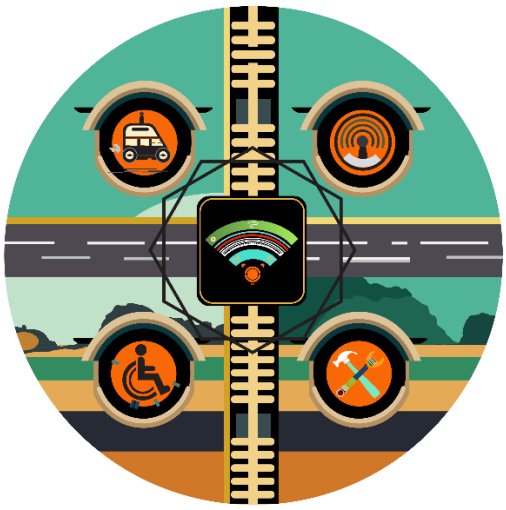

R-SEAT CENTER

Stony Brook University

Technology Driven Workforce Transformation in Transportation Industry: Assessing Workforce Readiness and Recruitment Gaps

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

The U.S. transportation sector is undergoing rapid technological transformation, yet little is known about whether workforce recruitment and training practices align with emerging skill requirements. This study addresses this gap by examining the skill capability-demand mismatch in transportation agencies through a national survey of 105 professionals from public agencies, consulting firms, and research institutions. The survey assessed workforce composition, skill gaps, hiring challenges, and organizational readiness for technology-driven transformation. Results reveal a substantial capability–demand gap: although 90% of respondents recognized the need for expertise in emerging technologies, only 23% rated their internal capacity as high. Digital skills, particularly programming, data analytics, and automation were the most frequently cited deficiencies (65% reported gaps in at least one digital area), yet those areas remain underrepresented in hiring priorities. Structural barriers compound these challenges: salary rigidity was cited by 83% as the primary recruitment obstacle, while 65% noted unclear role definitions for emerging positions. The analysis recommends modernizing job classifications to accommodate hybrid tech roles, clarifying role expectations through detailed technical competency frameworks, realigning salary structures to reflect market conditions, and developing structured internal training pathways. These findings provide actionable guidance for agencies seeking to build the technological capacity necessary for transformation.

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EXECUTIVE SUMMARY

The U.S. transportation sector is undergoing rapid technological transformation that has impacts on recruitment and training practices for the workforce to meet the emerging skill requirements. This study examines the skill capability-demand mismatch in transportation agencies through a national survey of 105 professionals from public transportation agencies (e.g., DOTs, MPOs), consulting firms, and research institutions. The survey assessed workforce composition, skill gaps, hiring challenges, and organizational readiness for technology-driven transformation in transportation sector and conducted from May to July 2025. Forty six percent (46%) of the respondents represent a senior cohort with over 10 years of experience and 66% of the respondents hold master's or doctorates degrees.

Key Findings

1. Capability-Demand Gap: A notable disconnect exists between awareness of the need for emerging skills and institutional capabilities. While 90% of respondents recognize the need for emerging technology expertise, only 23% rate their internal capacity.

2. Digital Skills Deficiencies: Digital competencies show significant gaps. 65% of respondents report deficiencies in at least one digital area. Programming expertise is particularly limited: only 7% demonstrate advanced proficiency in Python or C, while 60% have basic or no expertise. Specific gaps include technology and automation (35%), software skills such as GIS and AutoCAD (32%), and computer programming (23%).

3. Traditional Competencies Dominate: Organizations remain grounded in traditional skills. 82% hold Professional Engineer licenses versus only 12% with IT certifications. Soft skills (48% advanced proficiency), project management (35%), and technical engineering (33%) remain organizational strengths, though these do not fully address digital transformation requirements.

4. Hiring Misalignment: Recruitment priorities do not align with identified needs. Despite digital deficiencies, 75% prioritize technical engineering skills and 72% prioritize soft skills in hiring. Only 13% prioritize technology and automation skills, and just 10% prioritize programming indicating that digital requirements have not been fully integrated into recruitment strategies.

5. Structural Recruitment Barriers: Salary rigidity emerges as the primary obstacle (83% of respondents), compounded by lengthy hiring processes (50%), rigid pay scales (78%), and lack of remote work options (46%). About 60% perceive salaries as uncompetitive, and 28% face restrictions on performance-based incentives, making it difficult to compete for technology talent.

6. Role Ambiguity in Job Postings: 65% acknowledge vague or undefined responsibilities for emerging roles. 53% use single advertisements for multiple openings. While 86% update job responsibilities and 74% update qualifications, over 40% fail to update salary ranges, benefits, or remote work options—potentially creating confusion for applicants.

7. Dependency on Consultants: Organizations demonstrate considerable reliance on external consultants rather than building internal capacity for emerging technology applications. About 47% outsource technology and automation needs, and 38% outsource programming requirements. This approach may limit long-term adaptability and institutional knowledge retention.

8. Training Gap: 43% of organizations provide no training in emerging technologies, representing a missed opportunity to develop internal capacity for digital transformation.

Recommendations

1. Modernize Job Classifications: Update HR frameworks to create hybrid role classifications that bridge transportation expertise with digital competencies. Current systems often assign data scientists and AI specialists to traditional "Engineer" titles with misaligned pay grades. New classifications should explicitly recognize positions combining transportation knowledge with IT, data science, and systems thinking capabilities.

2. Implement Technical Competency Frameworks: Enhance job descriptions with specific technical requirements. Specify programming languages (Python, SQL), analytical tools (GIS platforms, data visualization software), and systems knowledge (ITS architecture, cloud platforms). Balance general qualifications with measurable technical competencies to provide clearer guidance for applicants.

3. Realign Compensation Structures: Address the salary competitiveness barrier cited by 83% of respondents by benchmarking and adjusting pay scales for data scientists, AI engineers, and cybersecurity specialists to reflect the market rates for similar positions. Where immediate increases are not feasible, consider performance-based incentives and emphasize non-monetary benefits such as flexible work arrangements, work-life balance, and professional development opportunities.

4. Establish Internal Training Programs: Reduce consultant dependency by developing structured training pathways in AI, data analytics, automation, and cybersecurity. Partner with universities and online platforms, create mentorship programs, and allocate dedicated professional development time. This addresses the 43% training gap and builds sustainable internal expertise.

5. Address the awareness-implementation paradox: The transportation sector faces an "awareness-implementation paradox": high recognition of technology needs (AI: 78%, big data: 63%, automation: 67%) has not yet translated into organizational capability due to structural constraints. Success requires institutional adaptation not just individual recruitment. Agencies should modernize job classifications, clarify technical requirements, realign compensation, and invest in internal training. Addressing these systemic factors can help bridge the 67-percentage-point capability gap, enabling agencies to advance their transformation initiatives and effectively serve a rapidly evolving transportation landscape.

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1. INTRODUCTION

The U.S. Department of Transportation's 2022-2026 Strategic Plan identifies "Transformation" as one of five critical initiatives, emphasizing the urgent need for workforce capabilities in data science, automation, and systems thinking [1]. The transportation sector in US, with a labor force exceeding 16 million workers across 75 job categories [2] is encountering difficulty in recruiting workers who possess the skills necessary for this transformation. Transportation agencies, including state DOTs, face recruitment and retention challenges due to salary competitiveness, perceptions of limited advancement opportunities and public-sector work [3, 4]. A recent analysis of job advertisements revealed that while technology-related skills such as data analytics and programming are increasingly mentioned, many postings still emphasize conventional qualifications such as professional certifications and degrees without specifying the skillsets required for emerging roles [5]. Salary competitiveness compounds these challenges: roles demanding advanced degrees, particularly those tied to emerging domains, frequently offer compensation misaligned with comparable industries, potentially deterring qualified candidates despite increasing educational expectations [5]. Furthermore, recruitment efforts do not necessarily utilize mainstream job search platforms such as Indeed and LinkedIn, instead rely on agency-specific websites that reduce visibility and may limit access to broader and more diverse candidate pools [6]. Previous research has documented individual aspects of this challenge, e.g., salary competitiveness [5], job advertisement misalignment [6], and skills evolution [7]. This study examines the systemic nature of workforce recruitment barriers from the perspectives of agencies to understand the procedural bottlenecks and agency perspectives that inhibit transformation potential is essential for developing effective workforce strategies.

This study fills that gap by investigating how transportation professionals perceive workforce readiness, what structural obstacles prevent effective recruitment, and where organizational priorities diverge from stated technology needs. Specifically, we address three research questions (**RQ**s):

> ***RQ1*:** What are the gaps between recognized technology skill needs and internal organizational capacity?
> ***RQ2*:** What structural and institutional barriers prevent effective recruitment for emerging technology roles?
> ***RQ3*:** How do current hiring practices align (or misalign) with stated transformation priorities?

To answer these questions, a national survey was conducted and received responses from 105 transportation industry professionals from public agencies, consulting firms, and research institutions. The survey assessed current hiring practices, agency perspectives on workforce recruitment, critical emerging skills, and perceived barriers to recruiting for technology-driven roles including salary limitations, organizational readiness, and awareness gaps.

This study makes three key contributions by (1) providing an assessment of transportation agency perspectives on technology workforce readiness, (2) quantifying the capability-demand gap across multiple dimensions, and (3) identifying specific structural and institutional barriers amenable to policy intervention. By examining how current hiring practices reflect (or fail to reflect) the evolving workforce skill needs of the transportation sector, the findings provide actionable guidance for more effective workforce development strategies.

2. LITERATURE REVIEW

The U.S. transportation workforce is undergoing a significant transformation driven by technological innovation and changing industry needs. Traditional civil engineering and operations roles are expanding to encompass interdisciplinary competencies in information technology and data science [7]. Emerging technologies, including connected and automated vehicles (CAVs), big data analytics, shared mobility, and electrification, are affecting nearly every aspect of transportation agencies' operations, from planning and engineering design to maintenance and system management [8]. Pomoni et al. state that this digitalization and automation wave will fundamentally alter the skill requirements for transportation workers, calling for a "*digitalization literate workforce*" to meet future demands [9]. Not only are new technical skills in areas like autonomous systems, cybersecurity, and artificial intelligence required, but the workforce must also adapt quickly to continual technology updates. Industry observers warn that new tools are emerging faster than many agencies can absorb them, and new organizational processes are needed to evaluate and integrate these technologies into daily work [10]. The literature points at several key themes: 1) a transformation in workforce skills requirements driven by new technologies, 2) persistent recruitment and retention challenges in transportation, 3) the rise of new occupations and questions of institutional readiness, and 4) gaps in current hiring practices that may impede alignment with future needs.

2.1 Transportation Workforce Transformation and Skill Shifts

Transportation organizations are experiencing a profound shift in the skill sets their employees need. Industry reports note that the current workforce already has a skills deficit in key areas, a situation likely to be intensified by the introduction of innovative technologies [11]. As automation, digitalization, and new mobility solutions take hold, skills required in transportation jobs are expanding beyond the traditional domains of highway construction, operations, and maintenance [12].

A recent study describes this dynamic, noting that digitalization enables real-time data use and operational optimization, which in turn drives demand for data-savvy professionals even as some traditional labor needs decline [13, 14]. Emerging technical skills are essential to leverage innovations like smart infrastructure and connected vehicles. Crucially, scholars also caution that future skills in transportation are not only technical. [11]. In other words, strategic thinking, adaptability, and policy/social awareness are becoming as important as pure engineering prowess.

The ability to continuously learn and adapt is a critical emerging competency, given the rapid pace of change in transportation technologies [12, 13].

2.2 Recruitment Challenges in Transportation

Despite growing recognition of evolving skill requirements, the transportation sector continues to face persistent recruitment and retention challenges. A central concern is the aging workforce, with a large share of transportation professionals nearing retirement age and insufficient numbers of younger workers entering the field. This demographic imbalance has contributed to labor shortages and the risk of institutional knowledge loss. Compensation has repeatedly been identified as a primary barrier to recruitment, particularly in public-sector transportation agencies where rigid pay structures limit competitiveness with private-sector technology and engineering firms. Research indicates that transportation organizations often require comparable or higher educational qualifications for emerging roles, yet offer salaries that lag behind market alternatives. While non-monetary benefits such as work-life balance and job stability can partially offset salary limitations, compensation remains a critical constraint in attracting talent with in-demand digital and analytical skills. As skill needs are evolving, the transportation sector faces longstanding recruitment and retention challenges. Many transportation organizations are grappling with an aging workforce and difficulties attracting new entrants to replace those who retire [15]. Demographic trends show that a high share of workers are in their 50s and 60s, nearing retirement age. At the same time, younger workers remain underrepresented in transportation jobs. This imbalance highlights a pipeline problem: the industry is not drawing enough young talent to backfill the positions of an older generation. The consequence has been labor shortfalls in certain occupations. In 2021, approximately 6.7% of bus and coach driver positions and 9.7% of heavy-goods truck driver positions were unfilled [16]. Transportation agencies and contractors consistently cite workforce shortfalls and foresee significant losses of institutional knowledge as veteran employees retire [12].

A combination of factors underlies these recruitment difficulties. A key issue identified is the perceived attractiveness of transportation careers to new entrants. Some transportation jobs have a reputation for demanding conditions (e.g., long or irregular hours, or field-based work) without commensurate compensation, which can deter younger workers [17]. Indeed, researchers note that the transportation sector is facing many of the same challenges as the larger U.S. workforce, but some concerns, such as salary and benefits, appear more pronounced in the transportation sector. A national survey of state DOTs found that the most cited reason employees leave these agencies is compensation, including both salary and benefits [12]. Ershad et al. [6] indicate that salaries for emerging jobs are often uncompetitive compared to similar positions in other industries. This disparity exists despite transportation roles requiring comparable, and frequently higher, educational qualifications. This suggests a significant challenge in attracting and retaining talent within these vital, evolving sectors [6]. Experts suggest that transportation employers may need to emphasize other advantages, e.g., a better work-life balance, flexible work arrangements to attract and retain the next generation of workers [12]. This aligns with broader workforce trends indicating that Millennials and Generation Z value work-life balance, flexibility, and mission-driven work [17].

2.3 Emerging Occupations and Institutional Readiness

Industry needs shift and technologies change, therefore transportation employers must ensure they have people with the right expertise to oversee and implement these innovations [12]. In practice, this has led to new occupational titles and job functions appearing in the transportation sector. For example, many organizations are now seeking data scientists and analysts to make sense of the large volumes of transportation data generated by sensors and connected vehicles. Similarly, roles focused on software development and systems engineering have become critical as agencies deploy complex traffic management systems, autonomous vehicle pilots, and smart infrastructure (demanding skills in programming, software architecture, and development operations) [18]. Cybersecurity specialists are another emerging occupation, given the need to protect transportation systems from cyber threats and to ensure the safety of automated technologies; stakeholders have emphasized that overseeing modern automated transport systems requires data analysis and cybersecurity skills, among others [19]. New job categories are also developing around electric and connected vehicles (e.g., charging infrastructure planners, vehicle-to-infrastructure communication engineers) and around sustainability and resilience (for instance, roles focused on sustainable transportation planning and climate adaptation for infrastructure). These emerging occupations often combine traditional transportation knowledge with advanced competencies in IT, data, and systems thinking. The challenge is that many transportation organizations are not fully prepared in terms of awareness, organizational structure, and human resource practices to integrate these new occupations. Studies have found that while agencies recognize the need for new skills, their internal processes for workforce planning and hiring have lagged. A U.S. Department of Transportation workforce assessment identified important skill areas like regulatory expertise, data analytics, and cybersecurity that will be needed to oversee automated systems, but also revealed gaps in these skills among current staff [19]. Approaches to "workforce development" differ widely among DOTs, and fewer than one-third of states have their DOT and training offices (such as local technical assistance program (LTAP) centers) closely coordinate on such issues [12]. This fragmentation suggests that institutional readiness is uneven; some agencies have launched aggressive upskilling and recruitment initiatives for emerging roles, while others may not yet fully react to the urgency or scope of the skills transition. Another aspect of institutional readiness is whether transportation employers are proactively updating their training, educational partnerships, and awareness of future trends. The literature suggests that more could be done on this front. For instance, international bodies like the Organization for Economic Co-operation and Development (OECD) and International Labour Organization (ILO) have recommended strategies such as *"*upskilling and retraining programs*"*, *"*partnerships with educational institutions*",* and *"*social dialogue*"* to help the transport workforce adapt to automation and digitalization [15, 16, 20]. These strategies imply that transportation organizations should collaborate with universities, community colleges, and technical schools to develop curricula aligned with emerging skill needs (e.g., courses in data science for transportation or ITS engineering). There are examples of progress: some state DOTs have formed partnerships to create new academic programs (one case is a two-year associate degree in Highway Maintenance

Management developed with a university), and agencies like Ohio DOT have implemented sophisticated training and knowledge exchange programs to break down silos and spread new skills internally [12]. However, such examples are not yet universal. New occupations and job titles are emerging in transportation, yet the degree of institutional readiness and awareness varies considerably. Building this readiness is crucial so that transportation agencies and firms can effectively hire for the future by recognizing what roles will be needed and taking steps now to recruit that talent [12]. Recent research by Qian et al. further suggests that organizational readiness depends not only on hiring practices but also on how professionals within agencies perceive and respond to technological change, adding complexity to recruitment challenges as agencies must attract tech-savvy talent while maintaining engagement among existing employees who may hold different views about transformation [22].

2.4 Gaps in Current Hiring Practices

Finally, the literature identifies significant gaps between current hiring practices in transportation and the sector's future skill requirements. One recurring theme is the mismatch between employer needs and traditional hiring criteria or processes. Many transportation employers have reported difficulty finding candidates with the desired skills ("skills gap"), yet evidence suggests that in some cases, the issue lies with how employers are recruiting and hiring. For example, a study noted that numerous transportation and logistics firms struggled to fill vacancies and tended to blame a lack of skilled applicants, but these hiring challenges sometimes stemmed from the employers' own practices [14]. A key barrier lies in the content and structure of transportation job advertisements. Ershad et al. [6] indicates lack of specificity in many postings, noting that job ads often fail to clearly outline required qualifications, technical skills, or role expectations. This ambiguity is further compounded by limited outreach; many agencies rely on a narrow range of advertising platforms, sometimes posting multiple distinct roles under a single listing, which can confuse applicants and limit visibility to qualified candidates. In addition, salary competitiveness continues to be a challenge, particularly for positions demanding advanced degrees or specialized expertise. While many job ads include references to soft skills such as communication and collaboration, Ershad et al. question the mechanisms by which these skills are assessed during the hiring process.[6] Walters et al. [21] further contribute to this discussion by identifying disciplinary silos within transportation hiring. Their research shows that industry professionals increasingly acknowledge the value of interdisciplinary expertise, particularly in fields such as social sciences, economics, and computer science for addressing behavioral factors, policy analysis, and broader system-level challenges. Despite this recognition, these disciplines remain overlooked in actual hiring practices, where technical and engineering backgrounds continue to dominate. This disconnect shows a misalignment between the evolving demands of the transportation sector and the qualifications emphasized in recruitment strategies [21].

Another gap in current practices is the misalignment of skill assessment between employers and workers, which can be effective in hiring and training. Research has shown that transportation workers and their employers sometimes have very different perceptions of which skills are lacking. In one survey-based study, transportation workers believed they had no significant gaps in certain

technical skills, yet employers reported severe KSA (knowledge, skill, ability) gaps [14]. To close these gaps, agencies can conduct regular skills gap analyses to identify where the workforce is falling short, and devise targeted hiring or training initiatives [19]. It follows that hiring practices might not clearly communicate the true skill requirements of jobs, or that training opportunities for workers to gain those in-demand skills are insufficient. If job candidates are not aware of what competencies they truly need to demonstrate (or if current employees aren't getting feedback and upskilling to meet evolving needs), the hiring pipeline will suffer. Furthermore, closer collaboration with educational institutions can ensure a pipeline of graduates with relevant skills, reducing the gap between what schools teach and what employers need [13]. In summary, the current hiring practices in transportation have room for improvement to better align with emerging skill requirements.

3. METHODOLOGY

The project team prepared and distributed an online survey nationally to examine how transportation professionals perceive workforce challenges and opportunities in light of technological transformation. The survey instrument was structured around four themes:

1) **Current Workforce Composition**: Questions related to participants' roles, organization type, and general workforce characteristics to gather broad information about the current workforce landscape in transportation agencies.
2) **Existing Expertise and Skill Gaps**: Questions that assess existing expertise and readiness for emerging technologies.
3) **Hiring Practices and Recruitment Challenges**: Questions focused on recruitment strategies, job posting practices, and barriers to attracting qualified candidates to understand hiring practices and recruitment challenges.
4) **Emerging Technologies and Future Workforce Needs**: Questions exploring organizational engagement with emerging technologies such as data science, connected and automated vehicles (CAVs), system engineering, and cybersecurity, as well as future skills anticipated to be in demand to identify how emerging technologies are shaping future workforce needs.

The survey consists of 50 questions in total, including 46 close-ended multiple-choice questions, and 4 matrix table questions. The survey was designed to pose or skip certain questions based on the previous responses, leading to fewer than 50 questions per respondent. The medium response time was 15 minutes. The complete survey instrument, including all 50 questions is provided in Appendix A at the end of this report.

The survey targeted transportation industry professionals currently employed in the transportation sector, including those working in public agencies (e.g., state departments of transportation, metropolitan planning organizations) and private consulting firms. Eligibility was limited to individuals working in the transportation industry. Recruitment was conducted through professional networks and LinkedIn posts, with outreach to contacts established through past

transportation conferences and events. The survey was conducted on Qualtrics and remained open for eight weeks, from May to July 2025. A total of 105 valid anonymous responses were collected from professionals across various organizational types and geographic regions. The research protocol was reviewed and approved by the Institutional Review Board under protocol number 2025-00134.

3.1. Data

Figure 1 summarizes the roles, sectors, and organizational domains represented by the survey respondents. Participants work across various transportation domains, with a concentration in infrastructure, planning, and government agencies. Notably, 46% of respondents reported having more than 10 years of experience in the field, indicating the seniority and institutional knowledge is present in the sample. In addition, 48% of respondents reported holding a master's degree, indicating a high level of educational attainment. These characteristics suggest that the survey reflects the views of a highly educated, experienced workforce at managerial/supervisory roles, primarily from the public sector and strongly represented by professionals in engineering, planning and human resources (HR) roles. The high proportion of senior professionals and advanced degree holders suggests the sample captured perspectives from decision-makers with influence over hiring and training policies. A precise response rate cannot be calculated due to the snowball sampling approach and multiple distribution channels; however, the sample represents diversity across organizational types (public agencies, consultants), geographic regions, and experience levels.

Several limitations should be noted. First, the sample size (N=105), while sufficient for exploratory analysis, limits statistical power for subgroup comparisons. Second, the convenience sampling approach may introduce self-selection bias, as respondents are likely to have greater interest in workforce issues than non-respondents. Despite these limitations, the study provides valuable insights into agency perspectives rarely captured in workforce research.

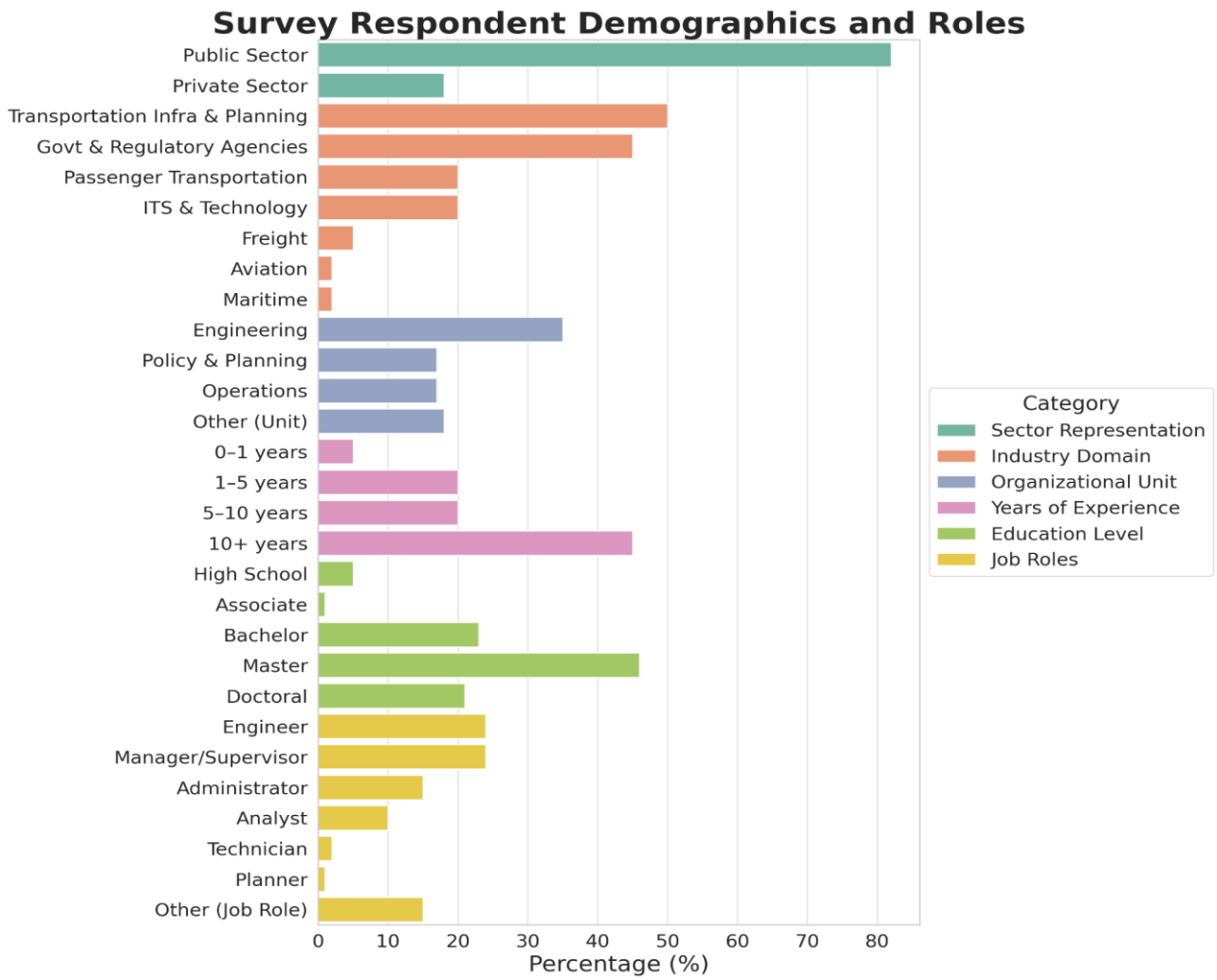

Figure 1- Survey Respondent Demographics and Organizational Characteristics

4. FINDINGS

4.1 Existing Expertise and Skill Gaps

This section presents insights from the survey on the current expertise levels of employees across various skill areas in the U.S. transportation workforce. Respondents were asked to assess their unit's proficiency across nine categories, including both traditional engineering competencies, soft skills, and emerging digital skills. Figure 2 illustrates the distribution of current skill expertise levels of workforce at the respondents' institution, along with the percentage of respondents who identified each skill as a skill gap.

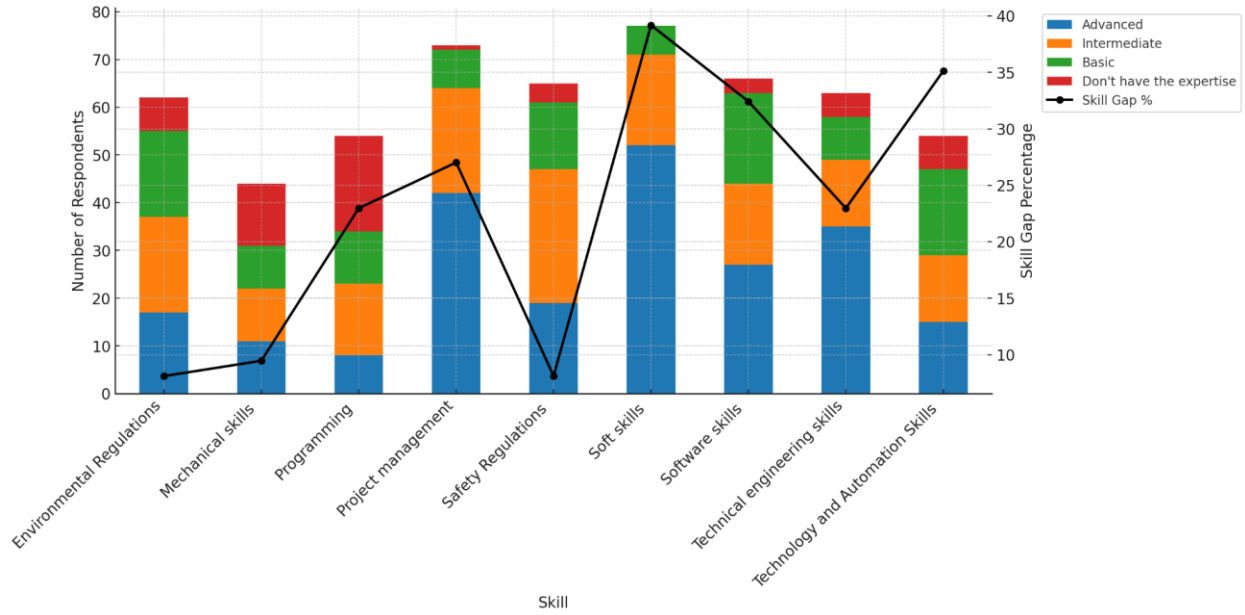

Figure 2- Current Workforce Expertise Levels and Identified Skill Gaps

The results show that soft skills, project management, and technical engineering capabilities are the most prominent areas of expertise within the current workforce. Specifically, 48% of respondents reported advanced proficiency in soft skills such as communication, collaboration, and teamwork, suggesting strong interpersonal foundations across organizations. Similarly, 35% of respondents reported advanced expertise in project management, and 33% did so for technical engineering skills, such as roadway design and traffic engineering. These capabilities reflect the traditional strengths of public-sector transportation agencies, where coordination, leadership, and core engineering functions remain central to operational success. However, the data shows skill gaps in digital and programming-related areas which pose challenges for transformation. Programming skills, including languages such as Python and C, had the lowest share of advanced expertise, with only 7% of respondents reporting advanced knowledge. To add on, nearly 60% of respondents noted either basic familiarity or no expertise. This is a concern given the sector's increasing reliance on data analytics, automation, and smart infrastructure.

When considered collectively, digital knowledge emerged as the most frequently cited area of workforce need. In total, 65% of respondents reported gaps in at least one digital or emerging technology area, underscoring a widespread need for improved digital competencies across the sector. Technology and automation skills (35%), software skills such as GIS and AutoCAD (32%), and computer programming (23%) were commonly identified as gaps. By contrast, the least frequently reported gaps were in mechanical skills (7%), safety regulations and compliance (8%), and environmental regulations and compliance (7%), suggesting that organizations may feel more confident in their current capacity in these traditional areas. Aligning with these results, when asked about the most common certifications or licenses held among employees in their organization, 82% of the respondents reported the Professional Engineer (PE) license, followed by the Fundamentals of Engineering (FE) (54%) and the Project Management Professional (PMP)

certification (44%). Only 12% indicated that IT certifications (e.g., Cisco, CompTIA), pointing to a relatively limited presence of formally certified digital and IT skills in the current workforce. These findings point to a disconnect between emerging demands and current capabilities in data-driven and technology-integrated transportation practices. An important pattern emerging from the results is that certain competencies —particularly soft skills and project management— are simultaneously identified as areas of strength and areas of skill gaps. This duality suggests that expertise in these domains may be unevenly distributed across units or individuals rather than uniformly embedded throughout organizations. While some teams or managers may exhibit advanced proficiency, other units may lack sufficient capacity, leading respondents to identify these skills as both present and insufficient. This finding highlights the importance of examining not only whether skills exist within an organization, but also how broadly they are diffused across roles and departments.

4.1.1. Strategies to Address the Identified Skill Gaps

Following the assessment of existing workforce capabilities and the identification of key skill gaps, the survey explored how organizations respond to these challenges. Organizations appear to favor internal solutions, with many emphasizing training initiatives, tutorials, and other development programs aimed at upskilling existing staff.

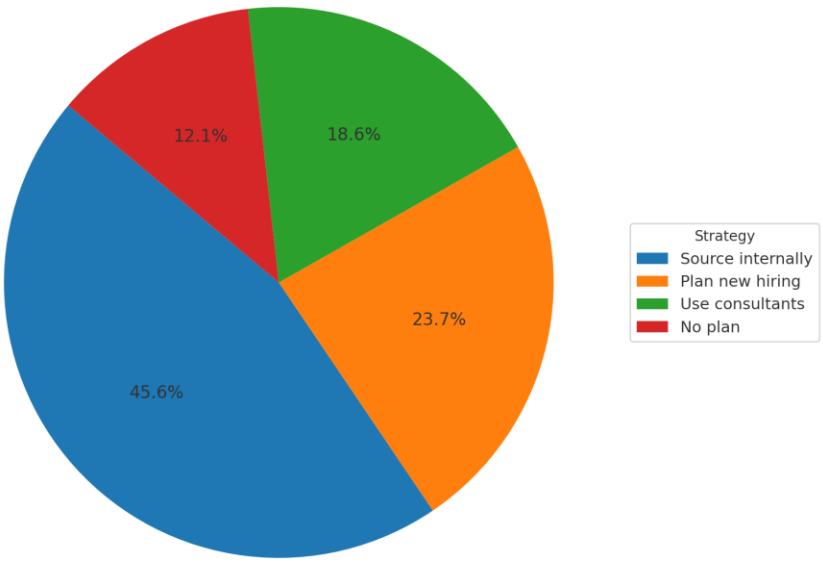

Figure 3- Organizational Strategies for Addressing Skill Gaps

As shown in Figure 3, 46% of organizations reported relying on internal sources (e.g., reskilling or training) as their primary strategy for addressing workforce skill gaps, while 24% planned new hiring, 19% used external consultants, and 12% had no plan in place. This suggests a potential gap between stated strategies and actual practices. The preference for internal solutions is not consistent across all skill gaps. Survey data reveals a dependence on external consultants to address

in digital skill gaps. Specifically, 46% of organizations with gaps in technology and automation skills, 47% with software skill gaps, and 38% with computer programming deficiencies reported using technical consultants. A previous study also notes that approximately half of the state transportation agencies depend heavily on consultants to fill key technical roles [7]. This reliance may reflect the specialized nature of digital competencies, which are often evolving too rapidly for internal teams to keep pace through traditional training. Instead of integrating in-house expertise, many transportation organizations are outsourcing these capabilities, which may limit long-term adaptability and increase dependency on external support.

4.2 Hiring Practices and Institutional Challenges

Besides the key skill gaps, the analysis examines the sought-after qualifications and the recruitment challenges.

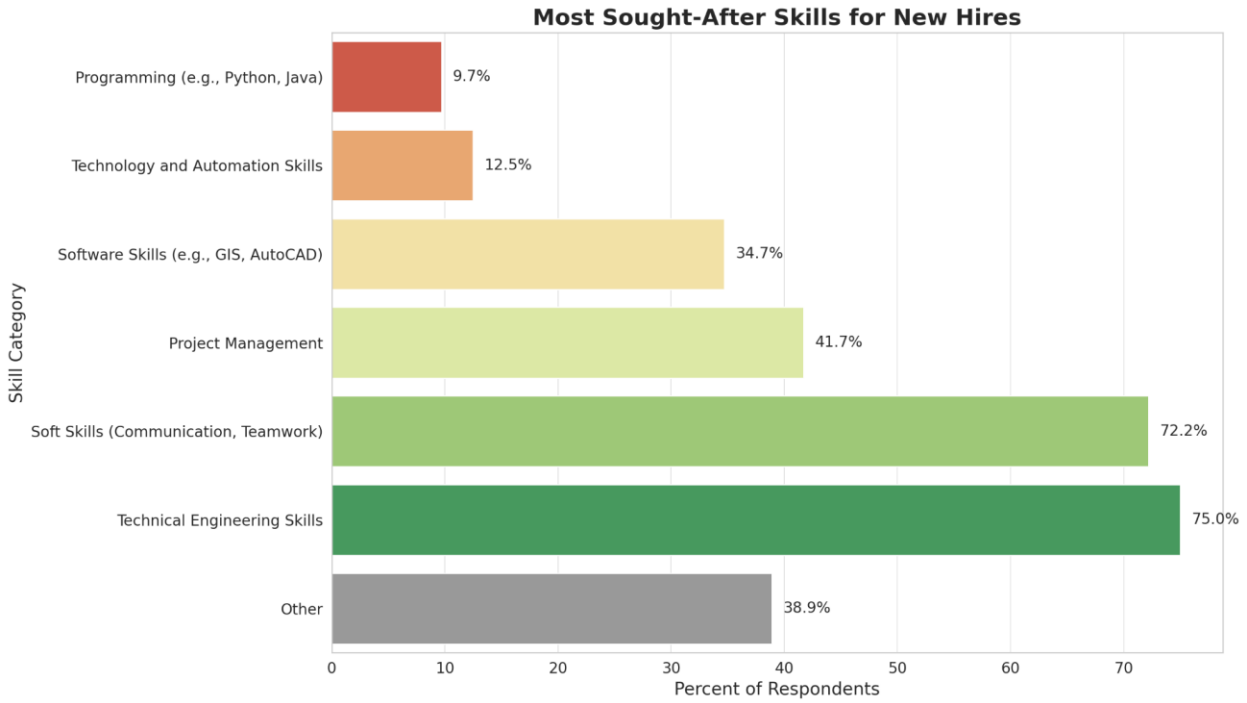

Figure 4- Top Skills Prioritized in New Hire Recruitment

Respondents identified technical engineering skills (75%), soft skills (72%), and project management (42%) as the most sought-after qualifications for new hires (Figure 4). Although digital skills such as software proficiency, programming, and technology and automation were identified as the most significant areas of skill gaps, only 13% of respondents regarded technology and automation skills as a key hiring criterion, and just 10% prioritized programming skills as a top priority. This discrepancy suggests that although digital skills are widely recognized as lacking within the current workforce, they are not yet systematically embedded in recruitment strategies.

To better understand the challenges facing the transportation workforce, the survey included a series of questions targeting known structural issues such as an aging workforce, outreach strategies, and the specificity of job postings. Responses provided insight into how organizations are adapting their recruitment practices considering these concerns.

4.2.1. Aging Workforce

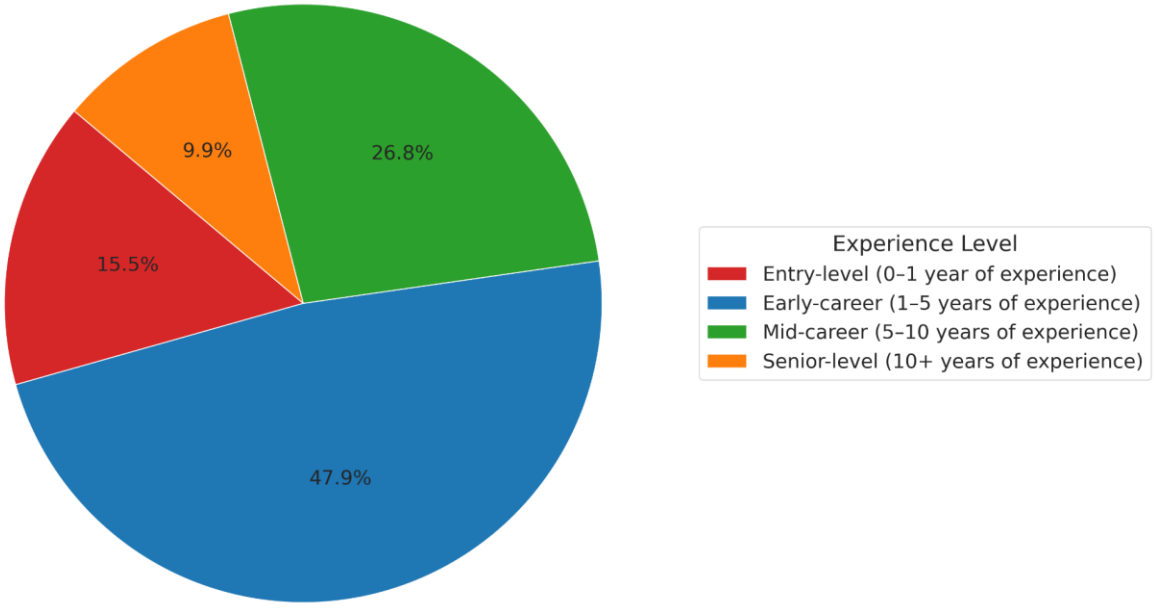

Figure 5- Target Experience Levels in Job Postings across Agencies

First, in recognition of the demographic pressures facing the sector, particularly the high proportion of workers nearing retirement age, the survey asked respondents about the experience levels targeted in their hiring efforts. Figure 5 reveals an emphasis toward a younger workforce profile. Nearly half (47.9%) of respondents indicated that their organizations are primarily seeking candidates with 1–5 years of experience, while an additional 15.5% are targeting entry-level professionals with 0–1 year of experience. This combined focus on less-experienced talent (totaling 63.4%) suggests a strategic shift toward building a younger workforce. Such hiring priorities are especially relevant given the persistent concerns surrounding the aging transportation workforce and the anticipated wave of retirement. By prioritizing younger and less-experienced candidates, agencies may be positioning themselves to address retirement-related labor shortages. In addition, early-career professionals are often more familiar with emerging tools and better equipped to support digital transformation initiatives.

4.2.2. Barriers in Outreach and Job Ad Specificity

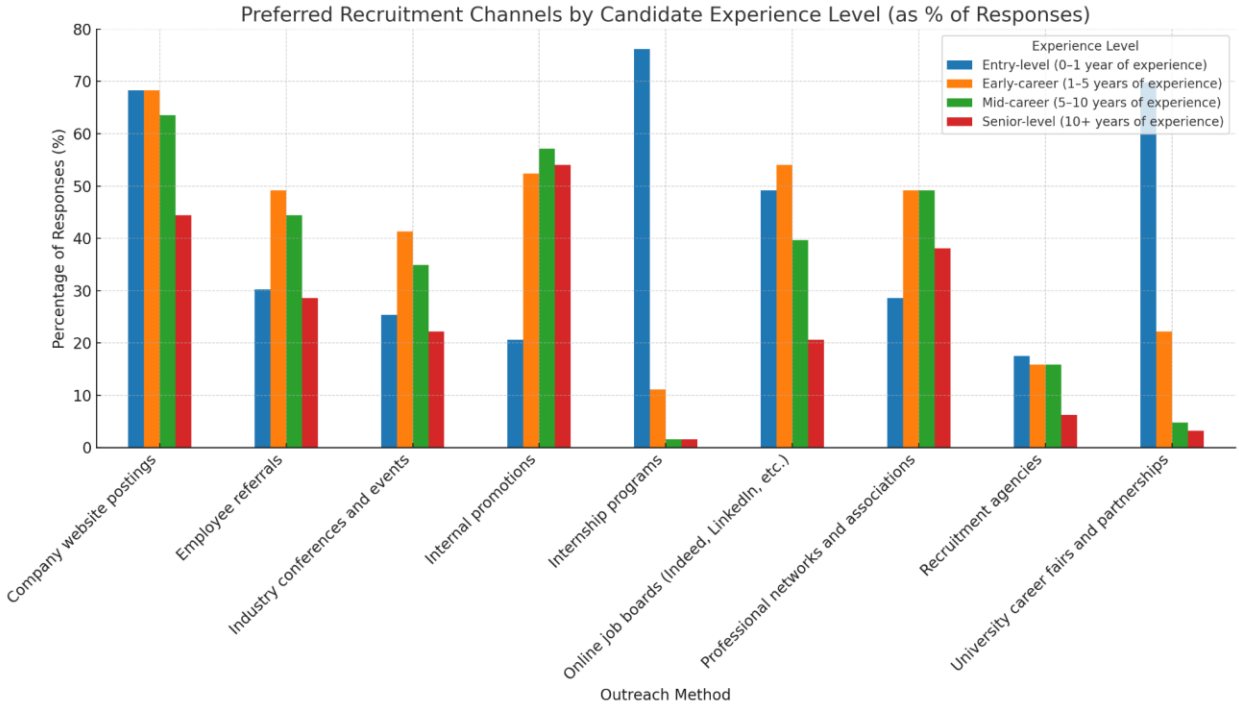

Figure 6- Recruitment Channels by Target Experience Level

Figure 6 shows how organizations recruit candidates at various career stages. For entry-level positions (0–1 year of experience), the most utilized recruitment channels are online job boards (used by approximately 76% of organizations), followed by company website postings (68%) and university career fairs and partnerships (43%). These platforms provide broad access to recent graduates and those entering the workforce for the first time, aligning well with the needs of junior roles. Early-career professionals (1–5 years of experience) are similarly reached through company websites (68%) and online job boards (54%), but there is a noticeable reliance on professional networks and associations (49%). This finding suggests that even a few years of experience begin to shift recruitment into more peer-driven and industry-specific spaces. As candidates move into the mid-career stage (5–10 years of experience), organizations place growing emphasis on internal promotions (57%) and professional networks (49%), while continuing to use company websites (64%) as a baseline channel. This shift implies that for experienced professionals, employers increasingly draw from internal talent pipelines and established reputational networks rather than casting a wide net. The same pattern holds and intensifies for senior-level roles (10+ years of experience), where internal promotions are the most common method (54%), followed by company websites (45%) and professional associations (38%). These trends underscore that advanced hires to fill high-responsibility positions are driven by trust, internal familiarity, and peer endorsements. The finding that recruitment becomes increasingly relationship-based as experience levels rise emphasizes the importance of retention strategies and succession planning within the transportation workforce.

When asked to identify which online recruitment platforms were most effective in attracting qualified candidates, 61% of respondents selected state or government job boards (e.g., USAJobs, DOT websites), followed by LinkedIn (50%) and industry-specific platforms like ITE, ASCE, and TRB job boards (23%). Job search platforms like Indeed were seen as most effective by only 21% of respondents, despite their widespread use. This finding suggests that while general-purpose job boards are popular for outreach, they may not deliver the highest quality applicants for transportation-specific roles.

To investigate the lack of specificity in job ads, survey included questions aimed at uncovering the underlying causes of vague or non-specific job postings [6]. Respondents noted inconsistencies in the types of information included or updated in job advertisements. While 86.4% reported that job responsibilities are regularly refreshed and 74.2% indicated that required qualifications are updated, other key elements are frequently overlooked. Specifically, more than 40% of respondents stated that salary ranges, benefits, and remote work options are not consistently updated in job postings, potentially limiting information accuracy and applicant engagement. Additionally, more than half (53%) of organizations tend to use a single job advertisement to promote multiple openings. Some agencies rely on internal or government-hosted platforms and use generic descriptions, reducing visibility to candidates. This heterogeneity in ad content, whether intentional or resource-driven, can confuse potential candidates regarding skill requirements, role expectations, application requirements, or organizational fit, ultimately undermining recruitment effectiveness.

4.3 Recruitment Challenges

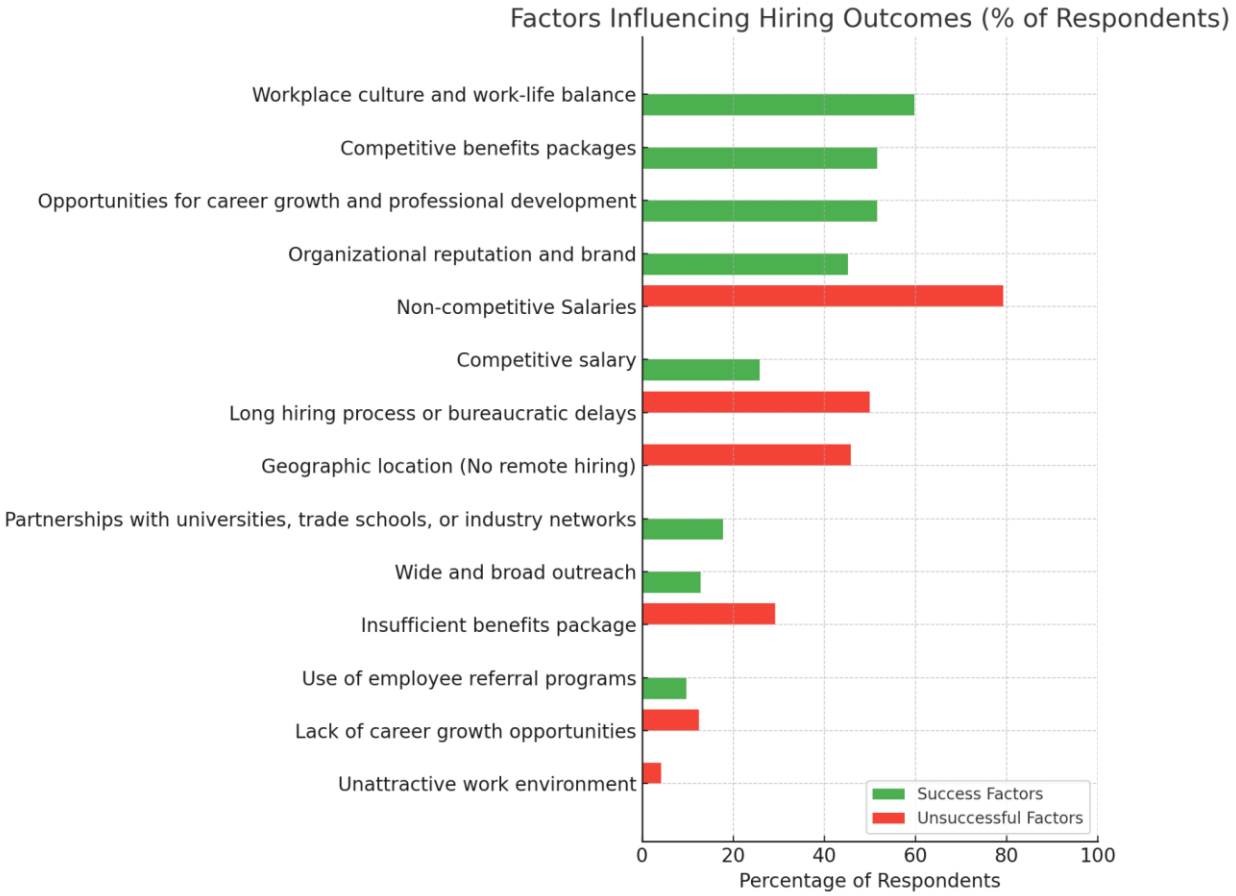

Figure 7- Factors Influencing Hiring Qualified Candidates

Ninety percent of respondents consider their organizations successful in attracting candidates with the required skills, yet only 60% believe they can hire the top candidates, suggesting a distinction between filling roles and competing for the most highly qualified talent. As shown in Figure 7, among respondents who reported challenges in hiring, the most frequently cited barrier was non-competitive salaries, identified by 83.3% of participants significantly outweighing other factors. Additional obstacles included lengthy hiring processes (50%) and geographically restrictive roles that did not allow for remote work (46%). These findings indicate that while multiple factors shape recruitment outcomes, the inability to offer competitive compensation is the main constraint for many transportation agencies, particularly when seeking candidates with in-demand technical skills. Organizations that reported successful recruitment outcomes appear to compensate the salary deficiencies with non-monetary aspects of the employment experience. As shown in Figure 8, 51% of respondents reported using non-monetary benefits like flexible work or additional leave to address salary discrepancies. The most commonly cited drivers of hiring successful hiring were work-life balance (61.3%), supportive leadership (59.7%), flexible work arrangements (51.6%), and clear career advancement opportunities (50%). Most organizations (77%) rely on predefined pay structures, indicating a formalized approach to setting salary ranges. This contrast indicates a

key dynamic in the public-sector transportation labor market: competitive compensation may be out of reach for many agencies, but a well-rounded value proposition focused on organizational culture, flexibility, and professional growth can still attract qualified candidates.

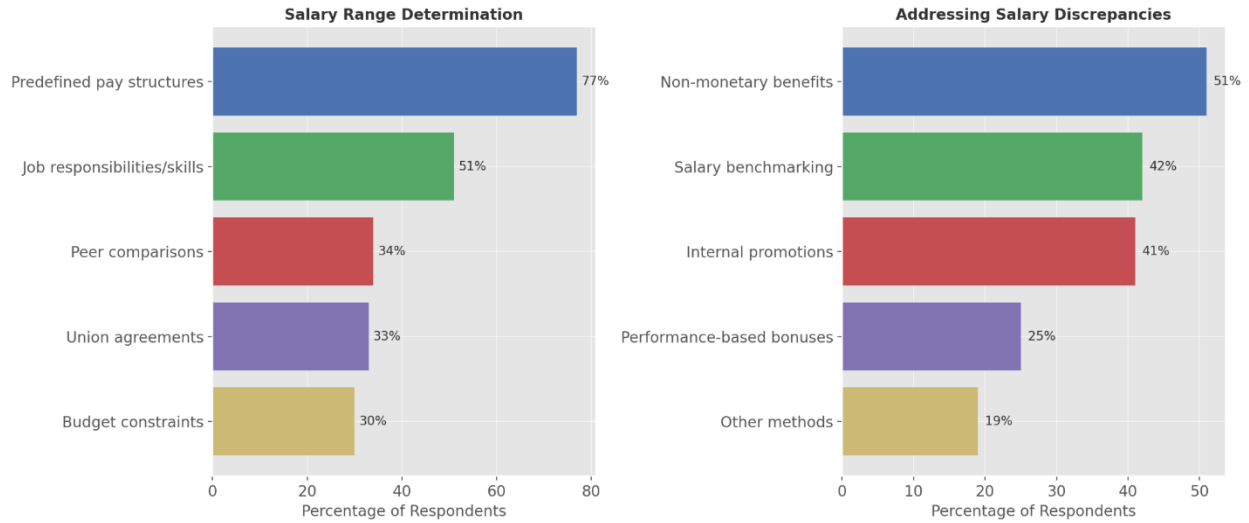

Figure 8- Salary Structures and Discrepancy Resolution in Transportation Organizations

4.4 Emerging Technologies and Future Workforce Needs

Emerging technologies is a widely used term, but its interpretation can vary considerably depending on organizational context and professional background. To clarify how this concept is understood within the transportation sector, the survey asked respondents to identify what they consider to be emerging technologies within the transportation domain.

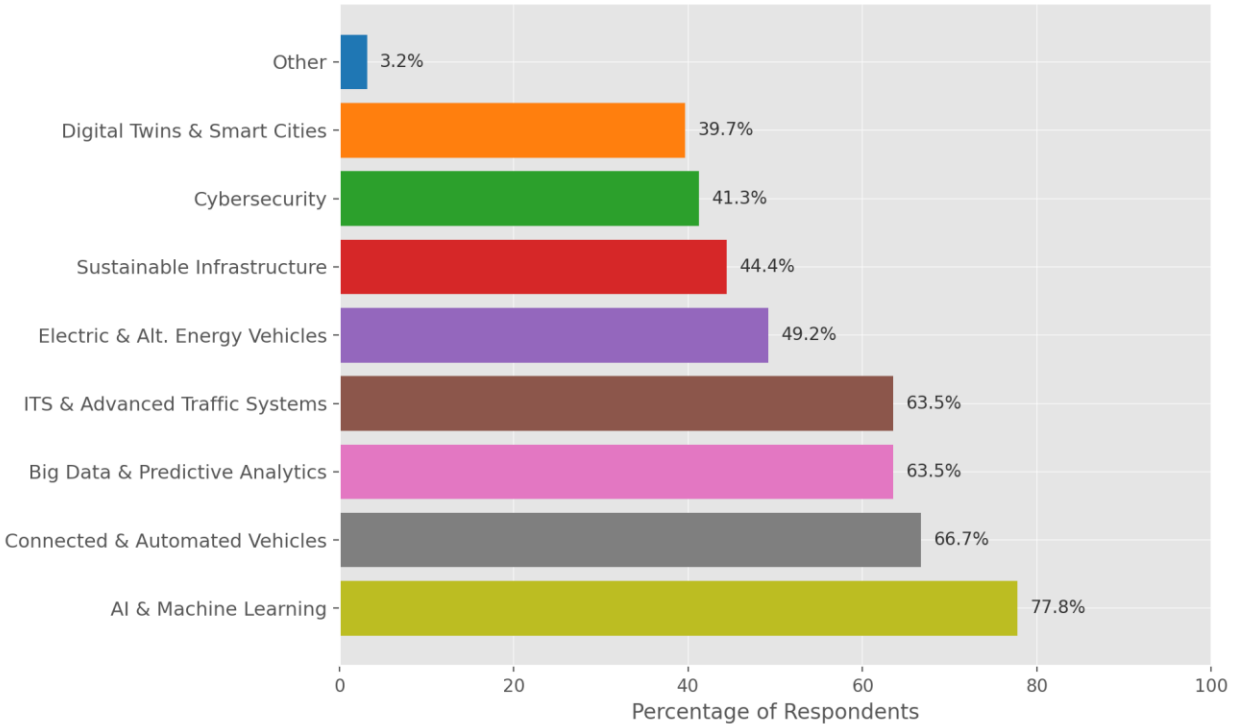

Figure 9- Emerging Technologies Identified by Transportation Professionals

Transportation professionals believe that emerging technologies are centered around automation, data, and sustainability (Figure 9). The most commonly identified area was Artificial Intelligence and machine learning, selected by nearly 78% of respondents. This was followed by connected and automated vehicles (67%) and big data and predictive analytics (63%), suggesting a strong emphasis on technologies that enhance operational efficiency and decision-making. Intelligent transportation systems and electric and alternative energy vehicles were also frequently mentioned, each by over 60% and 49% of participants, reflecting a recognition of infrastructure modernization and the shift toward cleaner energy. The relatively lower selection for sustainable infrastructure technologies suggests that although sustainability is a visible policy priority, it may not yet be perceived as a direct area of technological innovation, or perhaps it is seen as overlapping with other categories like electric vehicles.

4.4.1 Perceived Needs and Internal Capacity

Emerging technologies are frequently positioned as a forward-looking or conceptual topic within industry discourse. While nearly 90% of survey respondents acknowledged a clear and present need for emerging technology expertise within their organizations, the corresponding in-house capacity to support such roles remains limited. Despite widespread recognition of the importance of emerging skills, many agencies remain uncertain about their internal ability to support and sustain such roles. While assessing their unit's expertise in emerging roles, only 23.3% rated their in-house capabilities as “High.” The majority (53.3%) selected “Moderate,” while 23.3% characterized their internal capacity as “Low.” These findings suggest that although agencies recognize the urgency of transformation, many are still in the early stages of developing the

workforce capabilities necessary to support it. The predominance of "moderate" responses may reflect partial familiarity with emerging technologies such as data science, AI, or advanced mobility systems, without the depth required for full-scale integration or innovation. Over half of the respondents (53.1%) indicated that their organizations had engaged technical consultants within the past year. This reliance on external support points a potential shortfall in internal capacity, particularly in areas requiring specialized knowledge or technical depth.

In qualitative open-ended comments, several respondents noted that their organizations currently depend on external consultants or interagency collaborations to implement or manage advanced technologies. While such outsourcing may serve short-term project needs, it does not replace the institutional value of sustained in-house expertise, especially for data governance, cross-system integration, and continuity of operations. In some cases, this outsourcing can be deliberate and strategic; in others, it is a workaround in the face of internal constraints. Moreover, some respondents clarified that even nominally in-house roles often involve subcontracted technical work, blurring the line between in house expertise and external help. These patterns suggest that while interest in developing internal expertise is growing, many agencies remain dependent on external actors to bridge capability gaps in the near term.

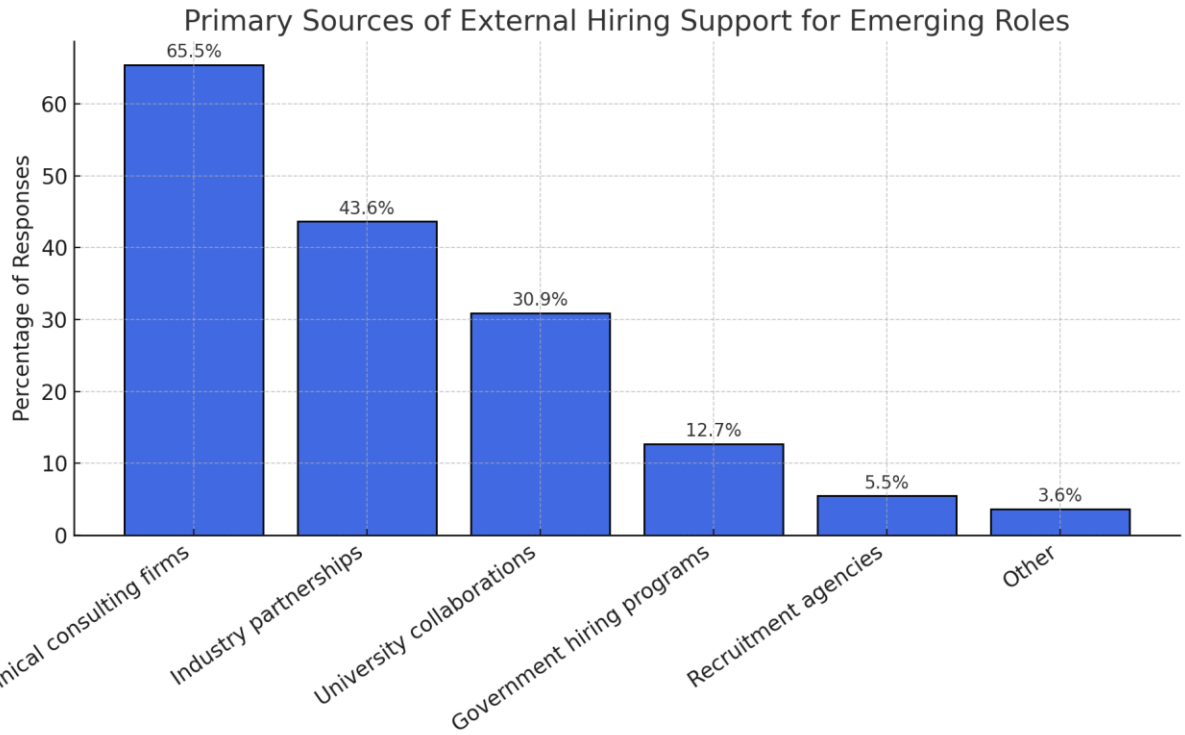

Figure 10- External Support Sources for Emerging Jobs Recruitment

As shown in Figure 10, after the use of external consultants, industry partnerships and university collaborations also emerged as common strategies used by agencies to compensate for limited in-house expertise. This suggests that some agencies are beginning to integrate more strategic, long-term relationships for talent development and access to innovation. Meanwhile, options such as

government hiring programs and recruitment agencies were used less often, an indication that broader institutional channels are either underutilized or misaligned with current workforce needs.

In addition, workforce training plays a pivotal role in translating organizational intent into operational capability. When asked whether their workforce had received training in emerging technologies, 43% reported no training efforts in their organization. This relatively low uptake of training reflects a broader issue. Agencies may acknowledge the importance of emerging technology roles, but many remain reactive rather than proactive in developing internal capacity. The absence of formal training programs may stem from budget constraints, competing priorities, or a lack of clarity about what competencies are most urgent to cultivate. Regardless of the cause, the result is a workforce that is unevenly equipped to support transformation initiatives. For agencies with some training activity, respondents noted that programs are often limited in scope, delivered through external workshops or vendor-led sessions, and not always tailored to the agency's long-term strategic needs. This points to a need for institutionalized, sustained workforce development frameworks, not just ad hoc learning opportunities. Without such investment, the ability to fill emerging roles internally will remain constrained, and agencies may continue to depend on external contractors or risk underutilizing emerging technologies already implemented.

4.4.2 Hiring Efforts, Role Definition, and Demand

Transportation agencies are taking steps to address the growing importance of emerging technologies. Forty percent (40%) of the respondents reported that they are currently looking to hire for emerging technology roles. This indicates an awareness of the need to modernize capabilities and signals a willingness to recruit talent equipped with next-generation skills. Yet this intent to hire exists within an organizational environment that often lacks clarity. When asked whether job responsibilities for these emerging roles are clearly defined, 65% acknowledged that role definitions remain vague or undefined. This ambiguity poses a serious challenge. Agencies may be eager to respond to external pressures such as technological change, policy mandates, or competitive labor markets, but without well-scoped positions, they risk attracting the wrong candidates, creating internal confusion, or setting up new hires for failure. The lack of clarity around role expectations also makes it difficult to communicate job requirements in a way that resonates with potential applicants. This gap between intent and execution becomes more evident when the in-demand skills are analyzed.

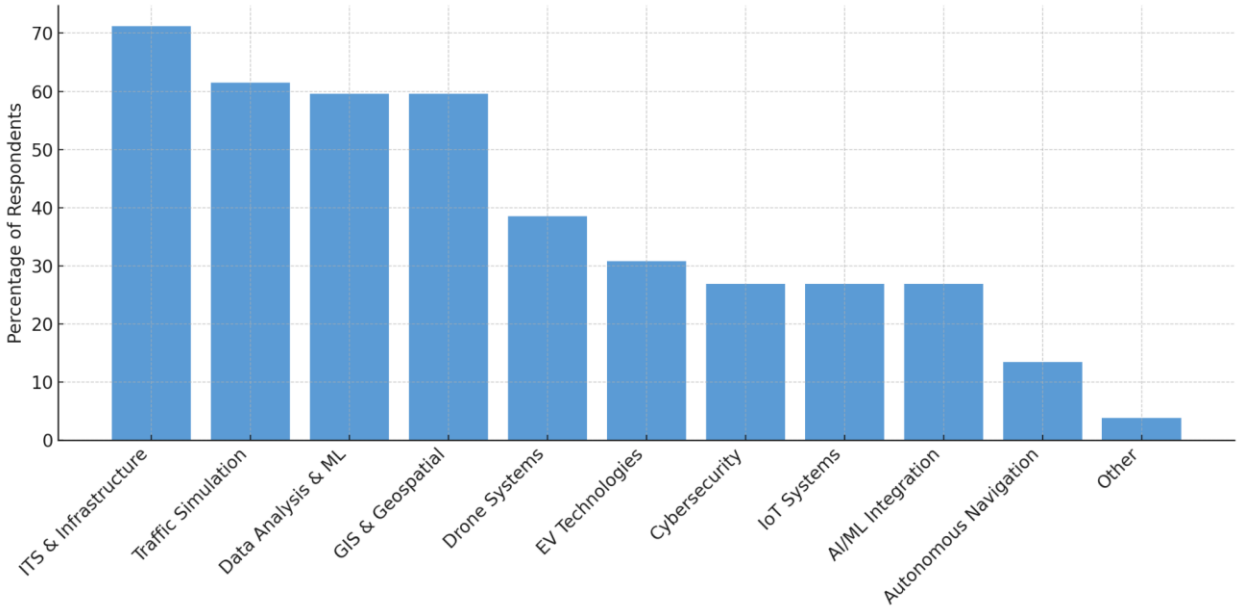

Figure 11- Most In-Demand Skills for Future Workforce

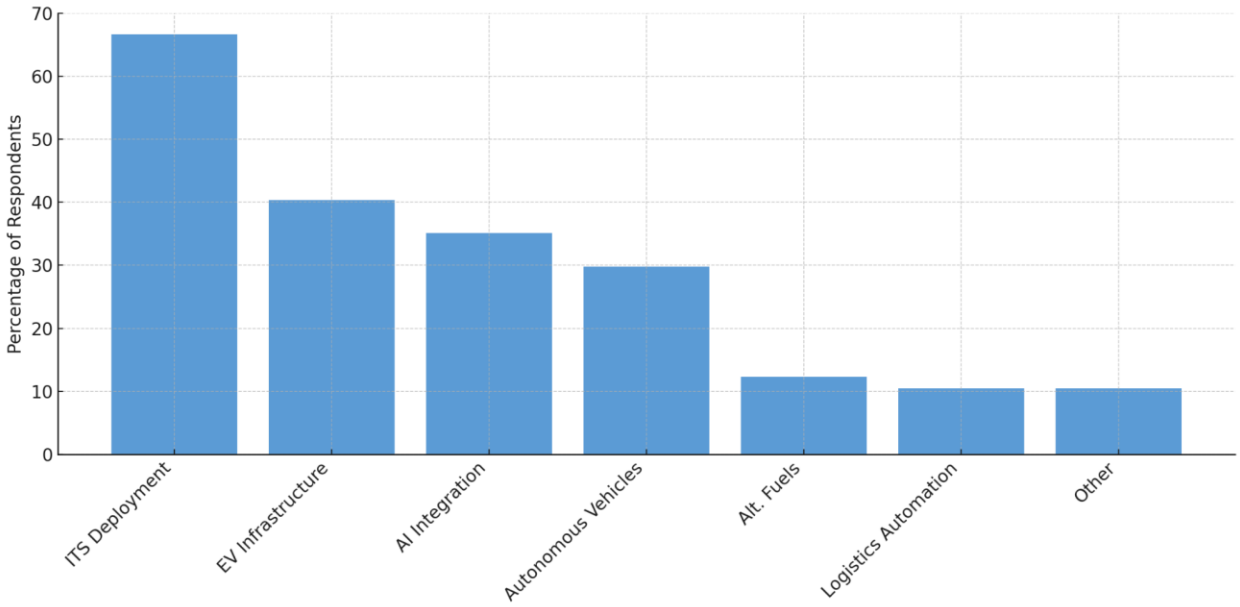

Figure 12- Implemented Technologies Across Transportation Organizations

As shown in Figure 11 and Figure 12, results highlight a strong demand for high-level technical expertise, in areas requiring digital fluency and data-driven decision-making. However, this demand must be contextualized within what has actually been implemented. When respondents were asked about technology-driven changes already adopted by their organizations, only 38.6% reported implementing AI-driven systems, 29.8% reported adopting autonomous or connected vehicle technologies. In contrast, 66.7% had deployed ITS and smart infrastructure, aligning closely with the top-cited skill demand. This problem has implications for both recruitment and retention. If agencies cannot offer an environment where in-demand skills are applied

meaningfully, they risk losing talent to sectors where such expertise is better utilized. To succeed, organizations must align their hiring strategies not only with long-term technological visions but also with realistic assessments of current infrastructure and internal capabilities.

Following the assessment of both current skill needs and implementation efforts, the survey included a question aimed at identifying what job advertisements should emphasize to attract candidates for emerging roles more effectively. The most frequently selected recommendation (68%) was to emphasize opportunities for career growth and innovation, which aligns with the observed preference for internal promotion in high-level roles. This was followed by specifying needed technology-related skills (56%), emphasizing on the value of clarity in conveying technical requirements. Offering higher salaries for tech-skilled roles was also identified as a key strategy by respondents (51%), pointing to potential mismatches between compensation levels and the expertise sought. Additionally, responses indicated the importance of including clearer descriptions of job responsibilities, suggesting that more detailed and accurate postings may enhance candidate alignment. These results suggest that effective talent attraction for emerging roles depends not only on identifying skill gaps but also on improving how opportunities are communicated.

4.4.3 Salary Constraints and Recruitment Barriers for Emerging Roles

One of the most significant challenges transportation agencies face in attracting and retaining technology-savvy talent is the competitiveness of salary compensation. According to survey responses, 60% of transportation professionals believe salaries for emerging technology are not competitive when compared to other sectors. This salary discrepancy places public-sector agencies at a distinct disadvantage in recruiting skilled candidates. The fundamental question emerges: why can't transportation agencies offer competitive salaries? The most critical barrier identified by 78.1% of respondents is the rigid and predefined pay scales, reflecting a broader systemic inflexibility in the public sector that struggles to adapt quickly enough to rapidly evolving salary expectations within the tech industry. Additionally, 43.8% of respondents identified misaligned salary classifications as a barrier to hiring for emerging technology roles, noting that traditional pay structures often fail to reflect the market value of specialized technical skills.

In parallel to salary challenges, structural HR barriers exacerbate the recruitment difficulties. Transportation professionals emphasized traditional job classification systems as a critical obstacle (61.8%) in creating new positions for emerging technology roles. Several respondents emphasized that many emerging positions do not fit neatly within existing job classifications. As a result, these roles are frequently categorized under conventional titles such as “engineer,” which are tied to pay grades that do not align with the salary levels for data science, automation, or cybersecurity roles. This classification mismatch not only limits salary competitiveness but also potentially discourage high-skill candidates from considering opportunities within transportation agencies. Other significant barriers exacerbating this challenge include a lack of internal prioritization for salary adjustments (34.4%), reflecting organizational inertia or conflicting strategic priorities that delay compensation reforms. Similarly, 34.4% acknowledged external competitive pressure, recognizing that private-sector employers

consistently offer higher salaries. Restrictions on performance-based incentives (28.1%) further limit agencies' flexibility in rewarding and retaining high-performing tech talent.

Another concern emphasized by professionals was the perceived lack of qualified candidates (58.2%). However, rather than indicating a true shortage of technology professionals, this may reflect a mismatch between the qualifications of available candidates and the hybrid skill requirements typical of emerging transportation roles. Often, applicants possess strong technical backgrounds but may lack necessary domain-specific knowledge, such as civil engineering fundamentals, further complicating recruitment. Agencies also face challenges in internal technological adaptation (56.4%) and a limited external perception of transportation as an appealing career path (41.8%). Ultimately, addressing these intertwined salary and structural barriers is essential. Transportation agencies should revise pay scales, realign salary classifications, and introduce greater flexibility in compensation structures. Simultaneously, agencies should modernize HR frameworks, streamline hiring processes, and clarify job requirements. Addressing these issues is essential to enable transportation agencies to meet the sector's rapidly changing technological and operational needs.

5. DISCUSSION

The central finding of this research is that transportation agencies do not lack awareness of transformation needs, but that recognition fails to translate into institutional action. The capability-demand framework demonstrates how structural elements function as an interconnected system: rigid classifications constrain salary flexibility, which limits competitive positioning, which drives consultant dependency, which prevents internal learning, which perpetuates capacity gaps. This self-reinforcing cycle distinguishes transformation challenges from conventional recruitment problems addressable through procedural improvements. Transportation industry's unique challenge lies in requiring hybrid competencies bridging traditional civil engineering and emerging digital domains. A private-sector data scientist needs technical skills; a transportation data scientist requires those capabilities plus domain expertise in travel behavior modeling, network optimization, and infrastructure systems. This duality creates classification dilemmas: categorizing such roles as engineering positions undervalues technical expertise, while IT classifications undervalue domain knowledge. Current practice defaults to engineering frameworks with corresponding compensation, systematically disadvantaging agencies in competitive technology labor markets. This explains why digital skills remain under-emphasized in hiring priorities despite being one of the most frequently cited deficiencies. Organizations recognize the needs but lack institutional frameworks to appropriately define, classify, and compensate hybrid roles. The pattern of consultant dependency merits examination beyond simple capacity gaps. While outsourcing provides immediate expertise and budget flexibility, its prevalence suggests organizations may be treating transformation as a series of discrete technical projects rather than permanent operational evolution. This project-oriented approach positions digital capabilities as specialized occasional needs—appropriate for consultant engagement—rather than core competencies requiring permanent internal capacity. The distinction matters because core

competencies demand sustained organizational investment, internal expertise development, and institutional knowledge accumulation.

The misalignment between expressed skill demands and actual technology implementation reveals a coordination challenge. Effective transformation requires alignment between three timelines: technology adoption schedules, workforce development programs, and recruitment cycles. When these operate independently—as survey evidence suggests—organizations face difficult choices: recruit expertise prematurely, risking underutilization and attrition; delay recruitment until deployment, necessitating consultant dependency; or attempt just-in-time hiring in competitive labor markets. This coordination gap indicates absence of integrated transformation planning where workforce strategy derives systematically from technology roadmaps rather than operating as parallel independent activity. Organizations articulating future skill needs without corresponding implementation plans essentially express aspirations rather than requirements, explaining the observed gap between stated demands and hiring priorities.

While the survey documents the prevalence of consultant use (53% engaged technical consultants in the past year, and 46-47% outsource technology/automation needs), it does not directly measure organizational rationale for this approach. The interpretation that this reflects project-oriented rather than operational thinking is inferred from the pattern of high consultant dependency combined with limited internal training (43% provide no emerging technology training) and persistent capability gaps.

The survey findings also reveal a potential generational dimension to workforce planning. Organizations show a strong preference for early-career recruitment (63.4% target candidates with 0-5 years of experience), while the current respondent pool is predominantly senior (46% with 10+ years of experience). This recruitment focus on younger professionals may reflect an expectation that they bring digital fluency to complement the domain expertise of veteran staff. However, substantial digital skill gaps persist across organizations: 65% report deficiencies in at least one digital area, with programming expertise particularly limited (only 7% report advanced proficiency). The survey data does not allow us to determine whether these gaps reflect unsuccessful recruitment of digitally skilled younger professionals, challenges in integrating new hires' capabilities into existing operations, or insufficient mechanisms for knowledge transfer between experienced transportation professionals and digital specialists. Regardless of cause, the gap between recruitment targeting and current capability levels suggests organizational challenges in building hybrid expertise that bridges transportation domain knowledge with digital competencies. The compensation challenge identified in the survey extends beyond simple salary competitiveness. While 83% cite non-competitive salaries as the primary hiring barrier, organizations report utilizing non-monetary benefits as recruitment tools: 61% emphasize work-life balance, 60% cite supportive leadership, 52% offer flexible work arrangements, and 50% highlight career advancement opportunities. Additionally, 51% report using flexible work or additional leave to address salary discrepancies. These strategies suggest agencies are attempting to build competitive value propositions despite salary constraints. However, the effectiveness of this approach remains uncertain given the persistent recruitment difficulties reported. The survey

did not measure whether these benefits successfully attract technology talent or how candidates weigh these factors against salary differences. The continued prevalence of hiring challenges despite emphasis on non-monetary benefits suggests either that salary constraints outweigh these advantages in competitive technology labor markets, or that additional barriers beyond compensation prevent effective recruitment.

The survey data point to institutional structures as critical determinants of transformation capacity. Specific structural barriers identified include: rigid job classification systems (62% cite this as an obstacle to opening new positions), inflexible salary scales (78%), lengthy hiring processes (50%), and unclear role definitions for emerging positions (65% report vague responsibilities). These barriers appear interconnected—outdated classifications constrain appropriate salary positioning, which limits competitiveness, while unclear role definitions complicate both recruitment messaging and candidate evaluation. The survey findings suggest that addressing transformation challenges requires foundational reforms to these institutional structures. However, the survey did not assess organizational characteristics such as HR system flexibility, labor-management relationship quality, or strategic planning maturity; hence the organizational strategies that are better positioned for adaptation cannot be empirically identified. The structural barriers identified suggest that procedural improvements alone may be insufficient; classification frameworks, salary policies, and HR processes may need modernization to accommodate hybrid roles that bridge transportation expertise with digital competencies.

6. CONCLUSION

This study reveals a substantial capability-demand gap in the U.S. transportation workforce undergoing technological transformation. While 90% of respondents recognize the need for emerging technology expertise, only 23% rate their internal capacity as high. Digital skill gaps are widespread (65% report deficiencies in at least one area), training penetration remains limited (43% report no training), and consultant dependency is high (over 40% for key digital competencies). These findings quantify a sector-wide disconnect between transformation aspirations and organizational readiness. The capability-demand framework introduced here extends beyond simple skill shortages and reveals systemic institutional barriers. Three research questions guided this investigation: the gap between recognized needs and internal capacity (RQ1), structural barriers preventing recruitment (RQ2), and misalignment between practices and priorities (RQ3). Findings demonstrate that transformation challenges stem not from lack of awareness but from rigid compensation structures (cited by 83% as the primary recruitment barrier), outdated job classifications (62%), and unclear role definitions (65%). This misalignment manifests in hiring practices that prioritize traditional engineering skills (75%) over digital competencies (10-13%), despite widespread recognition of technology skill deficiencies. Addressing these gaps requires institutional redesign across four dimensions. First, job classifications must be modernized to accommodate hybrid roles combining domain expertise with technical skills, with salary bands reflecting competitive technology labor markets rather than

traditional civil engineering scales. Second, role expectations require clarification through detailed technical competency frameworks that specify required programming languages, analytical tools, and systems knowledge for emerging positions. Third, compensation structures need realignment, either through salary adjustments for technology-intensive roles or enhanced non-monetary value propositions (flexible work arrangements, professional development pathways, mission-driven culture). Fourth, internal capacity-building should replace consultant dependency for core competencies through structured training academies, cross-functional rotations, and partnerships with universities offering transportation-focused data science and systems engineering curricula.

Beyond transportation, these findings illuminate broader public-sector workforce challenges. The identified structural barriers — rigid pay scales, outdated classifications, unclear emerging role definitions — characterize government agencies across domains facing technological disruption. Successfully navigating transformation requires recognizing that workforce readiness depends not merely on recruiting individuals with new skills but on redesigning institutional structures that shape how roles are defined, compensated, and developed. Agencies that modernize classifications, clarify technical requirements, introduce compensation flexibility, and invest in sustained internal capacity-building will capture productivity gains from emerging technologies while building organizational resilience for continued evolution

6.1. Limitations

Several limitations warrant consideration. The sample size (N=105), while sufficient for exploratory analysis, limits generalizability and statistical power for subgroup comparisons. Convenience sampling may introduce self-selection bias toward respondents with greater interest in workforce transformation. The cross-sectional design captures a single time point during rapid technological change. Future research should pursue three directions: longitudinal studies tracking institutional adaptation and workforce strategy implementation outcomes; comparative analyses across agency types (state DOTs, MPOs, transit agencies) to identify sector-specific challenges; and experimental evaluations of specific interventions such as revised classification systems or alternative compensation models to provide causal evidence for policy recommendations.

7. RECOMMENDATIONS

Agencies should move beyond awareness and begin transforming institutional structures to close the widening capability–demand gap. The recommendations below address the major deficiencies identified in workforce composition, hiring practices, compensation and training:

1. Modernize Job Classification Systems for Emerging Technology Roles

Many emerging technology-driven roles in transportation—such as data scientists, automation specialists, AI engineers, and cybersecurity professionals—do not fit within existing public-sector job classification frameworks. As a result, agencies often force these positions into traditional engineering or analyst categories, leading to misaligned responsibilities, constrained salary bands, and reduced competitiveness. Transportation agencies should modernize job classification systems

to explicitly recognize hybrid roles that combine transportation domain knowledge with advanced digital and analytical skills. New classifications should be flexible, technology-oriented, and designed around skill sets rather than legacy titles.

2. Align Compensation with Market-Based Skill Valuation

Compensation structures should be tied to the market value of the required skills, not to outdated job titles. The findings show that rigid pay scales and misclassified roles are major barriers to recruitment and retention of technology talent. Agencies should benchmark salaries for emerging roles against comparable positions in data science, software engineering, and cybersecurity markets rather than traditional civil engineering roles. Where immediate salary adjustments are constrained, agencies should adopt alternative mechanisms such as special pay bands, retention bonuses, performance-based incentives, and flexible work arrangements to remain competitive.

3. Strengthen Role Definition and Transparency in Job Postings

Emerging positions are frequently characterized by vague or overly broad job descriptions, often used to fill multiple roles under a single posting. Agencies should develop clear, role-specific job descriptions that distinguish between traditional engineering responsibilities and emerging digital functions. Job postings should explicitly state required technical competencies (e.g., programming languages, data analytics tools, automation platforms), expected outputs, and career progression pathways. Clear role definition will improve applicant fit, reduce hiring friction, and signal organizational readiness for technological transformation.

4. Embed Technical Competency Frameworks in Hiring and Advancement

Hiring and promotion criteria should formally incorporate technical competency frameworks that reflect emerging workforce needs. These frameworks should specify proficiency levels in programming, data analytics, GIS, automation, and systems integration, alongside traditional engineering and project management skills. Doing so will help shift recruitment priorities away from an overreliance on legacy credentials and toward capabilities that directly support digital transformation.

5. Build Internal Capability to Reduce Reliance on External Consultants

The heavy reliance on external consultants for technology and automation reflects internal structural constraints rather than lack of awareness. Agencies should invest in internal training and reskilling programs that enable staff to fill emerging roles within redesigned job structures. Dedicated training tracks, partnerships with universities and online platforms, and protected time for skill development can help agencies transition from outsourced expertise to sustainable internal capability.

6. Advance Workforce Planning for Long-Term Transformation Readiness

Workforce planning should explicitly account for the mismatch between emerging technology needs and existing organizational structures. Agencies should assess which roles are systematically misclassified, identify future digital skill requirements, and proactively redesign positions and salary structures before recruitment begins. This forward-looking approach will reduce delays, improve retention, and better align workforce composition with long-term transformation goals.

These recommendations point that workforce transformation in the transportation sector is not primarily a recruitment challenge, but an institutional design challenge. While agencies broadly recognize the importance of emerging technologies, persistent gaps in job classification systems, compensation structures, role definition, and internal capacity prevent this awareness from translating into operational capability. Addressing these structural barriers—alongside targeted training, strategic workforce planning, and cultural support for innovation—will enable transportation organizations to build a resilient, future-ready workforce capable of effectively adopting data-driven, automated, and AI-enabled transportation system.

8. APPENDIX

SURVEY QUESTIONS

Start of Block: General Workforce Overview

What is your primary role within your organization?

- ○ Engineer
- ○ Planner
- ○ Technician
- ○ Manager/Supervisor
- ○ Administrator
- ○ Analyst
- ○ Other (Please specify) _____

What is the highest level of education you have completed?

- ○ High school diploma
- ○ Associate degree
- ○ Bachelor’s degree
- ○ Master’s degree
- ○ Doctoral degree
- ○ Other (Please specify) _____

What type of organization do you represent?

○ Public

○ Private

Which industry does your unit operate in? (Select all that apply)

☐ Freight Transportation

☐ Passenger Transportation

☐ Logistics & Supply Chain Management

☐ Transportation Infrastructure & Planning

☐ Automotive & Vehicle Manufacturing

☐ Maritime & Port Operations

☐ Aerospace & Aviation

☐ Intelligent Transportation Systems (ITS) & Technology

☐ Government & Regulatory Agencies

☐ Other (Please specify): _____

What describes your unit the best?

- ○ Administrative Services
- ○ Government and Community Relations
- ○ Communications
- ○ Division of Legal Affairs
- ○ Engineering Division
- ○ Operations Division
- ○ Policy & Planning Division
- ○ Other (Please specify): _____

How many years of experience do you have in the transportation industry?

- ○ 0–1 year (Entry-Level)
- ○ 1–5 years (Early-Career)
- ○ 5–10 years (Mid-Career)
- ○ 10+ years (Senior-Level)

End of Block: General Workforce Overview

Start of Block: Existing Expertise and Skill Levels

What is the current expertise level of employees in your unit for the following skills? (Examples are provided in parentheses for reference.)

	Advanced	Intermediate	Basic	Don't have the expertise	Not applicable
Environmental Regulations and Compliance	○	○	○	○	○
Programming (Python, C, Java)	○	○	○	○	○
Technical engineering skills (Roadway Design, Traffic engineering)	○	○	○	○	○
Project management	○	○	○	○	○
Technology and Automation Skills (ITS, Automated vehicles)	○	○	○	○	○
Soft skills (Communication, Teamwork)	○	○	○	○	○
Safety Regulations and Compliance	○	○	○	○	○
Software skills (GIS, Autocad)	○	○	○	○	○
Mechanical skills (Equipment maintenance, Vehicle and bridge inspection)	○	○	○	○	○
Other	○	○	○	○	○

What types of certifications or licenses are most common among your current workforce? (Select all that apply)

- [ ] Fundamentals of Engineering (FE)
- [ ] Professional Engineer (PE)
- [ ] Project Management Professional (PMP)
- [ ] Commercial Driver's License (CDL)
- [ ] IT certifications (e.g., Cisco, CompTIA)
- [ ] Professional transportation planner (PTP)
- [ ] Certified Transportation Planner (CTP)
- [ ] GIS Professional Certification (GISP)
- [ ] Other _____

Which of the following skills have been identified as gaps in your unit/organization over the past year? (Select all that apply.)

- [ ] Technical engineering skills
- [ ] Mechanical skills
- [ ] Project management
- [ ] Technology and Automation Skills
- [ ] Software skills
- [ ] Computer programming
- [ ] Safety Regulations and Compliance
- [ ] Soft skills
- [ ] Environmental Regulations and Compliance
- [ ] No skill gaps were identified
- [ ] Other _____

How do you address the skill gaps?

	Source internally (Training, tutorials etc.)	Use technical consultants	Plan new hiring	No plan
Technical engineering skills	☐	☐	☐	☐
Mechanical skills	☐	☐	☐	☐
Project management	☐	☐	☐	☐
Technology and Automation Skills	☐	☐	☐	☐
Software skills	☐	☐	☐	☐
Computer programming	☐	☐	☐	☐
Safety Regulations and Compliance	☐	☐	☐	☐
Soft skills	☐	☐	☐	☐
Environmental Regulations and Compliance	☐	☐	☐	☐
No skill gaps were identified	☐	☐	☐	☐
Other	☐	☐	☐	☐

End of Block: Existing Expertise and Skill Levels

Start of Block: Hiring Practices and Recruitment Challenges

Which venues does your unit/organization use to advertise job openings? (Select all that apply)

- [ ] Professional networks and associations
- [ ] Industry conferences and events
- [ ] Recruitment agencies
- [ ] Employee referrals
- [ ] Online job boards (Indeed, LinkedIn, etc.)
- [ ] Company/Institutional website postings
- [ ] University career fairs and partnerships
- [ ] Internship programs
- [ ] Other _____

Are you involved in the hiring process within your organization?

- ○ Yes, I actively participate in hiring decisions.
- ○ Yes, I provide input or support during the hiring process.
- ○ No, but I am aware of the hiring process.
- ○ No, I am not involved in hiring activities.
- ○ Other _____

What are the top 3 most sought-after qualifications and skills for new hires in your organization?

- [ ] Technical engineering skills (Roadway Design, Traffic engineering)
- [ ] Mechanical skills (Equipment maintenance, Vehicle and bridge inspection)
- [ ] Project management
- [ ] Technology and Automation Skills (ITS, Automated vehicles)
- [ ] Software skills (GIS, Autocad,)
- [ ] Programming (Python, C, Java)
- [ ] Safety Regulations and Compliance
- [ ] Soft skills (Communication, Teamwork)
- [ ] Environmental Regulations and Compliance
- [ ] Other _____

What is the most common level of experience in your organization's job postings?

- ○ Entry-level (0–1 year of experience)
- ○ Early-career (1–5 years of experience)
- ○ Mid-career (5–10 years of experience)
- ○ Senior-level (10+ years of experience)

Where does your organization primarily seek candidates for different experience levels?

	Entry-level (0–1 year of experience)	Early-career (1–5 years of experience)	Mid-career (5–10 years of experience)	Senior-level (10+ years of experience)
Professional networks and associations	☐	☐	☐	☐
Industry conferences and events	☐	☐	☐	☐
Recruitment agencies	☐	☐	☐	☐
Employee referrals	☐	☐	☐	☐
Online job boards (Indeed, LinkedIn, etc.)	☐	☐	☐	☐
Company website postings	☐	☐	☐	☐
Internal promotions	☐	☐	☐	☐
University career fairs and partnerships	☐	☐	☐	☐
Internship programs	☐	☐	☐	☐
Other (Please specify):	☐	☐	☐	☐

Which parts of a job advertisement does your organization typically update when a new position becomes available?

- [ ] Job responsibilities
- [ ] Required skills and qualifications
- [ ] Salary range and benefits
- [ ] Job location or remote work options
- [ ] Application deadlines and process
- [ ] Company or department overview
- [ ] Other _____

Does your organization post a single job advertisement for multiple positions?

- ○ Yes
- ○ No

How effective are your unit/department's job ads in attracting candidates who meet the required skills?

- ○ Ineffective
- ○ Somewhat effective
- ○ Highly Effective

Is your unit/department able to successfully hire the top candidates from the available candidate pool?

- ○ Yes
- ○ No

What factors make your organization successful in hiring qualified candidates?

- ☐ Competitive salary
- ☐ Competitive benefits packages
- ☐ Organizational reputation and brand
- ☐ Opportunities for career growth and professional development
- ☐ Workplace culture and work-life balance
- ☐ Wide and broad outreach
- ☐ Use of employee referral programs
- ☐ Partnerships with universities, trade schools, or industry networks
- ☐ Other (Please specify): _____

What factors make your organization unsuccessful in hiring qualified candidates?

- ☐ Non-competitive Salaries
- ☐ Unattractive work environment

- [ ] Competition with other employers
- [ ] Insufficient benefits package
- [ ] Lack of career growth opportunities
- [ ] Long hiring process or bureaucratic delays
- [ ] Geographic location (No remote hiring)
- [ ] Other _____

Which online recruitment platform has been most effective in attracting qualified candidates in your organization? (Skip this question if you do not have direct knowledge or experience with it.)

- [ ] LinkedIn
- [ ] Indeed
- [ ] Glassdoor
- [ ] Monster
- [ ] ZipRecruiter
- [ ] Industry-specific platforms (ITE, ASCE, TRB job boards)
- [ ] State or government job boards (USAJobs, DOT websites)
- [ ] Other _____

In your opinion, which positions are the most difficult to fill in your organization?

- [ ] Technical Engineering Roles (e.g., Roadway Design, Traffic Engineering, Structural Engineering, Geotechnical Engineering)
- [ ] Mechanical Roles (e.g., Equipment Maintenance, Vehicle and Bridge Inspection, Traffic Signal Technicians)
- [ ] Project Management Roles (e.g., Construction Managers, Transportation Project Coordinators, Program Managers)
- [ ] Technology and Automation Roles (e.g., Intelligent Transportation Systems (ITS), Automated Vehicles, Smart Infrastructure Specialists)
- [ ] Software and Data Roles (e.g., GIS Analysts, AutoCAD Technicians, Transportation Modelers)
- [ ] Programming and IT Roles (e.g., Python, C, Java Developers, Machine Learning in Transportation)
- [ ] Safety and Compliance Roles (e.g., Traffic Safety Analysts, Environmental Compliance Officers, Risk Managers)
- [ ] Soft Skill-Based Roles (e.g., Leadership, Communication, Teamwork, Public Engagement, Negotiation)
- [ ] Environmental and Sustainability Roles (e.g., NEPA Compliance, Air Quality Specialists, Climate Adaptation Experts)
- [ ] Other (Please specify):

_____

Has your organization worked with any technical consultants in the past year?

- ○ Yes
- ○ No

Does your organization seek assistance from outside recruitment agencies (e.g., head hunters) to identify candidates for open positions?

- ○ Yes
- ○ No

What information does your organization typically provide to outside hiring companies?

- ☐ Job title
- ☐ Job description
- ☐ Preferred skills
- ☐ Key responsibilities
- ☐ Required education level
- ☐ Salary range
- ☐ Employment type (full-time, contract)
- ☐ Work location or remote eligibility
- ☐ Expected start date or project duration
- ☐ Other (Please specify): _____

What information does your organization typically provide to technical consultants to identify candidates for open positions?

- [ ] Job title
- [ ] Job description
- [ ] Preferred skills
- [ ] Key responsibilities
- [ ] Required education level
- [ ] Salary range
- [ ] Employment type (full-time, contract)
- [ ] Work location or remote eligibility
- [ ] Expected start date or project duration
- [ ] Other (Please specify): _____

Does your organization seek assistance from technical consultants you work with to help identify or supply candidate pools for opened positions?

- ○ Yes
- ○ No

Does your organization seek assistance from technical consultants you work with to help assess candidate expertise?

- ○ Yes
- ○ No

How does your unit/organization determine salary ranges for different jobs? (Select all that apply.)

- ☐ Predefined pay scales and compensation structures
- ☐ Job responsibilities and required skill levels
- ☐ Budget constraints and funding availability
- ☐ Comparison with peer organizations or competitors
- ☐ Union agreements
- ☐ Other (Please specify): _____

How does the organization address salary discrepancies in the industry?

- ☐ Regular salary benchmarking
- ☐ Performance-based bonuses
- ☐ Non-monetary benefits (e.g., flexible work arrangements, remote work)
- ☐ Encouraging internal promotions
- ☐ Other _____

End of Block: Hiring Practices and Recruitment Challenges

Start of Block: Emerging Technologies and Future Workforce Needs

What do you consider to be an emerging job area in transportation industry?

- [ ] Artificial Intelligence & Machine Learning (e.g., AI-driven traffic management, predictive analytics, autonomous decision-making systems)
- [ ] Connected & Automated Vehicles (CAVs) (e.g., Level 4 & 5 automation, vehicle-to-everything (V2X) communication, Automated vehicle traffic planning)
- [ ] Cybersecurity & Data Protection (e.g., secure data transmission, encryption for connected infrastructure, transportation network resilience)
- [ ] Digital Twins & Smart Cities (e.g., real-time city modeling, infrastructure simulations, integrated digital mobility planning)
- [ ] Intelligent Transportation Systems (ITS) & IoT (e.g., smart traffic signals, real-time transit tracking, connected infrastructure)
- [ ] Electric & Alternative Energy Vehicles (e.g., battery advancements, hydrogen fuel cells, wireless EV charging stations)
- [ ] Big Data & Predictive Analytics in Transportation (e.g., AI-driven demand forecasting, congestion prediction, real-time routing)
- [ ] Sustainable & Resilient Infrastructure Technologies (e.g., self-healing roads, climate-adaptive transportation systems, carbon-neutral construction)
- [ ] Other (Please specify): _____

Does your unit/organization recognize a need for expertise in emerging technologies in transportation?

- ○ Yes
- ○ No

How would you assess the in-house expertise in emerging roles within your unit/organization?

- ○ High
- ○ Moderate
- ○ Low

Is your unit/organization currently looking to hire for any emerging technology roles in transportation?

- ○ Yes
- ○ No

Are job responsibilities for emerging technology roles in your organization clearly defined?

- ○ Yes
- ○ No

Which of the following technology-driven changes have been implemented in your organization? (Select all that apply)

- [ ] Adoption of autonomous or connected vehicle technologies
- [ ] Integration of artificial intelligence (AI) in operations
- [ ] Implementation of electric mobility (EV infrastructure, battery tech)
- [ ] Use of automation in logistics and supply chains
- [ ] Deployment of intelligent transportation systems (ITS)
- [ ] Transition to alternative fuels (hydrogen, biofuels)
- [ ] Other (please specify) _____

Have your workforce has received training in emerging technologies?

- ○ Yes
- ○ No

What are the biggest challenges in hiring professionals with technology-related expertise?

- ☐ Unsatisfatory Benefits packages
- ☐ Unsatisfactory Salary packages
- ☐ Lack of qualified candidates in the applicant pool
- ☐ Unattractive work environment
- ☐ Rigid job requirements in hiring forms
- ☐ Limited awareness of transportation as a career path for tech professionals
- ☐ Slow adaptation of new technologies in transportation agencies
- ☐ Not searching for these roles
- ☐ Other _____

How does your unit/organization determine salary ranges for emerging technology jobs in transportation?

- [ ] Comparison with traditional transportation roles
- [ ] Predefined pay scales and salary bands
- [ ] Funding availability and budget constraints
- [ ] Peer organization comparisons
- [ ] Challenges in attracting and keeping qualified candidates
- [ ] Other (Please specify): _____

Are salaries for emerging roles in transportation industry competitive with other industries in your organization?

- ○ Yes
- ○ No

What factors limit competitive salaries for emerging technology roles in transportation? (Select all that apply.)

- [ ] Rigid and predefined pay scales
- [ ] Budget constraints
- [ ] Misaligned salary classifications for emerging jobs
- [ ] Lack of prioritization for salary adjustments
- [ ] Other companies offer significantly higher salaries
- [ ] Hiring priorities favor traditional roles
- [ ] Restrictions on performance-based incentives
- [ ] Other (Please specify): _____

How would you assess your unit/organization's ability to hire top candidates for emerging roles?

- ○ Ineffective
- ○ Somewhat effective
- ○ Highly Effective

What are the main barriers your organization faces in opening new positions for emerging jobs in transportation?

- [ ] Lack of awareness of these roles
- [ ] Traditional job classification systems
- [ ] Budget constraints
- [ ] Unclear responsibilities and skill requirements
- [ ] Established reliance on technical consultants
- [ ] Slow adaptation to technological change
- [ ] Hiring priorities favor traditional roles
- [ ] Low demand for these roles in current projects
- [ ] Other (Please specify): _____

In your opinion, what should the job ads emphasize to attract candidates with the required skills for the emerging roles?

- [ ] Specify needed technology-related skills
- [ ] Offer higher salaries for tech-skilled roles
- [ ] Include clearer descriptions of job responsibilities
- [ ] Emphasize opportunities for career growth and training
- [ ] Other (Please specify) _____

Which of these skills are most in demand for transportation tech jobs?

- [ ] Data Analysis & Machine Learning (Python, R, SQL, Big Data, AI/ML applications)
- [ ] Autonomous Navigation & Path Planning (SLAM, GPS-based localization, Motion Planning Algorithms, Route Optimization)
- [ ] Geospatial Analysis & GIS (ESRI ArcGIS, QGIS, spatial data visualization)
- [ ] Traffic Simulation & Modeling (VISSIM, CORSIM, SUMO, TransCAD, Aimsun)
- [ ] Intelligent Transportation Systems (ITS) & IoT (Connected and Automated Vehicles, Smart Infrastructure, Edge Computing, Sensor Networks)
- [ ] Cybersecurity & Risk Management (Network security, Encryption, Incident Response, Risk Mitigation for transportation systems)
- [ ] Software Development & Programming (C++, Java, JavaScript, Python, SQL, Web and Mobile Applications for Transportation)
- [ ] Control Systems & Automation SCADA, PLCs, Automated Traffic Signals, Industrial Automation in Transportation)
- [ ] Telecommunications & Networking(5G, Fiber Optics, V2X Communication, Wireless Network Management)
- [ ] Project Management & System Integration PMP Certification, Agile, DevOps, Transportation Systems Performance Management)

Other (Please specify): _____

- [ ]

Are emerging technology roles in transportation primarily outsourced to technical consultants or managed by in-house expertise in your unit/organization?

- ○ Primarily in-house
- ○ Mostly outsourced

If your organization lacks in-house expertise for emerging roles, where do you primarily seek external hiring support?

- ☐ Technical consulting firms
- ☐ Recruitment agencies
- ☐ Industry partnerships
- ☐ University collaborations
- ☐ Government hiring programs
- ☐ Other (please specify): _____

What approach in your opinion will be most effective in filling the emerging jobs in transportation?

- ○ Building strong in-house expertise
- ○ Relying on private tech partnerships
- ○ Expanding collaborations with universities and research institutions
- ○ Defining exact skills and responsibilities needed
- ○ Expanding funding and policy initiatives to support emerging roles
- ○ Other _____

9. AUTHOR CONTRIBUTIONS

Study conception and design: AE, AY; Data collection: AE, AY; Analysis and interpretation of results: AE, AY; Draft manuscript preparation: AE; All authors reviewed the results and approved the final version of the manuscript.

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