text-mining efforts delve into the job descriptions to identify the job skills and requirements that are not explicitly mentioned (such as required education level, experience, etc.) in the job advertisement.

3.1. Web Scraping for Job Advertisement Data

For the collection of job ad data, the web scraping tool Octoparse was used on 3 popular job search websites were utilized: Indeed, Monster, LinkedIn. For each website, the keywords in Table 5 were used in combination or individually. The data collection was performed between the dates of January 2023 to June 2024. In the search of job ads for DOTs some states such as Alabama, Michigan, Wyoming and etc., did not have any job ads on any other website than their own website which resulted in manual search of DOT websites job ads. Total of 8,193 relevant job advertisements were analyzed to extract key information, including job titles, locations, salary ranges, employment types (full-time/part-time), job descriptions, and posting dates. The collected data was checked for relevancy (e.g., job ads that include the keywords such as "maintenance" and "construction worker", but not related to transportation industry) and repetitions (e.g., the same job is advertised across multiple venues). Please note that the summation of the number of job ads for each keyword in Table 5 is less than the total number of job ads due to duplicate jobs that appear under multiple searches.

Table 5- Count of job ads for each keyword

Keyword	**Number of Jobs**
Transportation	3971
Transportation Engineer	1106
Transportation Planner	1188
Transportation Maintenance	818
Highway Construction	1179
Highway Maintenance	207
Department of Transportation	2596
All jobs based on all keywords	8193

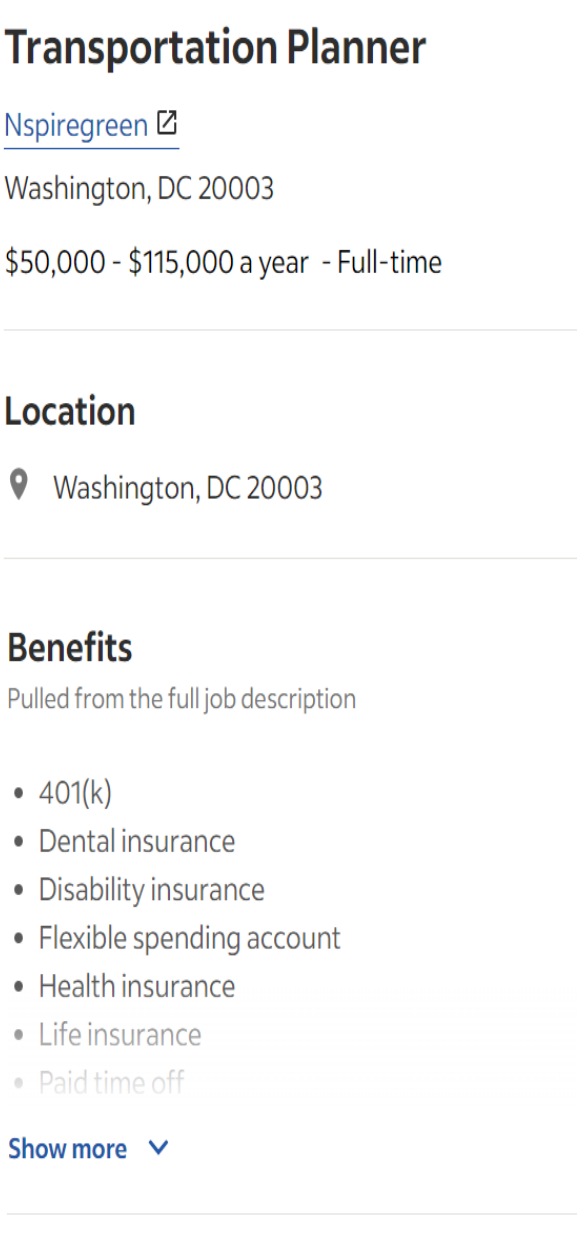
The contents of the collected job ads were parsed into the basic job-related fields as shown below:

- Job title
- Location
- Company
- Salary range

- Job type (Full time or Part time)
- Job description
- Job posting date

Table 6 provides an example of how an original job ad is handled with respect to its basic determinants.

Table 6- Sample Job Ad from Indeed Website [88]

	**Job Title: Transportation Planner** **Location: Washington, D.C.** **Company: Nspiregreen** **Salary Range: $50,000 - $115,000 a year** **Job Type: Full-time** **Job Posting Date: April 15, 2024** **Job Description:** • **Minimum Requirements:** Bachelor's degree in civil engineering, transportation engineering, or a related field. Minimum of 3 years of experience in transportation planning or engineering. • **Skills:** Proficiency in AutoCAD, GIS software, and traffic simulation tools. Strong analytical and problem-solving skills. • **Licenses:** Professional Engineer (PE) license required. • **Benefits:** 401(k) , Dental insurance, Disability insurance, Flexible spending account, Health insurance, Life insurance, Paid time off

3.2. Data Analysis

In addition to the descriptive analysis of the collected data (e.g., required education and experience levels, salary range, etc.), the job description text is further analyzed to extract the sought-after skills. The analysis segmented the extracted data into categories of education requirements, minimum qualifications, work experience, preferred skills, and responsibilities. A dual approach was employed by using regex libraries [89] for initial extraction followed by more advanced text analysis with AI model from OpenAI [90].

Regex is short form of "Regular expressions". It allows users to define search patterns that can identify and extract specific text sequences within larger bodies of text. Regex can search for a defined pattern, and it seems ideal for extracting data from structured documents. On the other hand, job ads are mostly generic and do not follow a structured format. Regex is less effective at handling unstructured or highly variable text, where the patterns are not clearly defined. Another downside for regex libraries is it lacks the ability to understand context which means it fails to work with natural language ambiguities. For instance, "Bachelor's degree preferred but not required" might make regex struggle for data extraction. Due to the limitations of regex in handling unstructured and complex text, more advanced GPT-3.5 Turbo AI model was employed to improve the accuracy and comprehensiveness of the text analysis. GPT-3.5 Turbo allows for more accurate extraction of information from unstructured text to interpret the meaning behind words and phrases, which is essential for categorizing job requirements and qualifications accurately. They also can work on a large number of job ads and learn from the patterns extracted from the job ads. This dual process of using standard and emerging text mining approaches allowed accurate categorization and analysis of the vast array of job descriptions, overcoming significant challenges in data consistency and computational demands.

4. FINDINGS

4.1. General Observations on Job Advertisements

4.1.1. Required Skills and Job-Related Info

Although the web scraping process is identical, there are some differences between DOT job posting and non-DOT job postings. DOT job descriptions typically have a structure that outline specific minimum qualifications such as bachelor's degree in civil engineering or a related field, minimum number of years of experience, benefits offered to employees etc., whereas private sector jobs do not have standard structures for similar requirements. In addition, DOT job descriptions often list required skills and licenses explicitly such as proficiency in software like AutoCAD and Professional Engineer (PE) license. The relatively less structured ads for private sector make it challenging to extract the necessary skillset in an automated fashion. Besides the challenges for data gathering and research purposes, it is not certain if the lack of information structure in job ads make it challenging also for job seekers to gauge their fit to the job.

4.1.2. Job Descriptions

While DOT job descriptions are mostly structured with specific qualifications, skills, and benefits

outlined, job descriptions may still be generic. For instance, a generic job description for a project manager role might mention the need for "strong problem-solving skills" without specifying the problems the role will entail. "Effective communication skills", "ability to manage yourself independently", "team player" and "demonstrated ability to lead " are other examples of this issue. Generic job descriptions can sometimes lack clarity to indicate the specific skillset. They may overlook the specific needs of the role or organization, making it challenging to understand the job's requirements fully. In addition to relevant skills and qualifications, some job ads include a summary or overview of the company to provide context for potential applicants. This summary typically highlights information about the company, such as its mission, values, culture, workplace environment, and notable achievements. Such information was not utilized for the analysis.

4.2. Overall Job Characteristics and Statistics

4.2.1. Job Titles

The dataset contains about 2,000 job titles with varying frequencies. For the analysis, the experience level (e.g., Transportation planner I, Transportation planner II) are considered as the same job title. Accordingly, the most common job titles were identified as Truck Driver, Maintenance Technician, Transportation Engineer, Construction Laborer, Transportation Planner, Transportation Manager, Senior Transportation Planner, Logistics Planner and Concrete Finisher. *Table 7* shows the most common words in the job titles and their frequencies.

Table 7- Most common keywords in Job titles

Keyword	Count
Driver	2,105
Engineer	1,514
Planner	972
Maintenance	802
Construction	713
Logistics	304
Concrete	245

4.2.2. Geographic Location

The job ads are scattered across the US with over 1600 locations.

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Intelligent Transportation Systems Training Opportunities for Today and Tomorrow", 2016. and Figure 8 show the heatmap for the number of DOT and non-DOT jobs postings for each state.

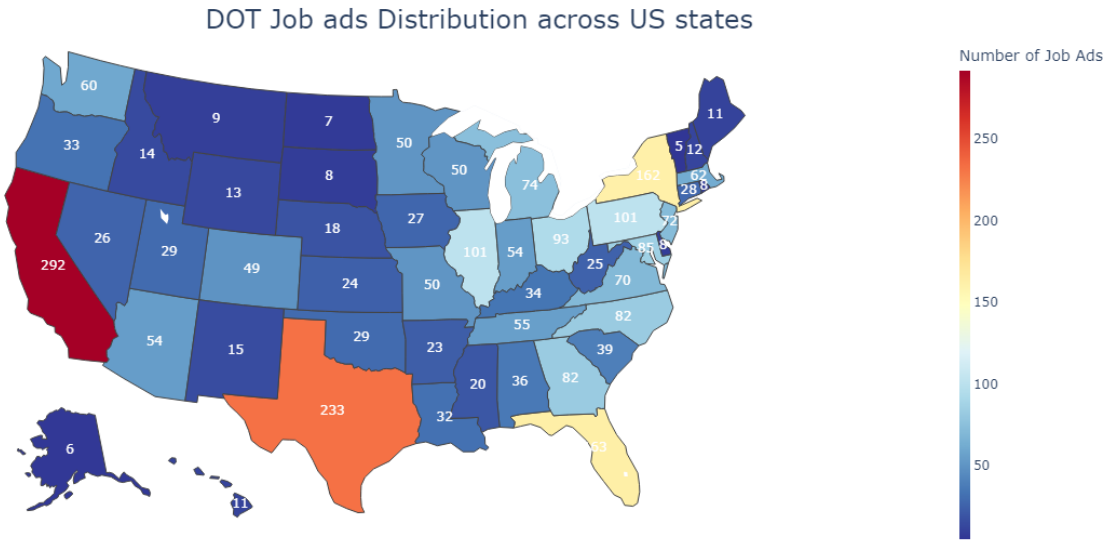

Figure 7- DOT Job Ads Distribution Across US States

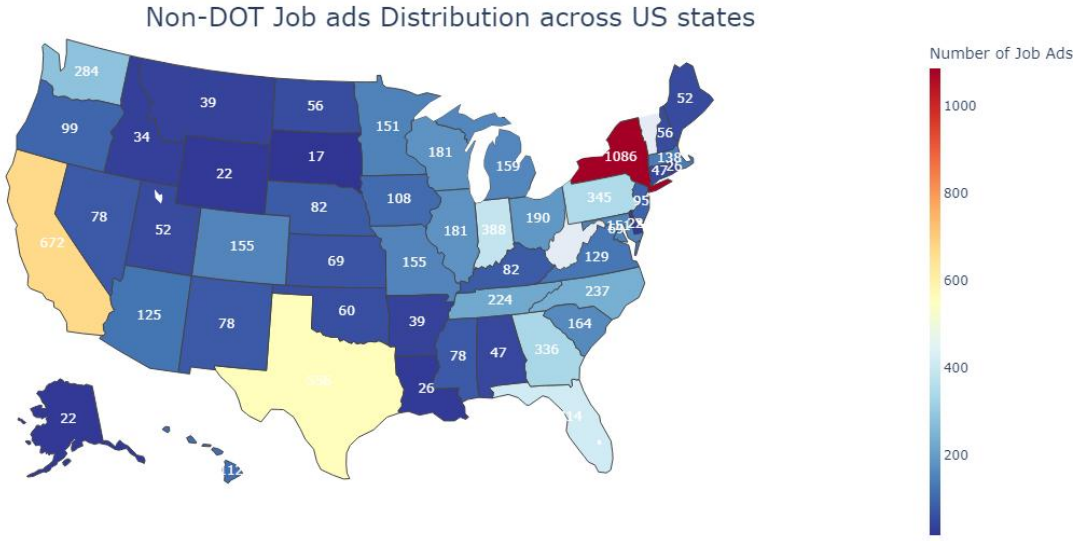

Figure 8- Non-DOT Job Ads Distribution Across US States

When examining employment distribution across US states, a complex interplay of factors comes into play, including population demographics, industry composition, and state-level policies.[91] Certain states boast robust economies and thriving job markets, driven by diverse industries such as technology, finance, tourism, and agriculture. States like California, Texas and New York offer job opportunities across various sectors which transportation sector is not an exception too. The number of DOT jobs in these states support the claim. As shown in Figures, states mentioned above contribute to the most job ads posted. There are 1,086, 672 and 556 job ads relative for New York, California, and Texas for non-DOT Job Ads. California, Texas, Florida and New York also have the most DOT job ads presented by count of 292, 233, 163, 162.

4.2.3. Employer Characteristics

The job ad data contains 2,931 unique companies. About 34% of the job ads are from the state departments of transportation, and the remaining 66% are posted by the private sector.

The 10 most frequently mentioned companies in the search through job ads are:

1. California Department of Transportation
2. Texas Department of Transportation
3. Florida Department of Transportation
4. New York Department of Transportation
5. AECOM
6. Amazon
7. Aerotek
8. Maryland Department of Transportation
9. HNTB Corporation
10. Stantec

Top 10 companies with respect to the number of job ads include 5 DOTs, namely CALTRANS (#1), TXDOT (#2), FDOT (#3), NYSDOT (#4) and MDOT (#8). Companies like AECOM (#5), HNTB (#7), Stantec (#10) offer more consulting positions which require higher degree and requirements. The presence of Amazon (#6) (mostly for delivery and warehousing, such as truck driver job ads) in this list underlines the importance of the transportation sector even for a technology company. The presence of Aerotek (#7) – a recruiting and staffing company that connects experts to companies – may suggest that matching employer needs and employee needs is a challenging issue in the transportation industry that necessitates intermediaries.

4.2.4. Salary Ranges

The dataset contains 4,679 job advertisements with salary information available that are stated as hourly salary, monthly or yearly salary. Mostly stated salaries have a range and are not defined exactly, for example: $30 - $40 an hour, $64,959 - $98,661 a year, from $80,174 a year or $5,856 - $9,079 a month. The median salary is also calculated for each state and is shown in *Figure 9*. While calculating the yearly salary for hourly paid jobs, 40 hours per week for 52 weeks was assumed, following the approach by the Bureau of Labor Statistics [92]. Please note that these median salaries do not necessarily indicate the current salaries of the existing workforce but relates only to the new job ads. For instance, Idaho or Luisiana have high salary medians mainly because there are a few job ads at those states for the data collection period of January 2023 to June 2024 with higher salary ranges. Indiana has a high salary median but only 106 jobs out of the total 442 job ads in Indiana indicate the salary for the job.

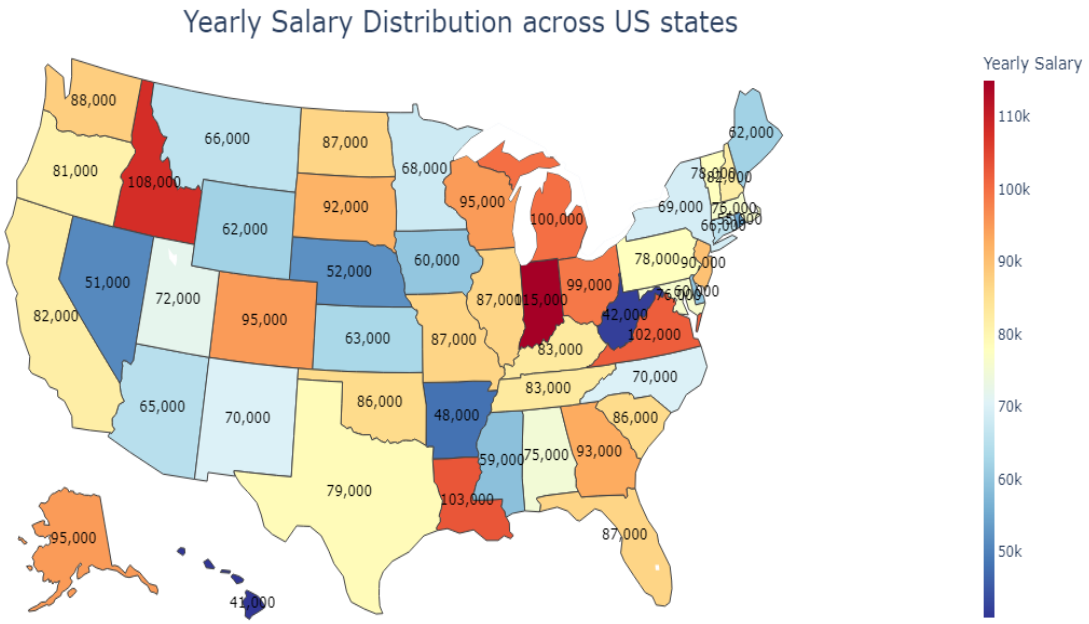

Figure 9- Median Salary for each state

4.2.5. Salary Differences with respect to Geographical Area, Employer, and Qualifications

Salary differences in the transportation sector are influenced by various factors including geographical area, employer, and qualifications. Geographically, regions with higher living costs or greater demand for transportation services, such as major metropolitan areas or logistics hubs, tend to offer higher salaries. Furthermore, qualifications, including educational background, professional certifications, and years of experience, significantly impact salary levels. Higher qualifications typically lead to more specialized roles and higher pay. Consequently, professionals with advanced degrees or extensive experience in the transportation sector generally earn more than their less qualified counterparts. Based on the Census Bureau's designation of regions in the U.S.[1], the median salaries for Midwest, Northeast, South and West are $80,000, $74,000, $78,000 and $82,000, respectively.

Salaries also differ based on the type of employer. Positions within the Department of Transportation (DOT) tend to offer a median salary of $66,000, whereas non-DOT positions offer a slightly higher median of $70,000. This difference might be attributed to the budgetary constraints and standard pay scales of government positions compared to the private sector. Besides the geographical and employer type, qualifications (in terms of both the technical

[1]**Northeast**: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont; **Midwest**: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin; **South**: Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia; **West**: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming

certifications and immigration status) have an impact on salaries in the transportation sector. For instance, median salary for a job that require Professional Engineering (PE) is $85,000 whereas median salary for the jobs with only FE (Fundamentals of Engineering) requirement is $69,000. A similar jump is observed between greencard holders and non-greencard holders, i.e., median salaries are $92,000 and $75,000 respectively. The median salary differences are visually summarized Figure 10- Median Annual Salaries Figure 10.

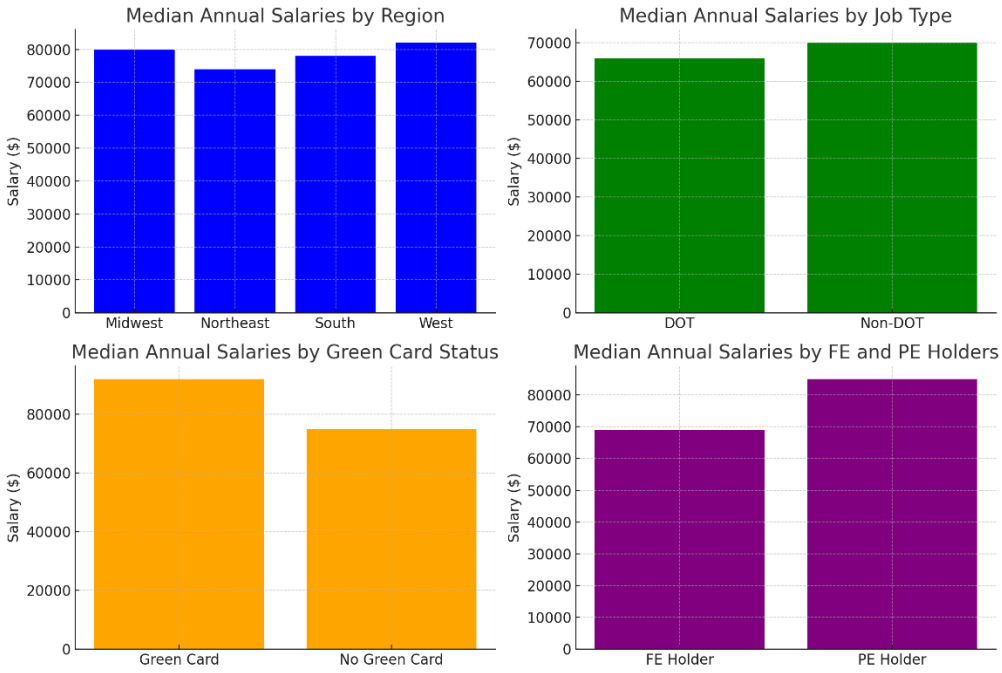

Figure 10- Median Annual Salaries by Different Characteristics

4.2.5.1. Salary Differences with respect to Educational Requirements

The median salary for jobs with respect to educational degree is shown in Table 8. As expected, the median salary increases as the level of education requirement increases. Please note that many job ads list both Bachelor's and Master's degrees or multiple positions with salary ranges, leading to blended median salaries that may not capture the premium for higher level degrees. In addition, job ads often include multiple positions within a range of salaries, leading to inaccuracies in determining the exact salary difference attributed to specific education requirement.

Table 8- Annual Salary Relative to Degree Required

Degree required	Annual Salary
Highschool Degree	63,500
Associate Degree	73,000
Bachelor's Degree	85,000
Master's Degree	92,000

4.2.5.2. Comparison of Salaries with BLS data

Using the BLS data, the median annual salaries for transportation-related jobs with other occupations that require similar education levels were compared. According to the BLS Occupational Employment and Wage Statistics (May 2022 data) [], the median annual wage for all occupations was $45,760. Occupations that typically require a bachelor's degree had a median annual wage of $78,580. Civil Engineers median annual wage was $88,570. Urban and Regional Planners' median annual wage was $78,500. Environmental Engineers median annual wage was $96,890. Table 9 provides a salary comparison between the common job titles in the collected job ad data and comparable occupations in the BLS data- Comparison of Common Job Titles with BLS Data.

Table 9- Comparison of Common Job Titles with BLS Data

Job Title	**Salary in Job ads**	**Comparable BLS Occupation**	**BLS Salary**
Associate Transportation Planner	$78,000	Urban and Regional Planners	$78,500
Area Construction Engineer (Transportation Engineering Manager)	$81,000	Civil Engineers	$88,570
Assistant Division Chief - Licensed Land Surveyor (Transportation Engineering Manager)	$123,000	Environmental Engineers	$96,890
Assistant Transportation Engineer	$88,000	Civil Engineers	$88,570
Transportation Planner (Environmental Permitting Specialist)	$71,000	Urban and Regional Planners	$78,500
Transportation Planner-Engineer	$76,000	Urban and Regional Planners	$78,500

The comparison with BLS data in Table 9 shows that salaries in the transportation sector are generally competitive, where some roles such as Assistant Division Chief pays considerably higher (about 26% higher) whereas the salaries for other job titles pays in-line or lower (e.g., about 9% for transportation planner and area construction engineer) than the BLS counterparts. Those differences can also be attributed to factors such as the specific job responsibilities, the level of specialization required, regional demand for certain skills, and the financial resources of employers. Overall, the transportation sector appears to provide salaries that are slightly below those of comparable occupations, highlighting the importance of job specifications and employer type in determining pay.

4.3. Sought-after Job Skills and Requirements

To analyze the job requirements and necessary skillset for transportation industry jobs, the ads were analyzed under 3 major criteria: Education, Work experience and Required Skillset.

4.3.1. Educational Requirements

About 40% of the job ads do not explicitly indicate any education requirement. The job ads that do not require a degree typically fall into categories where practical skills, certifications, and hands-on experience are more critical than formal education. Many of these positions emphasize work experience, such as years spent in relevant roles or specific technical skills. Physical and manual labor jobs frequently do not require a degree. These roles are often found in construction, maintenance, and related fields. Positions such as Asphalt Paving Foreman, Heavy Highway Construction Workers, and Maintenance Workers are prime examples. The qualifications for these roles are grounded in practical skills, such as operating machinery, performing repairs, and executing construction tasks. Employers look for individuals who can demonstrate reliability, a strong work ethic, and the physical capability to meet the job's demands. These roles prioritize hands-on experience, technical know-how, and physical stamina over academic credentials. Another prominent category of jobs without degree requirements is the jobs requiring Commercial Driver's License (CDL). Jobs like warehousing driver or CDL driver fall into this category. The essential qualification for these roles is the possession of a CDL, which ensures the driver has the necessary skills and knowledge to operate commercial vehicles safely. Employers in this field prioritize practical driving experience and adherence to safety standards over formal education. The primary concern is that the driver can perform the job's practical aspects, such as handling large vehicles, navigating routes, and ensuring timely deliveries, which do not necessitate a degree but do require specialized training and certification.

4.3.1.1 Focus on Middle Skill Jobs

A notable trend was the fewer number of job advertisements for white-collar positions, indicating a potential bias towards middle-skill job listings in publicly available data. In search of white-collar positions, white-collar job ads were mostly concentrated within DOT website compared to other websites observed. On the other hand, about 40 percent of job ads do not require a degree such as jobs like maintenance workers, CDL drivers, Highway construction workers. The word “Truck” was one of the most repeated words in the job ads with more than 800 occurrences that reinforces this observation.

For the remaining about 60 percent of job ads were categorized based on the following degrees:

- High School Degree
- Associate Degree
- Bachelor's Degree[2]
- Master's Degree
- Doctorate Degree

[2] Job ads that required a college degree was also considered as Bachelor’s degree.

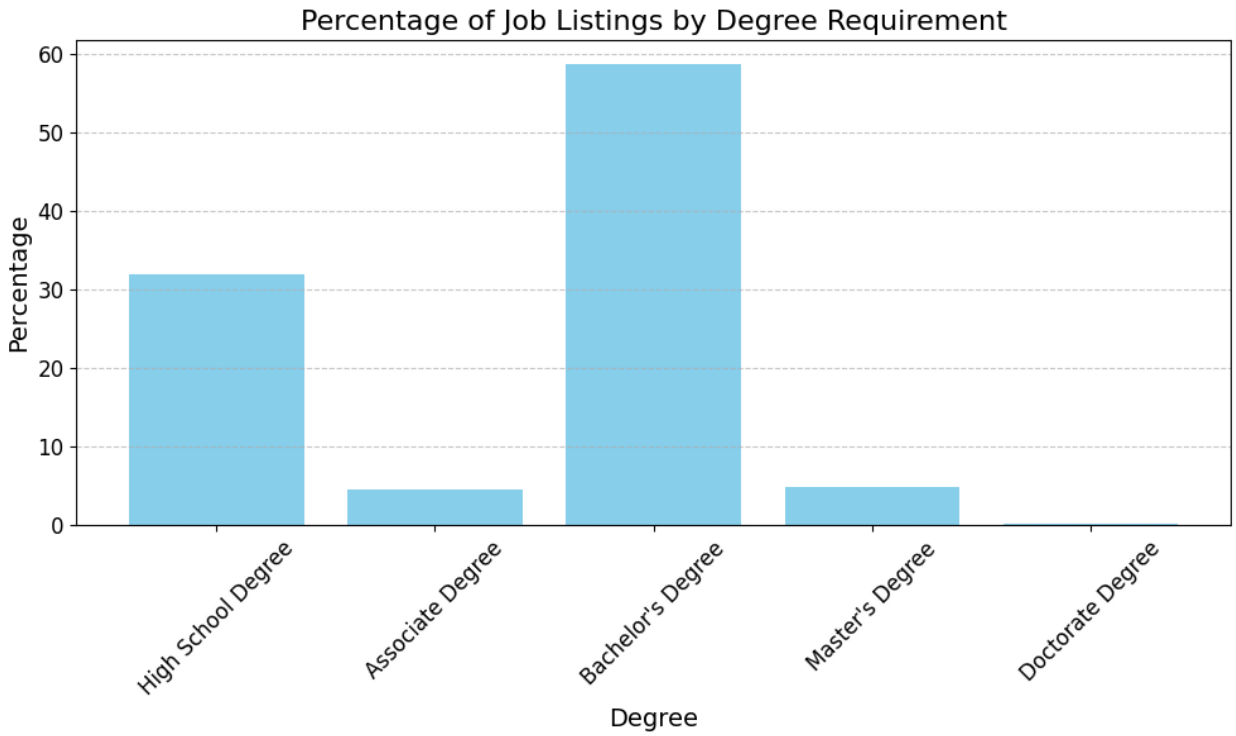

Figure 11- Percentage of Job Listings by Degree Requirement

Furthermore, the most frequent jobs requiring different degrees are stated in Table 10:

Table 10- Most Frequent Job Titles Relative to Degree Requirement

Degree Needed	**Most Frequent Job Titles**
High School Degree	• CDL Driver • Construction Laborer • Bus driver • Maintenance Technician • HVAC Technician • Cement Masonry • Maintenance Technician • Transportation Manager
Associate Degree	• Logistics Planner • Service Planner and Equipment Logistics • Locomotive Engineer • Maintenance & Repair Mechanic • Maintenance Technician • Controls Technician • Field Service Technician

	• Facility Technician • Industrial Maintenance
Bachelor's Degree	• Transportation Planner • Transportation Engineer • Senior Transportation Planner • Transportation Design Engineer • Supply Chain Planner • Senior Transportation Engineer • Logistics Engineer • Transportation Planning Analyst
Master's Degree	• Transportation Planner • Senior Transportation Planner • Transportation Engineer • Transportation Design Engineer • Traffic Engineer • Transportation Supervisor Transportation Planning Analyst

4.3.2. Work experience

About 71 percent of all the job ads mention work experience in their job description. The distribution of work experience (in years) is shown in Figure 12. The most frequent years of experience are between the range of 1 to 5 for all types of transportation jobs. Figure 13 breaks down the required work experience for the most common job titles.

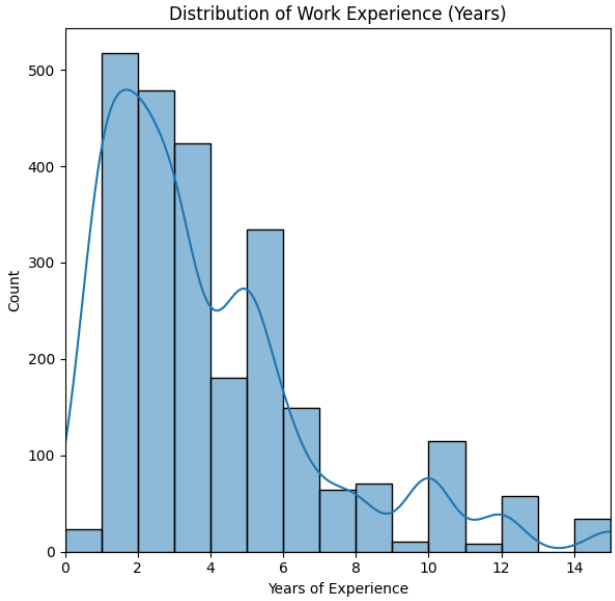

Figure 12- Distribution of Work experience years

Roles such as Line Service Technician, Truck Driver, Transportation Mechanic, Laborer, etc. generally require lower levels of experience, with median values around 1-3 years. This finding is consistent with the discussions on middle-skill jobs (the jobs that require some postsecondary training but not a college degree) in the literature. Middle-skill jobs account for 53% of the United States' labor market, yet only 43% of the workforce is trained to the required level [75, 76]. This skills gap is a significant challenge for the industry, particularly in operational and maintenance positions that are among the hardest to fill. Furthermore, the literature emphasizes that fewer people are enrolling in trade schools compared to traditional four-year colleges, leading to a shortage of workers in production-based industries like transportation. This is exacerbated by competition with other industries that offer better compensation packages for similar skill sets [78]. As a result, transportation agencies often face difficulties in recruiting talent with specialized skills. The lower experience requirements can be attributed to transportation industry's attempt to broadening the pool of potential applicants by not demanding extensive prior experience to attract more individuals. This approach not only helps fill the immediate demand for workers but also provides an opportunity for these workers to gain experience and advance within the industry, ultimately addressing the skills gap.

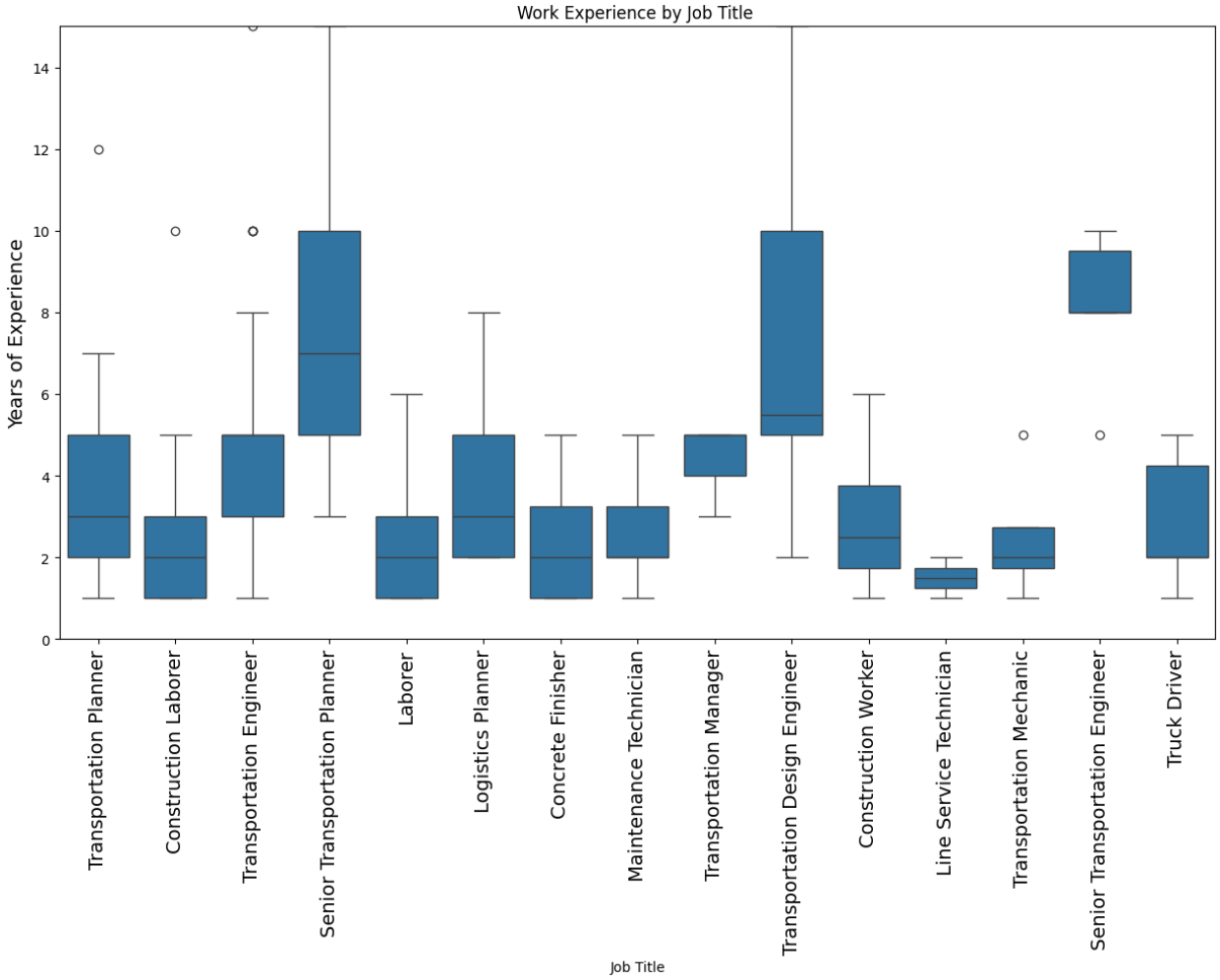

Figure 13- Work Experience for Most Repeated Job Titles

4.3.3. Required Skillset

Building on the discussion of work experience, it is crucial to examine the specific skill sets required for various job roles within the transportation industry. To identify these requirements, responsibilities and preferred skills were extracted from job advertisements and analyzed. An n-gram frequency analysis was performed on the responsibilities and preferred skills text data to identify the most common bigrams and trigrams. N-gram analysis is a text analysis technique that involves breaking down text into sequences of n items (words, letters, etc.). A bigram is a sequence of two consecutive words in a text, while a trigram is a sequence of three consecutive words. Figure 14 shows the frequency bar chart for top 20 preferred skills for job ads dataset.

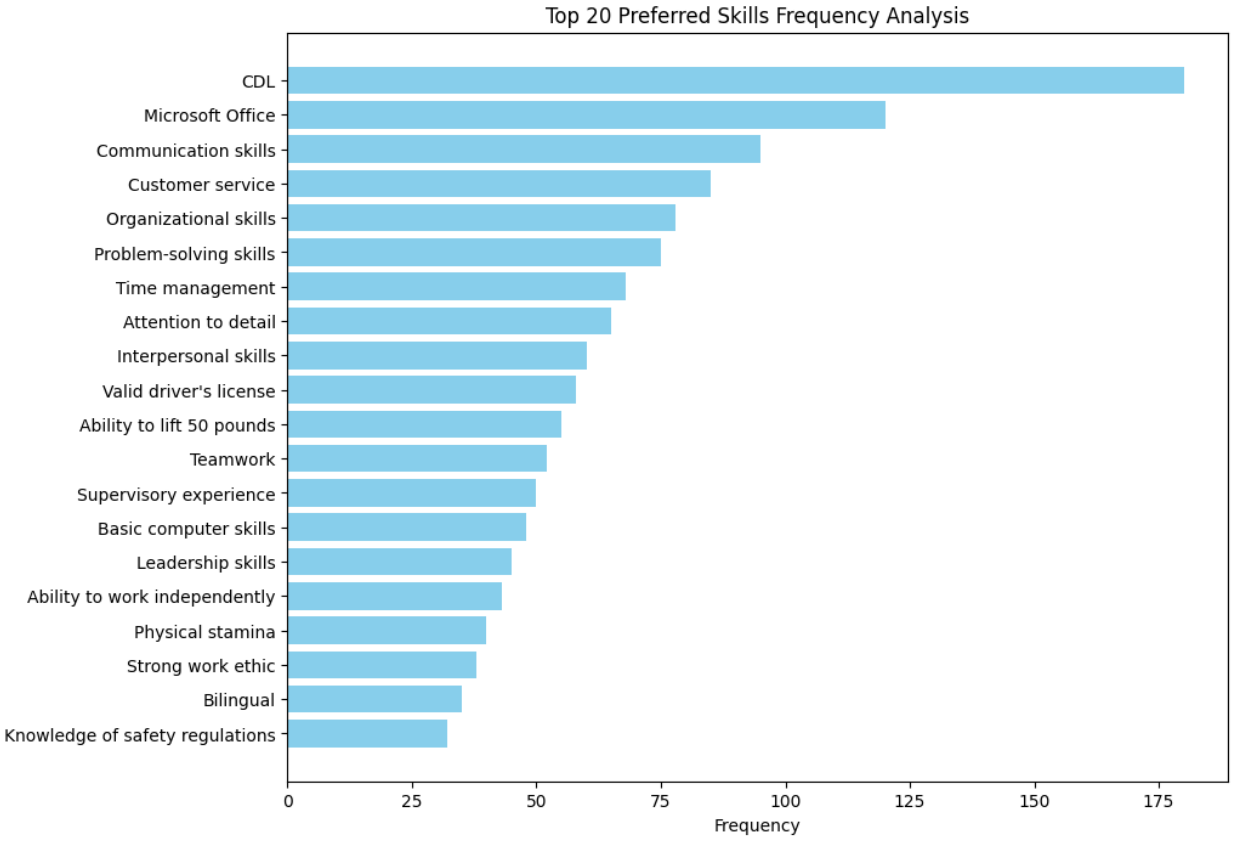

Figure 14- Top 20 Preferred skills

The analysis reveals that a Commercial Driver's License (CDL) is by far the most frequently mentioned skill, highlighting its critical importance in the transportation industry. This finding is consistent with the literature, which emphasizes the high demand for CDL holders due to the central role of trucking and logistics in the transportation sector. CDL is essential for operating heavy vehicles and is a fundamental requirement for many transportation roles, underscoring the need for formal training and certification. Microsoft Office skills are also highly ranked, indicating the necessity of basic computer proficiency across various job roles. This aligns with the industry's increasing reliance on digital tools for operations, planning, and communication. This kind of skills

are considered as Hard skills. Communication skills, Time management, Attention to detail, Interpersonal skills, Teamwork, Ability to work independently, Strong work ethic are considered as soft skills. These skills are vital for roles that involve direct interaction, coordination among team members, and effective handling of logistical challenges. The literature highlights the significance of these soft skills in ensuring operational efficiency and enhancing customer satisfaction.[83,84] Organizational and problem-solving skills are also frequently mentioned, further emphasizing the need for a well-rounded skill set that includes both technical and soft skills. These skills are crucial for managing complex transportation systems, addressing unforeseen issues, and maintaining smooth operations. One challenge with soft skills is that they do not have distinguished boundaries, making them harder to define and assess compared to technical skills. For instance, while technical skills like operating a vehicle or using specific software can be clearly measured and tested, soft skills such as communication or teamwork are more subjective and context-dependent. This lack of clear boundaries can lead to discrepancies in how these skills are perceived and valued across different job roles and industries.

This analysis highlights the balance between hard skills (such as CDL and computer proficiency) and soft skills (such as communication and interpersonal skills) required in the transportation industry. Analyzing the skillsets from the job advertisements, it is evident that both technical expertise and interpersonal abilities are crucial for the effective performance and growth of this workforce. By understanding these requirements, companies can tailor their recruitment and training efforts better to build a capable and versatile workforce. Table 11 provides the top 10 skills (ranked based on frequency) for the most common job titles in the dataset.

Table 11-Most Frequent Jobs Skillset

Job	Skills
Transportation Planner	Analytical skills, Project management, Communication skill, GIS, Data analysis, Planning software, Stakeholder engagement, Public speaking, Report writing, Policy knowledge
Construction Laborer	Physical stamina, Attention to detail, Hand tools Safety knowledge, Teamwork, Heavy lifting, Communication skills, Time management, Basic math skills, Construction knowledge
Transportation Engineer	Civil engineering, Project management, Traffic analysis, CAD software, Data analysis, Communication skills, Problem-solving, Report writing, Planning software, GIS
Senior Transportation Planner	Leadership, Project management, Communication skills, Policy knowledge, GIS, Data analysis, Stakeholder engagement, Report writing, Public speaking, Planning software
Logistics Planner	Supply chain management, Data analysis, Communication

	skills, Problem-solving, Time management, ERP software, Project management, Customer service, Organizational skills, Inventory management
Concrete Finisher	Concrete finishing, Physical stamina, Attention to detail, Hand tools, Safety knowledge, Teamwork, Communication skills, Time management, Problem-solving, Construction knowledge
Maintenance Technician	Problem-solving, Mechanical skills, Electrical skills, Communication skills, Physical stamina, Time management, Attention to detail, Safety knowledge, Teamwork, Technical skills
Transportation Manager	Leadership, Communication skills, Project management, Data analysis, Organizational skills, Problem-solving, Planning software, Time management, Stakeholder engagement, Policy knowledge
Truck Driver	Valid driver's license, Communication skills, Customer service, Time management, Physical stamina, Attention to detail, Safety knowledge, Problem-solving, Map reading, Basic math skills

As shown in Table 11, the most common jobs in the transportation sector often require specialized technical skills, such as proficiency in Geographic Information Systems (GIS), Computer-Aided Design (CAD) software, traffic analysis tools (e.g., micro/macro simulation) in addition to knowledge in statistical modeling and software packages for traffic data analysis under logistics and traffic engineering domains. Many transportation jobs also require knowledge of safety standards and protocols. For higher level executive/manager positions, project management skills become also important. In addition to hard skills which are generally measurable (through formal courses, certificates, training etc.), soft skills are also considered central to the job effectiveness [60], e.g., communication, problem-solving, teamwork and collaboration, leadership, time management and attention to detail.

Across all experience levels, there is a blend of hard and soft skills, and the emphasis shifts as the employee progresses. To identify, skillset emphasis in different experience levels, Experience level was categorized into 3 different levels of Entry-level, Mid-level and Senior-level, where job titles were categorized into experience levels based on specific keywords listed below:

- Entry-level: Keywords like "Entry Level," "Intern," "Junior," "I"
- Mid-level: Keywords like "Mid," "Associate," "II"
- Senior-level: Keywords like "Senior," "Lead," "Manager," "Director," "III"

Table 12- Skillset Needed Corresponding to Experience Level

Experience Level	Entry-level	Mid-level	Senior-level
Skills	• Analytical skills	• Supply chain management	• Leadership
	• AutoCAD	• Data analysis	• Project management
	• Communication skills	• Communication skills	• Communication skills
	• GIS	• Problem-solving	• Policy knowledge
	• Data analysis	• Time management	• GIS
	• Planning software	• ERP software	• Data analysis
	• Customer service	• Project management	• Stakeholder engagement
	• Public speaking	• Stakeholder engagement	• Report writing
	• Report writing	• Organizational skills	• Public speaking
	• Policy knowledge	• Inventory management	• Urban planning

Table 12 (color-coded based on certain skills) illustrates the shift in the required skillsets required at different experience levels, as professionals progress through their careers in the transportation sector. At the entry-level, the emphasis is predominantly on technical skills such as AutoCAD and GIS. These foundational technical proficiencies are essential for new entrants to perform their roles effectively and build a strong knowledge base. Entry-level roles also necessitate basic communication skills. As individuals advance to mid-level positions, the focus begins to shift from technical abilities to managing operations and solving more complex problems. Skills such as supply chain management, organizational skills and problem-solving become increasingly important. At this stage, professionals are often tasked with coordinating projects, necessitating the development of project management and stakeholder engagement skills. Effective time management and the ability to handle organizational tasks also become crucial, reflecting the need for greater responsibility and efficiency in operations. When professionals reach senior-level roles, strategic and leadership skills come to the forefront. Leadership becomes vital, as senior professionals are responsible for guiding teams and overseeing large-scale projects. Project management remains critical. At this level, the ability to engage with stakeholders and

communicate policies effectively is vital. Strategic communication skills, including public speaking, become essential as senior professionals represent their organizations and influence key decisions.

Throughout this progression, there is an increasing emphasis on soft skills such as leadership, stakeholder engagement, and strategic communication, reflecting the broader responsibilities and strategic nature of senior roles. Communication skills remain consistently important, though their nature evolves. Based on the job ads descriptions extracted, In mid-level roles, communication involves coordinating and managing projects and teams. At the senior level, communication encompasses strategic elements, including public speaking and policy advocacy, highlighting its critical role in leadership and strategic decision-making.

5. REQUIRED SKILLS IN JOB ADS VS. INDUSTRY CONSENSUS: COMPARISON WITH O*NET DATABASE

Understanding the skills required in the transportation industry is crucial for aligning workforce capabilities with industry needs. To facilitate this understanding, Occupational Information Network (O*NET), an extensive database developed by the U.S. Department of Labor/Employment and Training Administration (USDOL/ETA) collects information by first identifying a statistically random sample of businesses expected to employ workers in the targeted occupations and selecting a random sample of workers in those occupations within those businesses. O*NET categorizes the jobs under the 2018 Standard Occupational Classification (SOC) system which is used by federal agencies to classify workers into occupational categories. For each job title, the following information are aggregated under main categories and listed under subcategories of Occupation-Specific Information (Tasks, Technology Skills, Tools Used); Occupational Requirements (Work Activities, Detailed Work Activities, Work Activities Outline, Work Context); Experience Requirements (Job Zone, Training & Credentials, Apprenticeship Opportunities); Worker Requirements (Skills, Knowledge, Education); Worker Characteristics (Abilities, Interests, Work Values, Work Styles); Workforce Characteristics (Wages & Employment Trends, Job Openings on the Web); More Information (Related Occupations, Crosswalk, Professional Associations). [77] The job titles are aggregated under industry, job family or career cluster for the users. O*NET provides detailed information about various occupations, helping to delineate job requirements and worker competencies across the U.S. labor market. The transportation industry requires a diverse set of skills to meet the demands of various job roles. By analyzing and comparing the skills listed in O*NET with those required in job ads, one can gain insights into the current state of the workforce and identify areas for improvement. Table 13 provides comparison of the most frequent job titles skillset in our data with O*NET database.

*Table 13- Comparison of Most Frequent Job Titles Skillset with O*NET Database [77]*

Job Title	Skills Required in Job Ads	O*NET Skills	O*NET Technology Skills
Transportation Planner	Analytical skills, Project management, Communication skills, GIS, Data analysis, Planning software, Stakeholder engagement, Public speaking, Report writing, Policy knowledge	Active Listening, Complex Problem Solving, Critical Thinking, Reading Comprehension, Speaking	GIS (ESRI ArcGIS), CAD (AutoCAD), Data analysis tools (SQL), Project management software (Microsoft Project)
Construction Laborer	Physical stamina, Attention to detail, Hand tools, Safety knowledge, Teamwork, Heavy lifting, Communication skills, Time management, Basic math skills, Construction knowledge	Manual Dexterity, Multilimb Coordination, Physical Strength, Attention to Detail, Safety knowledge	Hand tools, Power tools, Construction equipment
Transportation Engineer	Civil engineering, Project management, Traffic analysis, CAD software, Data analysis, Communication skills, Problem-solving, Report writing, Planning software, GIS	Complex Problem Solving, Mathematics, Critical Thinking, Active Listening, Speaking	CAD software (AutoCAD), GIS (ESRI ArcGIS), Traffic analysis tools
Senior Transportation Planner	Leadership, Project management, Communication skills, Policy knowledge, GIS, Data analysis, Stakeholder engagement, Report writing, Public speaking, Planning software	Critical Thinking, Reading Comprehension, Complex Problem Solving, Active Listening, Coordination	GIS (ESRI ArcGIS), Project management software (Microsoft Project), Data analysis tools (SQL)
Logistics Planner	Supply chain management, Data analysis, Communication skills, Problem-solving, Time management, ERP software, Project management, Customer service, Organizational skills, Inventory management	Coordination, Time Management, Active Listening, Critical Thinking, Reading Comprehension	ERP software (SAP), Data analysis tools, Inventory management software
Concrete Finisher	Concrete finishing, Physical stamina, Attention to detail, Hand tools, Safety knowledge, Teamwork, Communication skills, Time management, Problem-solving, Construction knowledge	Manual Dexterity, Physical Strength, Attention to Detail, Safety knowledge, Multilimb Coordination	Hand tools, Power tools, Construction equipment

Maintenance Technician	Problem-solving, Mechanical skills, Electrical skills, Communication skills, Physical stamina, Time management, Attention to detail, Safety knowledge, Teamwork, Technical skills	Repairing, Troubleshooting, Critical Thinking, Operation Monitoring, Quality Control Analysis	Diagnostic tools, Repair tools, Maintenance software
Transportation Manager	Leadership, Communication skills, Project management, Data analysis, Organizational skills, Problem-solving, Planning software, Time management, Stakeholder engagement, Policy knowledge	Coordination, Time Management, Active Listening, Critical Thinking, Monitoring	Project management software, Data analysis tools, ERP software
Truck Driver	Valid driver's license, Communication skills, Customer service, Time management, Physical stamina, Attention to detail, Safety knowledge, Problem-solving, Map reading, Basic math skills	Operation Monitoring, Operation and Control, Time Management, Active Listening, Coordination	Route navigation software, Vehicle maintenance software, Logistics software

The comparison between the skills provided for various job roles and those listed on O*NET reveals an overlap and some differences.

5.1. Alignment of Skills listed in Job Ads and O*NET

The required skills in job ads generally align well with O*NET, particularly in technical roles such as Transportation Planner, Transportation Engineer, and Logistics Planner. Both sets emphasize crucial skills like analytical thinking, project management, communication, and technical proficiencies (e.g., GIS for planners, CAD for engineers). For example, the role of a Transportation Planner requires skills like analytical thinking, GIS proficiency, and project management, all of which are consistently noted in both sources. These overlaps indicate an alignment between the job market demands and the competencies identified by O*NET. Middle skill jobs show that the skills listed in job ads tend to be straightforward and directly related to the job's practical requirements skills such as physical stamina, knowledge of tools and machinery, and adherence to safety protocols. These roles emphasize clear, specific skills that are necessary for job performance.

O*NET also includes more generic skills such as active listening, critical thinking and reading comprehension, which may not be explicitly mentioned in job ads but are implicitly required for effective project management and coordination. These skills are essential for successful job performance and are often considered integral components of broader skill categories listed in job ads. O*NET highlights several additional skills that are less emphasized

or missing in the provided lists. *Critical Thinking and Problem-Solving* are crucial for almost all job roles, especially in managerial and planning positions. O*NET places an emphasis on these skills across most job roles, reflecting the need for workers to adapt to complex situations and find effective solutions. Although, its excessive presence makes it difficult to distinguish between the critical thinking that is expected from a maintenance technician *vs.* a transportation manager. *Active Listening and Coordination* are frequently noted in O*NET but are not as prominently featured in the job ads. O*NET database includes ratings for 35 key skills, which are grouped into five major families: social skills, fundamental skills, analytical skills, managerial skills, and mechanical skills [77]. Skills like active listening seem to be fundamental skills which are mostly not mentioned in job ads because they are presumed to exist. O*NET lists more detailed technology skills, such as *Specific Technical Tools* (SQL, Microsoft Project, ERP systems) that are crucial for modern job performance but are not usually mentioned in job ads. The technology skills provided in the O*NET descriptions are more detailed and varied. They include:

- Software Proficiency: Specific software tools like ESRI ArcGIS for planners, AutoCAD for engineers, and SAP for logistics planners are highlighted.
- Project Management Tools: Tools such as Microsoft Project and Oracle Primavera are emphasized for roles involving significant planning and coordination.
- Diagnostic and Maintenance Tools: For technical roles like Maintenance Technician, O*NET includes specific diagnostic and maintenance software, reflecting the increasing reliance on technology in these positions.

6. EMERGING JOBS IN TRANSPORTATION INDUSTRY

Building on the transformation in the transportation sector, NCHRP Project 20-07(408) on Transportation Systems Management and Operations (TSMO) identifies 19 new and emerging positions. These 19 emerging job titles were identified through assessment of the needs of State Departments of Transportation (DOTs), input from a diverse group of stakeholders, review of existing educational programs, and exemplary practices in recruitment. These 19 jobs reflect the evolving needs of the transportation industry for TSMO, which is sub-category of transportation technical expertise. Although the 19 emerging jobs do not represent the necessary new job titles (and corresponding required skills) for the whole transportation industry, they jobs can be used as a proxy to examine whether emerging jobs are already being searched for in transportation industry. Assuming that similar jobs are going to form the future of transportation workforce, the emerging job titles in TSMO can provide an understanding on the presence of emerging jobs in current workforce in general. Table 14 gives an overview of the availability and demand and industrial characteristics for the 19 specialized job titles in the transportation industry based on National Operations Center of Excellence (NOCoE) and NCHRP Project 20-0752,95]. For instance, many of these roles, such as **Traffic Data Scientist**, **Cybersecurity Engineer**, and **Artificial Intelligence (AI) Scientist**, require specialized knowledge in data science, programming, machine learning, and cybersecurity, reflecting a shift towards data-driven decision-making. The demand for these roles is high, particularly due to the growing complexity of transportation networks and the adoption of **Intelligent Transportation Systems (ITS)** and

Autonomous Vehicle Technologies. Key skills such as communication, problem-solving, and technical reporting are frequently emphasized, alongside abilities like teamwork, professional judgment, and data collection, indicating that collaboration and analytical thinking are critical to these jobs. Several specialized roles, such as **Transportation Data Ethicist** and **Connected and Automated Vehicle (CAV) Program Manager**, highlight the emerging importance of data ethics, privacy, and autonomous vehicle development in transportation. These roles, though rare, are becoming increasingly important. The strategic roles of **TSMO Program Manager** and **Transportation Systems Performance Manager** reflect the growing focus on optimizing transportation systems to enhance efficiency, reduce congestion, and improve safety [56].

Table 14- Emerging Jobs Skills and Industry Characteristics

Job Title	Skills			Industry Characteristics	
	Knowledge	Skills	Abilities	Availability	Demand
Traffic Data Scientist/Statistician	Statistical Analysis, Modeling, Data/Computer Science, Programming, Software Engineering, Machine Learning	Communication, Analytical, Mathematical, Problem-Solving, Time and Task Management, Interpersonal, Organizational, Research	Teamwork, Data Collection, Professional Judgment, Good Attitude/Work Ethic	Moderately available in various transportation agencies and private companies focusing on traffic data analytics	High, driven by the need for data-driven decision-making in managing and optimizing transportation systems
TSMO Manager/Chief/Bureau Director	Transportation, Traffic Engineering, Operations, Project Management, Local Agency Procedures, ITS Technology	Managerial/Supervisory, Communication, Technical Communication, Report Development, Interpersonal, Time and Task Management, Analytical, Mathematical, Problem-Solving	Innovation/Creativity, Teamwork, Professional Judgment, Data Collection, Analysis	Several openings, especially within state and local DOTs	High, due to the focus on efficient traffic management and system optimization
Computer Engineer	Computer Systems, Data Networks, TSMO Applications, Support Applications, Operating	Technical Communication, Report Development, System Design, Compatibility Assurance	Teamwork, Data Collection, Analysis, Professional Judgment	Available but not specific to transportation, crucial in many sectors including transportation	High across various industries including transportation

	Systems, Device Firmware				
Artificial Intelligence (AI) Scientist	Data/Computer Science, Programming, Machine Learning, Deep Learning, AI Applications, Statistical Analysis, Big Data, Natural Language Processing	Analytical, Communication, Technical Communication, Report Development, Research	Data Analysis, Professional Judgment, Good Work Ethic, Teamwork	Increasing availability, especially in organizations investing in smart transportation and autonomous vehicle tech	Growing, driven by advancements in AI and machine learning applications in transportation
Visualization Specialist	Data Modeling, Visualization, Computer Science, Graphic Design, Visualization Software, AR/VR Software, Programming	Communication, Technical Communication, Report Development, Analytical, Mathematical, Problem-Solving, Time and Task Management	Independent Work, Innovation/Creativity, Data Collection, Analysis	Limited availability but critical for presenting data insights visually	Growing, as effective data visualization is crucial for understanding complex transportation data
Cybersecurity Engineer	Cyber Security Policy, Regulations, Standards, Data/Computer Science, Data Ethics, Compliance, Risk Management	Communication, Technical Communication, Report Development, General Computer Skills, Interpersonal, Analytical, Mathematical, Problem-Solving, Research	Teamwork, Professional Judgment, Data Collection, Analysis, Independent Work	Moderate availability, often integrated into broader IT or engineering teams within transportation agencies	High, critical for protecting transportation infrastructure
Transportation Data Ethicist	Transportation Industry	Communication, Technical	Teamwork, Professional	Very rare, reflecting the	Expected to increase as

	Operations, Data/Computer Science, Cyber Security Policy, Regulations, Standards, Data Ethics, Compliance, Risk Management, Public Policy, Regulations	Communication, Report Development, General Computer Skills, Interpersonal, Analytical, Mathematical, Problem-Solving, Research, Managerial/Supervisory, Leadership	Judgment, Data Collection, Analysis, Independent Work	emerging nature of this role	data privacy and ethics gain importance in transportation
Systems Engineer	Systems Engineering, Advanced Technologies, Performance Measurement, Management, Modeling, Transportation Industry Operations, Project Management, ITS, Public Policy/Regulations	Managerial, Communication, Interpersonal, Analytical, Mathematical, Problem-Solving	Teamwork, Innovation/Creativity, Professional Judgment, Data Collection, Analysis	Common availability with significant demand in integrating various transportation technologies	High
Transportation Systems Performance Manager	Transportation Industry Operations, Local Agency Procedures, Engineering Practice, Performance	Communication, Technical Reporting, Problem-Solving	Teamwork, Innovation/Creativity, Data Collection, Analysis, Professional Judgment	Limited availability but essential for managing and improving transportation	High, especially in urban areas optimizing transportation networks

	Metrics, Systems Analysis, ITS/Emerging Technologies, Data Analytics			system performance	
Integrated Corridor Management Manager	Transportation, Traffic Engineering, Operations, Project Management, Local Agency Procedures, ITS Technology	Managerial/Supervisory, Communication, Technical Communication, Report Development, Interpersonal, Time and Task Management, Analytical, Mathematical, Problem-Solving	Innovation/Creativity, Teamwork, Professional Judgment, Data Collection, Analysis	Limited availability, focusing on managing integrated corridor management systems	High in regions adopting integrated corridor management strategies
TSMO Program Manager				In demand across various regions	High, reflecting the strategic importance of transportation management programs
Telecommunications Engineer				Limited availability specifically to transportation, but available in broader contexts	Moderate to high, essential for modern transportation networks
Data Management Specialist				Moderate availability in transportation	High, due to the increasing importance of

				agencies and companies focused on managing large data sets	data management in decision-making
Connected and Automated Vehicle (CAV) Program Manager				Relatively rare, focused on regions and organizations heavily investing in autonomous vehicle technologies	High in tech-forward transportation sectors
Traffic Incident Management Program Manager				Necessary but less frequent, focusing on managing responses to traffic incidents	Steady, essential for maintaining traffic flow and safety
Surface Weather Specialist				Limited availability, typically part of broader environmental or meteorological roles	Important for regions where weather significantly impacts transportation
TSMO Modeling Specialist				Highly specialized and less	Moderate, reflecting the

				frequent availability	niche expertise required
Emerging Technologies Industry Liaison				Few, but critical for bridging the gap between transportation agencies and technology providers	Increasing as new technologies rapidly enter the transportation space
TMC Manager				Available, with job postings reflecting their crucial role in overseeing traffic operations	High, due to the importance of managing daily traffic operations effectively

Besides the conceptual/expected availability and demand that is presented in Table 14, the 19 emerging job titles were searched in the Indeed website and the corresponding job ads were extracted by using the webscraping tool Octoparse, in order to understand whether the future-oriented transportation jobs are actually sought after in the industry. Total of 2,870 jobs were extracted and it was found that only 885 (approximately 30.8%) were related to the transportation sector, mainly for the job titles Systems Engineer (34%) , Computer Engineer (16%) and Data Analyst (14%) (please see Figure 15). Many of the suggested job titles for the future of transportation, such as **Transportation Data Ethicist, Connected and Automated Vehicle (CAV) Program Manager, AI Scientist, Traffic Incident Management Program Manager, Emerging Technologies Industry Liaison and Integrated Corridor Management Manager** were not found in the extracted job ad data. This indicates a gap between the emerging job titles in TMSO that are expected to shape the future of the transportation industry and the current job market trends. Based on the analysis of job postings related to the transportation industry, several companies frequently appear as employers in this sector. The states that have higher highway infrastructure also have higher number of job openings, e.g., 16% and 10% in Texas and California respectively, with 1st, 2nd in total highway mileage in the U.S., also respectively.[96] Other companies include DKS Associates, AECOM and ICF, indicating opportunities in both public and private sectors. ICF is a consulting and technology services provider that hires for positions like Transportation Data Specialists. This indicates a focus on collecting, analyzing, and managing transportation-related data to inform policy decisions, improve operational efficiency, and analyze transportation networks. DKS Associates look to hire TSMO specialists that focus on planning for TSMO, ITS and broadband. Familiarity with design, modeling, data analytics, and operations are frequently needed for these positions.

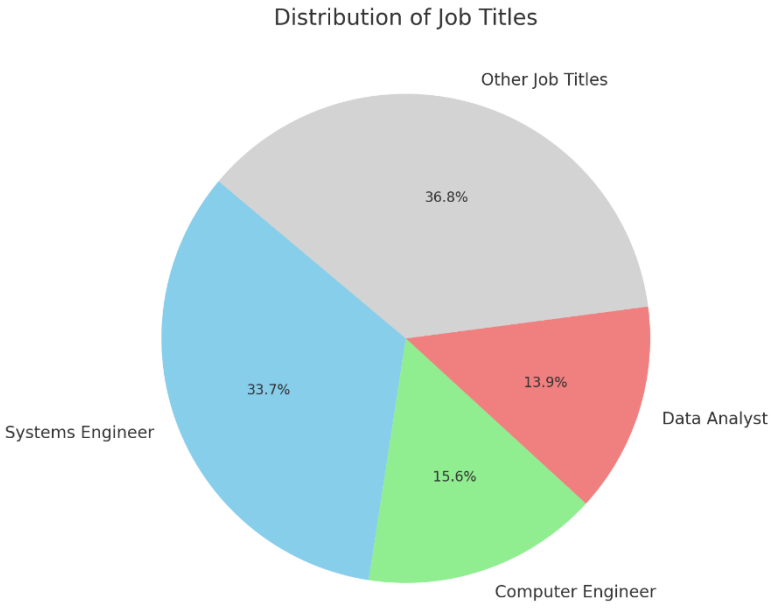

Figure 15- Distribution of Emerging Job Titles

The 855 emerging job ads related to transportation, degree distribution, work experience, salary and skillset were examined and compared with the non-transportation industry job ads. Job ads that had "transportation" keyword in their description or job title were considered as transportation jobs and the rest defined as non-transportation job ads. Figure 16, Figure 17, Figure 18 show the education, work experience and salary requirements, respectively, for emerging jobs in the transportation v. non-transportation industry.

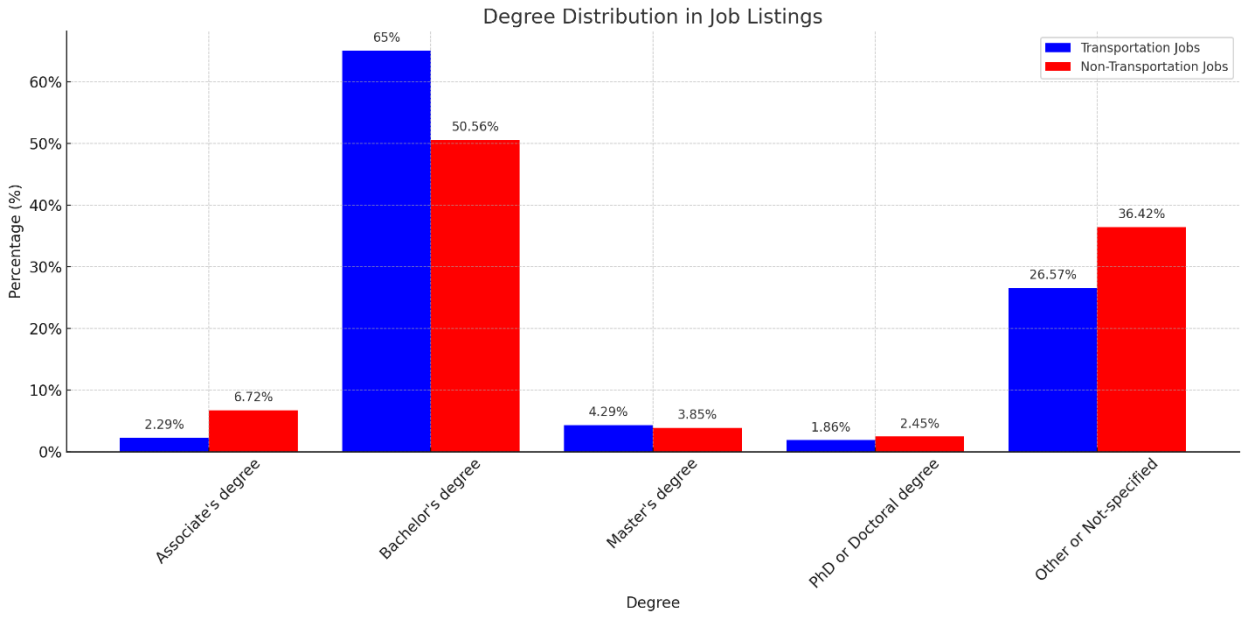

Figure 16- Degree Distribution for Transportation, Non-Transportation Jobs

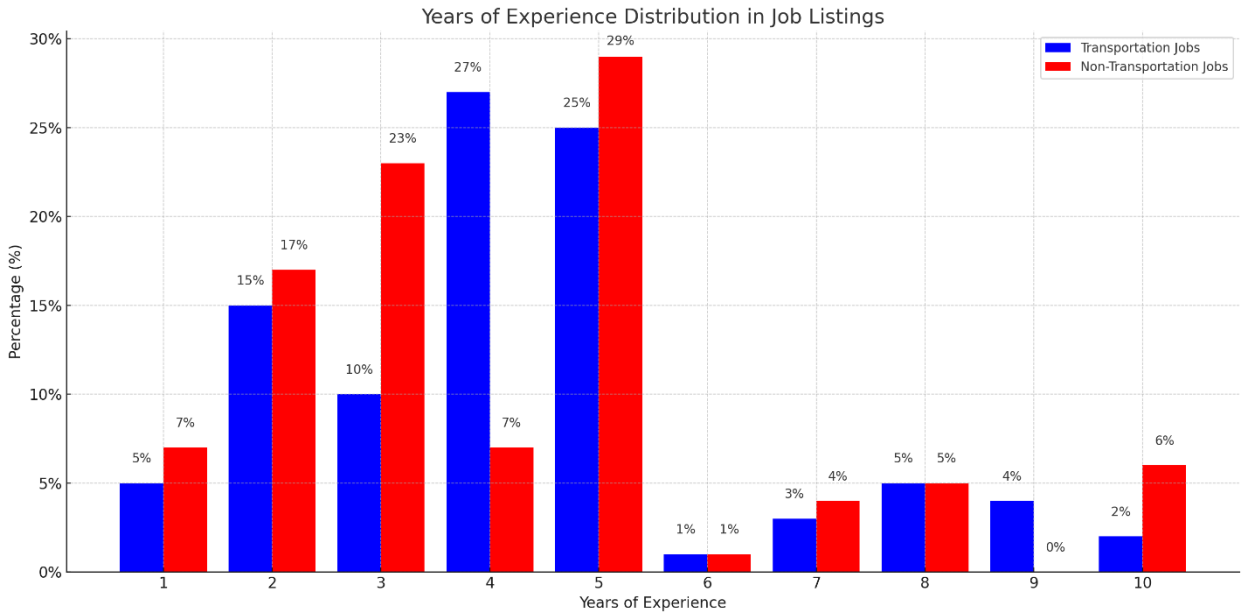

Figure 17- Work Experience Distribution for Transportation, Non-Transportation Jobs

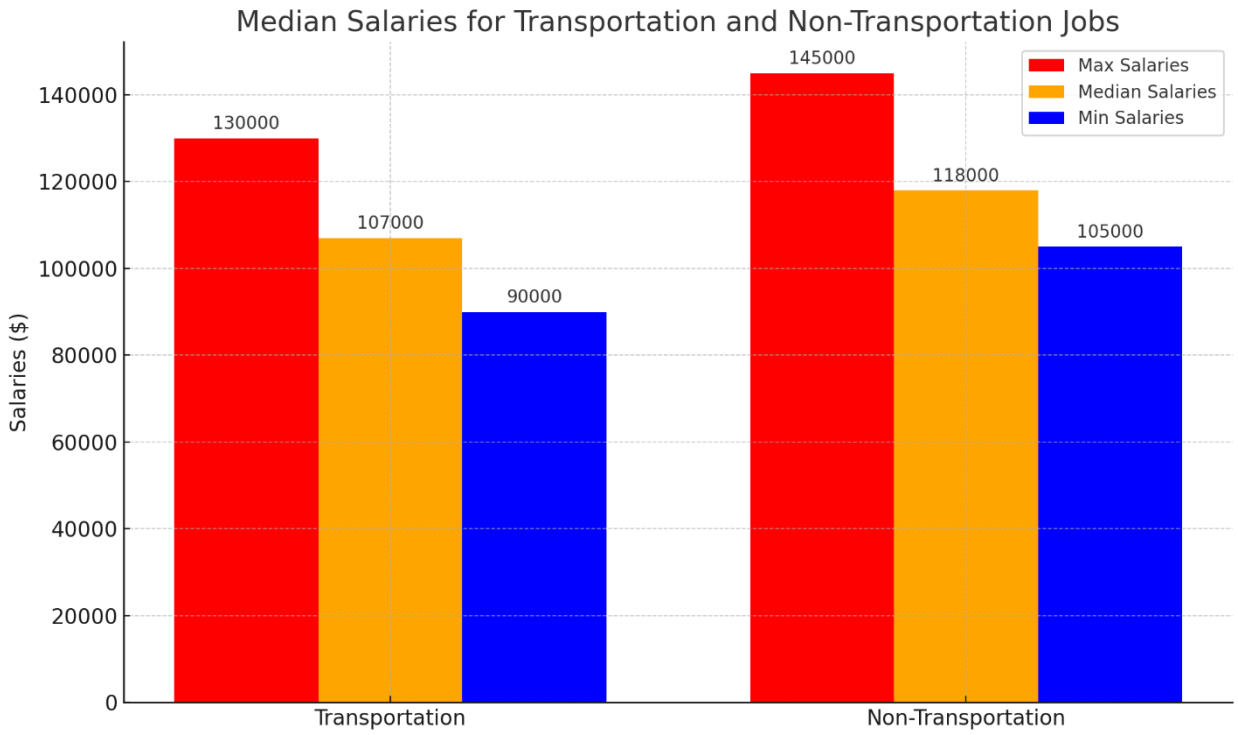

Figure 18- Median Salaries for Transportation, Non-Transportation Jobs

Figure 16 shows that transportation industry job ads require bachelor or masters degree more than non-transportation jobs (65% *vs.* 50.56% and 4.29% *vs*. 3.85%, respectively), but require PhD less (1.86% vs. 2.45%). Fewer non-transportation job ads require associate degree (2.29% vs. 6.72%). There are also fewer non-transportation job ads with "other or non-specified degree" (26.57% *vs.* 36.47%). Most of these job ads do not necessarily mean that there is no educational requirement but the listed skills for the job inherently indicate a certain education level. Expected experience levels are generally comparable (Figure 17). However, as shown in Figure 18, transportation jobs generally pay about 10% lower (i.e., $107K median yearly salary vs. $118K) compared to non-transportation jobs. On the one hand, the non-transportation job ads include high-level positions such as Vice President and other executive roles, which typically come with higher salaries and more attractive benefits packages. In contrast, transportation job listings do not feature these high-level positions as prominently, which could contribute to the lower median salaries within the sector. On the other hand, the minimum and maximum salaries for transportation vs. non-transportation jobs are $90K vs. $100K and $131K vs. $150K that indicates the generally lower salaries in transportation ads for the emerging positions. Hence, despite the higher percentage of transportation job ads with bachelor's and master's degree requirement, the offered salaries are behind the non-transportation jobs. This finding aligns with the overall challenges for the transportation industry in terms of recruiting and retaining workers due to salary-related issues. Departments of Transportation (DOTs) struggle to compete with private companies in attracting skilled workforce due to limitations on hiring salaries and incentives [97]. Additionally, the industry needs to overcome its negative public image and raise awareness about job opportunities,

particularly among youth and non-traditional labor pools, to successfully recruit entry-level workers [98].

6.1. Required Skillset for Emerging Transportation Jobs

The most common skillsets for emerging TSMO job titles in transportation job ads were found to be Communication skills, Microsoft Excel, Python, Problem-solving, Collaboration, Structured Query Language (SQL), Attention to Detail, Data Analysis, Negotiation skills, Organizational skills, Project Management, Customer Service, Analytical skills, Interpersonal skills, Leadership, and Time Management, Transmission Control Protocol (TCP) and socket programming. These skills include both soft and hard skills, similar to overall transportation job ads. The emergence of "Python", "SQL" and "Transmission Control Protocol (TCP) and socket programming" in the required skillset for emerging jobs aligns with the increasing use of technology and coding applications in transportation domain, not confined to TMSO positions but for the whole transportation industry

7. CONCLUSION

This report provides an analysis of job ads in the transportation industry to offer insights into the current state and future trajectory of the transportation workforce. For this purpose, total of 8,193 job ads were collected between the dates of December 2023 to June 2024 from Indeed, Monster, LinkedIn with web scraping tool Octoparse, by using the keyword list of Transportation, Transportation Engineer, Transportation Planner, Transportation Maintenance, Highway Construction, Highway Maintenance, Department of Transportation. The collected data categorized with respect to major job features (titles, education and experience requirements, salary, etc.) by using text mining tools, including AI tool (GPT-3.5 Turbo). The set of required skills in jobs were compared with O*NET database that documents the workforce skill expectations of the industry professionals. Then, in order to compare the currently sought-after workforce skills with the necessary workforce skills for the future of transportation industry, another job ad search is conducted by using the emerging jobs for the TMSO jobs in transportation industry (as suggested by [52]). The analysis of emerging TMSO jobs are used as a proxy for the overall transportation industry trends regarding the skillest of the overall future workforce. Overall findings from the job ads can be summarized as follows:

- **High Percentage of Transportation Job Ads for Middle-Skill Jobs:** Middle skills jobs are the jobs that require postsecondary training but not necessarily a college degree. This finding is consistent with existing literature that emphasize the importance of those jobs for most transportation industry operations, but also underline the insufficient number of skilled workforce to fill those positions – necessitating on-the-job training and apprenticeship for workforce development.
- **Mix of Soft and Hard Skill Requirements for Transportation Jobs:** The required skillset in the job ads emphasize both soft- and hard-skills, reflecting the industry's diverse demands. Soft skills such as communication, problem-solving, and teamwork are listed along with

technical proficiencies like Microsoft Office, GIS and specialized software tools. Overall, the required skills in the job ads generally align with the O*NET database, which documents industry professionals' expectations. However, some soft skills emphasized by O*NET such as Active Listening and Coordination are not always explicitly reflected in the job ads. While some transportation job ads include emerging technology-related skills such as Python and SQL, many emerging jobs for the TMSO jobs [76] such as Transportation Data Ethicist, Connected and Automated Vehicle (CAV) Program Manager, AI Scientist, Traffic Incident Management Program Manager, Emerging Technologies Industry Liaison and Integrated Corridor Management Manager are yet to appear in job ads. On the other hand, transportation companies advertise job titles such as Traffic Data Scientist, TSMO Manager, Computer Engineer, System Engineer indicating that the transformation in the transportation industry is not unnoticed.

- **Insufficient Specificity in Job Advertisements:** The jobs ads do not necessarily provide details about the required skills, especially for the soft skills for different kinds of jobs. Teamwork, collaboration etc. need some better clarification in job ads. Moreover, most job ads do not mention the exact responsibilities for their role or ask for multiple positions in a single job ad that can make it difficult for the job seekers to assess their fit.
- **Insufficient Representation of Emerging Job Titles in Job Ads:** The job titles that are relevant to the future transportation technologies and management practices (as suggested by [52] for the TMSO jobs) are not represented in the current transportation job market (30% of the related jobs ads are from the transportation sector). Many of the futuristic and specialized job titles expected to shape the future of transportation, such as Transportation Data Ethicist, Connected and Automated Vehicle (CAV) Program Manager, AI Scientist, Traffic Incident Management Program Manager, Emerging Technologies Industry Liaison and Integrated Corridor Management Manager were not present in the dataset. The lack of job ads for emerging job positions suggests that these positions are either being under-recruited or are not yet recognized as essential by organizations, leading to these positions not being integrated into the industry’s workforce development. Although the findings relate to the emerging TMSO jobs, the findings are arguably a proxy for the overall recruitment landscape for the transportation industry.
- **Non-Competitive Salary Offers for Emerging Job Titles:** Transportation industry was found to offer competitive salaries for traditional jobs, based on the comparison for job titles listed by the Bureau of Labor Statistics. However, the salaries for the emerging TMSO jobs are found to be not competitive when compared with the salary offers for similar job ads at other industries, although the required educational qualifications are comparable, if not higher for the transportation industry. The lower salary offerings for the emerging jobs suggests that the transportation industry needs to follow the job market trends to offer competitive salaries for the emerging job titles that are also sought-after in other industries. Such salary competition [75] is also reported for middle-skill workers due to competition with other industries for the limited number of skilled workforce.

7. RECOMMENDATIONS FOR THE DEPARTMENTS OF TRANSPORTATION

Based on the study findings, the following actions are recommended.

- **Establishing Critical In-house Expertise in Emerging Positions to Facilitate Further Job Openings**

Insufficient representation of emerging TMSO jobs (as a proxy for the emerging job opportunities in transportation sector in general) in the job ads can be attributed to several factors, including existing workforce profiles, i.e., about half of the state transportation agencies depend significantly on consultants for key technical positions like systems engineering and information technology [77]. The reliance on consultants can explain the lower number of job ads for these positions, as agencies might prefer outsourcing rather than hiring full-time staff for these specialized roles. Furthermore, insufficient in-house expertise can also limit the institutions/agency's capacity to assess the job candidate skills' fit to emerging job positions, and consequently lead to a slower adoption of critical emerging job roles. High-skilled positions typically come with higher salary demands that can hamper the recruitment efforts even when the agency/institution is willing to recruit for emerging positions. Establishing critical mass for in-house expertise can help with the recruitment process in terms of recruitment and retaining incoming employees, as well as creating momentum within the agency for prioritizing budget allocation for emerging positions.

- **Offering Competitive Salary Structures in Emerging Job Titles**

Literature on the transportation workforce consistently highlights challenges in attracting and retaining skilled professionals, especially in the face of competition from more resourceful private sector and technology firms [78]. To maintain a competitive edge and successfully navigate the technological transformation of the transportation industry, transportation companies and organizations need to ensure that the new emerging positions are actively recruited with appropriate salaries to beat the competition from other industries. Accordingly, DOTs should review and adjust salary structures to be more competitive especially for roles requiring advanced degrees and professional certifications, and consider offering additional benefits and incentives, such as professional development opportunities and flexible working conditions.

- **Improving Job Ad Specificity and Broaden Recruitment Channels**

Crafting compelling job descriptions that emphasize the details of required skills, unique aspects and growth potential of these roles can also help attract high-quality candidates [99]. Organizations should use multiple channels to reach a diverse audience, including job boards, social media, industry publications, and career fairs. For instance, some DOTs do not use popular job search sites. Accordingly, DOTs should ensure that the job ads are widely advertised through multiple channels, clear and specific about the skills and qualifications required, without generic descriptions that do not fully convey the job's requirements and the unique aspects of working in the transportation sector. Provide detailed information about career advancement opportunities, work environment, and the impact of the role on public transportation systems to attract motivated candidates.

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