A Vision for Multidisciplinary Transportation Engineering

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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METRIC CONVERSION CHART

When You Know	Multiply by	To Find
Length		
inches (in)	25.4	millimeters (mm)
feet (ft)	0.305	meters (m)
yards (yd)	0.914	meters (m)
miles (mi)	1.61	kilometers (km)
Volume		
fluid ounces (fl oz)	29.57	milliliters (mL)
gallons (gal)	3.785	liters (L)
cubic feet (ft^3)	0.028	meters cubed (m^3)
cubic yards (yd^3)	0.765	meters cubed (m^3)
Area		
square inches (in^2)	645.1	millimeters squared (mm^2)
square feet (ft^2)	0.093	meters squared (m^2)
square yards (yd^2)	0.836	meters squared (m^2)
acres	0.405	hectares (ha)
square miles (mi^2)	2.59	kilometers squared (km^2)

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16. Abstract

The transportation sector is undergoing rapid transformation, requiring a workforce equipped with interdisciplinary skills to address evolving challenges. This research project explores disciplinary synergies, skill gaps, and professional development needs within the industry, emphasizing the importance of multidisciplinary approaches. By analyzing survey data from transportation professionals across the U.S., the study identifies critical competencies, areas of integration, and disciplinary silos that hinder progress. Findings suggest that bridging gaps in social sciences, economics, and advanced computing will enhance transportation education and workforce preparedness. The results provide guidance for curriculum development, industry collaboration, and workforce training, contributing to a more resilient and adaptable transportation sector.

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EXECUTIVE SUMMARY

This research project provides valuable insights into the evolving transportation workforce by identifying critical skill sets, disciplinary synergies, and areas requiring greater collaboration that transcend both engineering and non-engineering disciplines. The findings emphasize the necessity of equipping transportation professionals with both technical expertise and multidisciplinary competencies to address complex industry challenges. By leveraging survey data from transportation professionals across the U.S., this research highlights the importance of bridging disciplinary silos in areas such as social sciences, economics, and advanced computing. The project, supported by broader workforce development initiatives, contributes to the advancement of transportation education and professional training. The insights gained from this research are essential for guiding curriculum development, industry collaboration, and policy decisions that will shape a more adaptive, innovative, and future-ready transportation workforce.

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1. INTRODUCTION

This chapter provides essential background information and context for the present research project on the evolving landscape of transportation engineering and the need for multidisciplinary approaches. The section is organized as follows: (1) an overview of the transformation of transportation engineering from a traditional focus on infrastructure design, safety, and traffic operations to a more comprehensive, integrated approach; (2) the necessity of a multidisciplinary perspective in addressing modern transportation challenges; (3) challenges in transportation engineering education, including the integration of interdisciplinary knowledge and evolving instructional practices; (4) the identification of key competencies and disciplinary synergies required for future transportation engineers; (5) primary and secondary objectives of this research project; (6) relevance of this work to workforce development, interdisciplinary collaboration, and transportation industry evolution; and (7) structure of this technical report.

1.1. Evolving Landscape of Transportation Engineering

Transportation engineering (TE) is evolving from its traditional focus on technical aspects of infrastructure design, safety, traffic operation, and construction to a more comprehensive approach. This shift recognizes the increasing complexity of transportation systems and their interconnections with other domains (Hansman et al., 2006). A multidisciplinary perspective is emerging, emphasizing the integration of technical, social, and human factors in system design and management (Peruzzini et al., 2020). This holistic view considers transportation as part of a larger system, requiring multi-domain, multidisciplinary efforts to address challenges effectively (De Weck et al., 2011; Hansman et al., 2006). The field of transportation now expanded to a broader range of topics, including intelligent transportation systems (ITS), connected and automated vehicles (CAVs), and the environmental and economic impacts of transportation. This evolution reflects the need for flexible, adaptable systems that can meet changing human needs in an increasingly complex technological world (De Weck et al., 2011).

1.2. The Need for a Multidisciplinary Approach

The call for multidisciplinary approaches to address complex transportation challenges is echoed across multiple studies. Giannakodakis (1994) advocates for a holistic systems approach that integrates societal, environmental, and economic aspects with traditional engineering considerations. Stock and Burton (2011) emphasize the necessity of multi-, inter-, and multidisciplinary research to tackle contemporary social and ecological problems. Grabowski et al. (2017) highlight the importance of interdisciplinary dialogue in addressing infrastructure challenges, considering socio-technical dimensions. They stress the need for a 21st-century vision that encompasses technological, social, and environmental aspects of infrastructure systems. Saviano et al. (2017) propose the “T-Shaped” professional model for educating future managers, emphasizing the importance of interdisciplinary thinking and a systems approach. These studies emphasize the need for integrated, cross-disciplinary solutions to address complex transportation and infrastructure challenges in a sustainable manner. Recognizing that contemporary transportation challenges extend beyond the boundaries of conventional engineering considerations, a holistic approach is required. This approach needs to include social, economic, environmental, and policy dimensions beyond transportation engineering expertise. The interplay of these diverse disciplinary facets is essential for fostering sustainable community growth and prosperity in an era where transportation systems are integral to the framework of interconnected infrastructure service networks.

Despite the recognized need for a multidisciplinary approach in TE, there remains a significant opacity within the sector regarding how to bridge engineering and non-engineering disciplines. This lack of clarity on operationalizing synergies between these disciplines leads to inefficiencies and misalignments between engineering solutions and societal needs. The growing complexity of transportation challenges, driven by technological advancements and evolving societal demands, necessitates a more integrated perspective. Chang et al. (2019) emphasize that today's transportation engineers must continuously seek workforce development opportunities to expand their skill set and knowledge across various subject areas. Hurwitz et al. (2016) highlight the critical role of evolving transportation engineering curricula at both undergraduate and graduate levels in developing the necessary technical competencies, suggesting that curricula must adapt to include interdisciplinary topics to meet future challenges. Similarly, West et al. (2021) point out that technological transformations and shifts in employment opportunities highlight the need for curricula to prepare students for future careers effectively. Thus, identifying existing synergies and gaps between engineering and non-engineering disciplines is crucial for informing the development of a multidisciplinary transportation workforce. As a first step towards this end goal, our study sought to elucidate and characterize the disciplinary synergies and disciplinary silos that exist in the transportation sector.

1.3. Challenges in Transportation Engineering Education

The transportation industry is at a pivotal point in its development, facing a host of complex and evolving challenges. These challenges range from rapid technological advancements, such as the integration of autonomous vehicles and smart infrastructure, to pressing environmental concerns, including the need for sustainable and resilient transportation systems. On the other hand, transportation engineering education has expanded into economics, operations research, and management. This expansion has been heavily influenced by funding from departments of transportation and other modal agencies throughout the 20th century (Sinha et al., 2002). The research findings of (Hurwitz et al., 2016) show that transportation practitioners have consistently agreed with the key topics offered in the universities. There is a growing recognition of the importance of including transportation planning, intelligent transportation systems, bicycle, and pedestrian facilities in these courses to address industry trends and priorities. However, transportation engineering education is still evolving, characterized by its inherent complexity and strong reliance on multiple academic disciplines such as planning, economics, and environmental considerations. (Rhonda et al., 2015) highlight the use of more inclusive instructional practices such as simulation, visualization, concept mapping, and other active learning techniques to keep up with the pace of the evolving field. To enhance students' learning process, learning outcomes should be aligned with competencies and skills, using suitable teaching methods, and rigorously evaluating the achievement of these outcomes (Prado Da Silva et al., 2015). Additionally, issues related to safety and efficacy continue to demand innovative solutions to ensure that transportation systems serve all segments of society effectively.

1.4. Competencies and Disciplinary Synergies

From the challenges mentioned above, the role of transportation engineers is becoming increasingly critical. Despite the recognition of these needs, there is a limited understanding of the specific skill sets and competencies that will be essential for future transportation engineers. Moreover, the identification of key interdisciplinary areas that should be integrated into engineering education and practice remains underexplored. This lack of clarity can impede the development of educational programs and collaborative frameworks designed to prepare engineers for the transportation challenges of the future. To address these gaps, this research project leverages survey data to provide a range of perspectives from transportation industry professionals. The survey captures insights into near-term and long-term industry challenges, essential skills and competencies for future engineers, and disciplinary areas that require bridging or integration to tackle these challenges effectively. By analyzing this data, this research project aims to offer a comprehensive overview of the current and anticipated demands on transportation engineers. The findings seek to inform educational institutions about necessary curriculum adjustments and promote interdisciplinary collaboration to better prepare engineers for future transportation challenges. This effort is crucial for ensuring that the transportation industry can adapt and thrive in an era of rapid change and increasing complexity. Furthermore, this research project aims to re-envision the transportation sector by addressing infrastructure challenges through a multidisciplinary lens. A survey of transportation professionals was conducted to identify key disciplinary synergies and silos within the sector.

1.5. Project Objectives

The objectives of this research reflect the need to understand the integration of interdisciplinary knowledge within the transportation sector and its implications for workforce development. As transportation challenges become more complex, addressing gaps in disciplinary integration is essential to fostering a more effective, adaptable, and future-ready industry. This study explores the alignment of disciplinary synergies, gaps, and critical skill sets required to address near-term and long-term challenges. The following outlines the key research questions guiding this study:

- Identify the most common disciplinary areas that are currently well incorporated within the transportation sector, highlighting their contributions to innovation and efficiency.
- Determine the most common disciplinary areas that require bridging to meet the evolving needs of the transportation sector, ensuring a more cohesive and comprehensive approach to problem-solving.
- Explore the specific skill sets that transportation professionals consider essential for addressing both near-term and long-term industry challenges.
- Investigate the disciplinary areas in professional development and continuing education that transportation professionals should prioritize to remain relevant and effectively tackle both immediate and future challenges in the industry.

1.6. Project Relevance to the R-SEAT Themes and USDOT Strategic Plan

The proposed project fits very well the broad themes of the R-SEAT Center and explicitly contributes to the workforce development thrust area. This project aligns with the Rural Safe Efficient Advanced Transportation (R-SEAT) themes and the USDOT Strategic Plan by addressing workforce development needs critical for the future of transportation. It highlights the importance of equipping transportation professionals with interdisciplinary skills to navigate evolving challenges, ensuring a workforce capable of integrating technological, social, and environmental considerations. By identifying gaps in education and professional development, this research supports strategies to enhance training programs that foster innovation in rural transportation systems. Ultimately, the findings contribute to building a more resilient and adaptable workforce that can drive sustainable and inclusive mobility solutions.

1.7. Structure of This Report

This report is structured to guide readers through the key activities associated with understanding the disciplinary synergies, silos, and skill sets needed to develop a future-ready transportation workforce. The remaining chapters of this report are organized as follows. Chapter 2 details the data collection process, including the implementation of the online survey, survey participant information, demographics, and the design of the survey instrument. It also presents the qualitative analysis conducted to identify emerging themes and insights from the survey responses. Chapter 3 presents and discusses the results and key findings, including the most common disciplinary synergies, existing silos, and critical skill sets identified by transportation professionals. Finally, Chapter 4 provides concluding remarks, summarizing the main takeaways from this research project and outlining future directions for workforce development and interdisciplinary integration in transportation education and practice.

2. DATA AND METHODLOGY

This chapter focuses on the data collection and survey implementation process used to gather insights from transportation professionals. First, the implementation of the online survey and survey participant information is detailed, including participant selection criteria and recruitment methods. Second, the demographic characteristics of survey participants are presented to provide context for the range of perspectives captured. Third, the survey instrument is described, outlining the key questions and themes designed to assess disciplinary synergies, silos, and critical skill sets within the transportation industry.

2.1. Implementation of the Online Survey and Survey Participant Information

The study protocol was drafted and submitted for review by the Institutional Review Board of the two academic institutions working on the project (Cleveland State University, Ohio, and the University of Washington Tacoma, Washington). The Qualtrics™ platform was utilized for conducting the survey.

Overall, 65% of the survey respondents were from the Washington State Department of Transportation (WSDOT), with the remainder of the participants representing the DOTs from Ohio, Oregon, California, Colorado, Michigan, South Dakota, Utah, and other private organizations. These respondents hold a wide range of positions, including senior roles such as Director of the Active Transportation Division, State Traffic Engineer, Vice President, County Engineer, and Chief Safety Officer, just to mention a few. Participants had work experience in various areas of transportation work, including maintenance, construction, design, traffic management, operations/ITS, supervision/management, and incident management, among others. These proportions suggest that survey participants work on projects that are in diverse geographic settings. Multiple rounds of email invitations were sent from November 2023 to June 2024 to encourage participation. Based on the study protocol, all responses were anonymized to remove any identifying information about the companies or the specific individuals responding to the survey. This ensured that no specific company or person could be linked to the survey data when sharing or reporting results.

2.2. Survey Participant Demographics

The study design was approved by the University of Washington IRB (#STUDY00018622). The data collection and analysis structure for this study are presented below. A total of 85 transportation professionals responded to the survey; as shown in **Figure 1**, these respondents were from different private and public sectors and their proportions. Among the respondents, 65 individuals (constituting ~76% of the total responses) were currently working in the public sector, and 20 (corresponding to ~24%) were currently working in the private sector. **Figure 2** shows the years of experience in the transportation industry of the survey respondents. It is observed that 11% of respondents had less than five years of experience, 12% of respondents had 5-10 years of experience, 22% of respondents had 10-20 years of experience, and 55% of the respondents had more than 20 years of experience. Most respondents in the survey had over 20 years of experience in the transportation industry, indicating that a large group of experienced workers provided their views and perceptions in the survey. Moreover, 67 participants (representing ~79% of the total) are working on transportation projects that are in both rural and urban settings, 16 (19%) work on transportation projects that are in urban settings, 2 individuals (2%) are working on transportation projects in rural settings as shown in **Figure 3**. This proportion indicates that survey respondents work on projects that are in diverse geographic contexts.

Figure 1 Proportion of participants either in public or private.

Figure 2 Years of experience among survey participants.

Figure 3 Proportion of participants working on transportation projects in urban or rural settings.

Survey participants were selected using a snowball sampling process catalyzed with the help of the Washington State Department of Transportation (WSDOT). Further participation was obtained through word of mouth and targeted dissemination through specific individuals within both public and private transportation companies.

Approximately 65% of these respondents were from WSDOT, with the remainder representing DOTs from Ohio, Oregon, California, Colorado, Michigan, South Dakota, and Utah. The respondents hold a wide range of positions, including senior roles such as Director of Active Transportation Division, State Traffic Engineer, Vice President, County Engineer, and Chief Safety Officer. Participants had work experience in various areas of transportation work, including maintenance, construction, design, traffic management, operations/ITS, supervision/management, incident management, among others. These proportions indicate that survey respondents work on projects that are in diverse geographic contexts.

2.3. Survey Instrument

The primary objective of the survey questionnaire was to gather data on near-term and long-term challenges in the transportation industry and the skill sets or competencies that future engineers must have to address these challenges. It also aimed to identify the disciplinary areas within or outside engineering that should be bridged to address these challenges effectively. The questionnaire targeted professionals in the transportation industry, including those in the private and public sectors. The introduction of the survey detailed the specific objectives of the study for each question in the survey. To ensure the protection and privacy of the participants, an informed consent form was also included. Following the survey introduction, there were open-ended questions pertaining to demographic information, transportation challenges facing society, key competencies, and multidisciplinary areas needed for the transportation workforce to address these future transportation challenges. Open-ended survey questions were the chosen method for data collection as they allowed survey participants to provide rich detail regarding disciplinary synergies and silos (Saldaña, 2009).

In summary, the questionnaire was structured into four main sections, each addressing key areas of interest as informed by the study RQs.

- Section 1: Demographic Information. This section included questions designed to obtain demographic information pertaining to the survey participants' years of experience, whether their transportation projects are in urban or rural settings, and whether they are working in the private or public sector.

- Section 2: Near-term and Long-term. This section included questions designed to receive input on what the transportation professionals considered to be the key transportation challenges facing society in both the short-term and long-term.
- Section 3: Required Skillsets and Competencies. This section included questions aimed at gathering inputs on what the transportation professionals perceived to be the key competencies needed for the future transportation workforce to address the transportation challenges mentioned in section 2.
- Section 4: Disciplinary Areas. This section had a question that aimed to gather opinions from transportation professionals on which areas or disciplines within and/or outside engineering should be bridged to most effectively address the transportation challenges mentioned in section 2.
- Section 5: Integrated Disciplinary Areas. This section aims at identifying disciplinary areas that are most effectively being bridged and/or integrated currently in the transportation sector to address the transportation challenges you mentioned earlier
- Section 6: Siloed Disciplines. This section aimed at identifying disciplinary areas that are not currently bridged and/or integrated effectively in the transportation sector to address the transportation challenges mentioned in section 2.

2.4. Qualitative Analysis

A process of emergent qualitative coding on each participant's survey responses for each survey question was applied to pull out themes regarding disciplinary synergies and silos within the transportation sector workforce. Analysis of qualitative codes entailed counting references to synergistic or siloed disciplinary areas mentioned for each participant. Discipline counts, therefore, were compared across the number of participants who mentioned said disciplines – with the existence of various instances where multiple disciplines were mentioned by a single individual. Discipline (synergies or silos) counts were of specific interest to our team because they represented a discipline's level of importance – where a discipline referenced across many participants would be assumed more important than one referenced across a small number of participants.

While we aimed to create codes that were like the verbatim responses provided by survey participants, more generalized disciplinary terms (i.e., mechanical engineering, social sciences) were ultimately used when binning codes for disciplinary counts. Complete intercoder consistency and agreement were obtained using a co-coding process by the two lead authors on the research team. This structure for assessing intercoder reliability was reasonable due to the relatively small sample size (n = 70), and responses that ranged between 40 and 100 words in length.

3. RESULTS AND DISCUSSION

This chapter summarizes the results and findings of the questions in sections 2, 3, and 4 of the questionnaires based on the analysis of respondents' feedback in the online survey. These questions were open-ended, so the participants could mention more than one challenge, skillset, or disciplinary area in their respective questions. Therefore, the frequency of the challenges, skillsets, and disciplinary areas does not equate to the number of respondents. The findings from each survey question are provided below, starting with short-term transportation challenges.

3.1. Short-term Transportation Challenges

In the survey, 74 participants responded to the question regarding short-term and long-term challenges. **Table 1 and Table 2** present summaries of the key insights from each theme regarding the most frequently mentioned short-term challenges facing the transportation industry, based on excerpts from the survey responses.

The most mentioned short-term challenges were related to workforce development, funding, aging infrastructure, poor systemic response to technology, and multimodal transportation. Other short-term challenges mentioned with significant frequency were the environmental impacts of the current modes used in transportation, car-centric infrastructure, maintenance, and efficiency in transportation, to mention a few. Under workforce development, respondents indicated their opinions about the shortages of experienced professionals and recruitment issues due to the attrition of experienced staff and rapid technological advancements. Moreover, respondents highlighted that existing funding mechanisms have not kept pace with inflation and rising costs, resulting in insufficient investments in necessary projects and asset preservation.

Table 1 Short-term challenges.

Short-Term Challenge	Frequency
Workforce Development	40
Funding	33
Aging Infrastructure	16
Poor Systemic Response on Technology	9
Multimodal Transportation	7
Environmental Impacts	6
Car-Centric Infrastructure	5
Maintenance	5
Transportation Efficacy	5
Capacity Constraints	4
Increased Fatalities	3
Teleworking	3
Transportation Safety	3
Data Management	2
Freight Parking & Mobility	2
Urban Sprawl	2
Accessibility	1
Connected Vehicles	1
Incomplete Streets	1
Knowledge Transfer	1
Labor Shortages-Mid Career Professionals	1
Lack of Accommodations	1
Lack of Signal Coordination	1
Outdated Traffic Technology	1

Short-Term Challenge	Frequency
Population Growth	1
Regulatory Uncertainty	1
Transportation Accessibility	1
Transportation Planning	1
Transportation Resiliency	1

Table 2 Top five mentioned short-term challenges.

Short-term Challenge	Details
Workforce Development (40)	The transportation industry faces critical workforce challenges, including severe shortages of experienced professionals and mid-career project managers. Rapid technological advancements and recent funding surges demand specialized skills that current workforce development methods have not adequately addressed, leading to significant recruitment and retention issues.
Funding (33)	The existing funding mechanisms have not kept pace with inflation and rising costs, leading to insufficient investment in necessary projects and preservation of existing assets. Additionally, the current allocation and prioritization of funds often favor large mobility projects over essential maintenance and safety needs, create an imbalance in addressing comprehensive transportation requirements.
Aging Infrastructure (16)	A critical challenge in transportation infrastructure: aging systems across air- and seaports, roads, bridges, and public transit are in need of extensive maintenance and modernization. There is a pressing need to prioritize preservation efforts to extend the longevity and reliability of these crucial components. However, there's also concern about the lack of adequate support and political backing for these efforts, especially as infrastructure nears the end of its service life.
Poor Systemic Response to Technology (9)	A dual challenge in transportation technology: the potential benefits of leveraging new data and technologies, particularly for CAV applications, are significant but hindered by operational and safety concerns that affect public acceptance. Moreover, there is a critical gap in agency resources and expertise needed to effectively utilize and implement these technologies, exacerbated by a lack of regulatory guidance that hampers the deployment and interoperability of innovations like road user charging systems.
Multimodal Transportation (7)	There is a critical need to prioritize accessible and reliable alternatives to alleviate growing congestion, particularly in rural areas. Cities face decisions about public transit options that may not fully meet community needs while addressing last-mile commuting challenges remains a persistent issue. Additionally, shifting the transportation conversation nationally toward accommodating diverse modes, including micro-mobility

3.2. Long-term Transportation Challenges

In total, 74 (representing ~ 87%) participants responded to the question regarding long-term transportation challenges. Table 3 contains a list of long-term challenges mentioned in response to question 4. Table 4 presents a summary of the key insights from each theme regarding the most frequently mentioned long-term challenges facing the transportation industry.

The top five long-term challenges were related to funding, workforce development, environmental impacts, aging infrastructure, and poor systemic response to technology. Other long-term challenges mentioned with significant frequency were multimodal transportation (adopting other modes of transportation), dependence on car-centric infrastructure and population growth in transportation and transportation planning. Participants mentioned funding as the long-term challenge, as securing sustainable and reliable transportation infrastructure funding is crucial due to outdated tax strategies like gas tax. As mentioned in the short-term challenges, workforce challenges come second here with the same theme that there's a declining and aging workforce and a shortage of graduates with specialized degrees in traffic engineering and other related fields in transportation engineering.

Table 3 Long-term challenges.

Long-Term Challenge	Frequency
Funding	24
Workforce Development	18
Environmental Impacts	16
Aging Infrastructure	14
Poor Systemic Response to Technology	12
Car-Centric Infrastructure	9
Transportation Efficacy	9
Multimodal Transportation	7
Population Growth	6
Transportation Planning	6
Maintenance	5
Urban Sprawl	5
Taxing Strategies	4
Transportation Accessibility	4
Transportation Safety	3
Data Management	2
Artificial Intelligence	1
Community Engagement & Stakeholder Engagement	1
Connected Vehicles	1
Contractor Hiring	1
Digital Transition	1
Accessibility	1
EV Transition	1
Fuel Efficiency	1
Increase in Fatalities	1
Knowledge Transfer	1
Regulatory Compliance	1
Resilient Infrastructures	1
Revenue Sources	1
Security	1
Sustainable Fuel	1
Teleworking	1
Transportation Capacity	1

Table 4 Top five mentioned long-term challenges.

Long-Term Challenge	Details
Funding (24)	Securing sustainable and reliable funding for transportation infrastructure is a critical challenge due to the outdated gas tax model, which fails to account for the rise in fuel-efficient and alternative fuel vehicles. The need to transition to new revenue sources, such as vehicle miles traveled taxation and alternative methods for non-motorized transport, is essential to address funding shortfalls. There is a pressing need to balance funding between preserving aging infrastructure, maintaining new technology, and

	supporting expansion of technologies like electric vehicle charging facilities.
Workforce Development (18)	There's a declining and aging workforce, difficulties in recruiting and retaining skilled professionals, and a shortage of graduates with specialized degrees in traffic engineering and related fields. The rapid evolution of technology further complicates the situation, requiring a more interdisciplinary and adaptable workforce to keep pace with industry changes. Addressing these challenges will involve improving workforce quality, enhancing training programs, and encouraging new talent to enter the field, particularly through public service and civil infrastructure roles.
Aging Infrastructure (16)	The US faces significant challenges with aging transportation infrastructure, including the need for extensive maintenance and upgrades to prevent further deterioration. The infrastructure is increasingly strained by rising construction costs and inadequate funding, particularly for critical elements like major bridges. Additionally, the transition to new technologies, such as electric vehicles and connected infrastructure, is hampered by the outdated and deteriorating state of existing systems.
Environmental Impacts (14)	There is a need to reduce greenhouse gas emissions and adapt to climate change impacts like extreme weather and sea level rise. Transitioning to cleaner and more sustainable modes of transportation, such as electric vehicles and public transit, is essential to mitigate the sector's significant carbon footprint. Additionally, the sector must focus on integrating eco-friendly construction materials and practices, designing infrastructure to be climate-resilient, and promoting transportation systems that minimize environmental impact while enhancing accessibility and sustainability.
Poor Systemic Response to Technology (12)	The US faces challenges with poor systemic response to technology in transportation, including difficulties in integrating emerging innovations such as autonomous vehicles and smart infrastructure. Current systems struggle to adapt to the rapid pace of technological advancement, which impacts regulation, safety, and infrastructure adaptation. Additionally, the integration of new technologies requires significant long-term planning, collaboration, and investment to effectively incorporate various modes of transport and address potential disruptions.

3.3. Transportation Workforce Skillsets and Competencies

In total, 74 participants responded to the survey question related to the skillsets and competencies required to address the transportation challenges they mentioned in response to the previous question. **Table 5** contains a list of skillsets mentioned in response to question 5. **Table 6** presents a summary of the key insights from each theme regarding the most frequently mentioned skillsets that future engineers must have to address the transportation challenges mentioned above.

Table 5 Workforce skillsets and competencies.

Skillset	Frequency
Communication Skills	25
Collaborative Skills	22
Innovative Solutions	18
Emerging Technologies	17
Technical Skills	17
Data Analytics	12
Resource Allocation	12
Project Management	10
Justice	8
Leadership	6
Data Management	5
EdTech Integration	5
Environmental Impact Assessment	5
Policy Understanding	5
Software Skills	5
Decision Making	4
Recruitment	4
Systems Engineering	4
Transportation Planning	4
Traffic Management	2
Risk Management	2
Dashboard Creation	1
Ability to do field & office work	1
Privilege Awareness	1
Public Transit Expertise	1
Safety Design	1

The top five mentioned skillsets identified were related to communication skills, collaboration skills, capability for innovative solutions, adaptability to emerging technologies, and basic technical skills. Other skillsets mentioned with significant frequency were data analytics, resource allocation (economics), project management, and leadership skills, to mention a few. The top skillset mentioned was communication skills, which here was defined as the ability to effectively engage with a wide range of stakeholders, including community members, government agencies, and other professionals in both verbal and written forms. This skill is essential for understanding and addressing project needs, resolving conflicts, and incorporating input into decision-making processes. Collaboration skills were also emphasized, being mentioned 22 times. This key theme highlighted the importance of working seamlessly across multi-disciplinary teams, integrating expertise from other fields, especially with emerging technologies, to develop holistic solutions.

Table 6 Top five mentioned skillsets/competencies.

Skillset	Details
Communication Skills (25)	Strong communication skills to effectively engage with a wide range stakeholders, including community members, government agencies, and other professionals. Both verbal and written communication are essential for understanding and addressing project needs, resolving conflicts, and incorporating input into decision-making processes. Additionally, engineers should be adept at storytelling and presenting complex information clearly, as well as using hybrid and in-person communication methods to enhance collaboration and project success.
Collaboration Skills (22)	Collaboration skills involve effectively engaging with a range of stakeholders, including government agencies, private sector partners, and community groups. They need to work seamlessly across multi-disciplinary teams, integrating expertise from urban planning, environmental science, and technology to develop holistic solutions. Strong collaboration also involves building relationships, navigating complex constraints, and fostering trust to achieve cohesive and effective project outcomes across jurisdictions and modes.
Innovative Solutions (18)	Future transportation engineers must focus on innovative thinking to develop novel solutions for complex transportation challenges, including reducing car dependency and integrating new technologies. There's a need to adapt to emerging technologies such as AI, digital modeling, and autonomous vehicles, while also being able to navigate complex constraints and balance various solutions beyond traditional standards. Emphasizing creativity and critical problem-solving will be crucial for addressing evolving needs and achieving efficient, flexible, and environmentally conscious transportation systems.
Emerging Technologies (17)	Integrating emerging technologies such as autonomous vehicles, electric vehicles, and intelligent transportation systems into transportation networks. They need to stay current with advancements in digital technologies, including AI and data analytics, and understand their implications throughout the asset lifecycle—from design to operation and maintenance. Additionally, engineers should be versatile, balancing technical and technological skills with an understanding of human factors and industry practices to effectively address evolving transportation challenges.
Technical Skills (17)	A wide range of technical skills for engineers, including traditional engineering expertise in traffic engineering, roadway design, and public transportation systems. Engineers must also be proficient in emerging technologies such as vehicle connectivity, intelligent transportation systems (ITS), and sustainable design practices, while understanding the importance of environmental stewardship and long-term infrastructure resilience. Additionally, these engineers will need to integrate technical skills with human factors, policy planning, and innovative problem-solving to effectively address complex transportation challenges and optimize infrastructure without extensive expansion.

3.4. Recommended Disciplinary Areas to Bridge

In total, 70 (i.e., 82%) of the participants responded to this question. **Table 7** presents a summary of the key insights from each theme regarding the most frequently mentioned disciplinary areas that future engineers must have to address transportation challenges. **Table 8** provides details of the five most mentioned disciplinary areas.

The top five mentioned disciplinary areas were social sciences, computer sciences, economics, transportation planning, and environmental sciences. Other disciplinary areas mentioned with significant frequency were civil engineering, policy development, urban planning, and intelligent transportation systems, to mention a few. The top discipline mentioned about 27 times was social sciences. Participants pointed out that bridging transportation engineering with disciplines such as sociology will enable engineers to consider the human element in their designs and engage effectively with communities. Computer Science was mentioned 26 times as professionals pointed out that the seamless integration of computer science with civil engineering and data science will enhance the development of intelligent transportation systems (ITS), data analytics, and smart city technologies. Leveraging these disciplines will enable the collection, storage, and analysis of data to optimize traffic management, improve safety, and develop innovative solutions for transportation infrastructure.

Table 7 Disciplinary areas.

Disciplinary Areas	Frequency
Social Sciences	27
Computer Sciences	26
Economics	20
Transportation Planning	15
Environmental Sciences	14
Civil Engineering	12
Policy Development	6
Transportation Efficacy	6
Urban Planning	6
Intelligent Transportation Systems	5
Software Engineering	5
Artificial Intelligence	4
Mechanical Engineering	4
Electrical Engineering	3
Health Sciences	2
History	2
Legal Studies	2
Material Engineering	2
Project Management	2
Systems Engineering	2
Writing and Literature	2
Advanced Driving Assistance	1
Chemical Engineering	1
Construction Management	1
Cybersecurity	1
Dashboard Development	1
Geotechnical Engineering	1
GIS	1
Logistics	1
Smart Technology	1
Structural Engineering	1
Telecommunication Engineering	1
User Experience Design	1

Table 8 Top five mentioned disciplinary areas.

Disciplinary area	Details
Social Sciences (27)	Social Sciences address the consequences of past transportation choices and ensure projects align with social needs and values. Understanding human behavior, community engagement, and societal impact analysis is essential for developing sustainable transportation solutions. Bridging engineering with social

Disciplinary area	Details
	sciences, such as sociology, economics, and psychology, will enable engineers to consider the human element in their designs and engage effectively with communities.
Computer Sciences (26)	Computer Science efficiently addresses emerging transportation challenges through data analysis and informed policy choices. The seamless integration of computer science with civil engineering and data science will enhance the development of intelligent transportation systems (ITS), data analytics, and smart city technologies. Leveraging these disciplines will enable the collection, storage, and analysis of data to optimize traffic management, improve safety, and develop innovative solutions for transportation infrastructure.
Economics (20)	Economics is a discipline that ensures the sustainability and financial viability of transportation projects, focusing on long-term impacts and innovative funding models. Conducting comprehensive cost-benefit analyses and understanding asset management principles are essential for informed investment decision-making and evaluating different transportation solutions. Newer economic concepts like doughnut economics and well-being economy, alongside traditional economic analyses, will help engineers balance the industry's needs and promote a suite of transportation modes effectively.
Transportation Planning (15)	There's a need to integrate transportation planning with engineering to develop comprehensive solutions that address safety, land use, and long-term sustainability. Understanding state laws and their implications for design and safety, and collaborating closely with planners and law enforcement, is crucial for creating effective and enforceable transportation systems. Additionally, embedding planners and engineers together in teams will enhance the overall quality and impact of transportation projects by combining big-picture thinking with technical expertise.
Environmental Sciences (14)	Environmental Science to assess and mitigate the environmental impacts of projects, ensuring sustainability and adherence to regulations. This includes understanding and incorporating climate science to develop adaptive strategies for infrastructure in the face of climate change and collaborating across disciplines to align projects with long-term ecological goals. Additionally, addressing past environmental damage, such as correcting fish passage barriers, and integrating climate considerations into planning and program areas are essential for holistic and sustainable transportation solutions.

3.5. Disciplinary Areas that are Effectively being bridged and not bridged in the Transportation Sector

In total, 69 participants responded to the first survey question related to disciplinary synergies (**Table 9**) and 61 participants responded to the second survey question related to disciplinary silos. Table 9 and **Table 10** provide the code counts for disciplinary synergies and silos, respectively. The frequency (count) represents the number of times a synergy or silo was mentioned by each survey respondent.

Table 9 Disciplinary areas that are effectively being bridged in the transportation sector.

Coded Disciplinary Synergy	Frequency
Civil Engineering	14
Computer Science	12
Transportation Planning	9
Environmental Sciences	6
Social Sciences	6
Technology Integration	6
Economics	4
Safety	4
Transportation Efficacy	4
Electrical Engineering	3
Mechanical Engineering	3
Project Management	3
Computer Engineering	2
GIS	2
ITS	2
Policy Development	2
Structural Engineering	2
Traffic Engineering	2
Urban Planning	2
Health Sciences	1
Information Technology (IT)	1
Material Sciences	1
Multidisciplinary Research	1

Table 10 Disciplinary areas that are not currently being bridged and/or integrated effectively in the transportation sector

Coded disciplinary silo	Frequency
Social sciences	17
Economics	11
Computer science	11
Transportation planning	8
ITS	4
Transportation Efficacy	3
Urban planning	3
Civil engineering	2
Electrical engineering	2
Environmental science	2
Health sciences	2
Law and Legal Studies	2
Policy development	2
Telecommunications engineering	2
Advanced Driver Assistance Systems	1
Architecture	1
Construction management	1
History	1
Information Technology	1
Mechanical engineering	1
Project Management	1
Real estate	1
Systems engineering	1
Technology Integration	1
Writing and Literature	1

3.6. Discussion of findings

3.6.1. Key Transportation Challenges

The survey reveals several key challenges facing the transportation industry, with the foremost being the need to secure sustainable funding. Given the inadequacy of the outdated gas tax model, there is a growing need for new revenue sources like vehicle miles traveled taxation. The dramatic revenue decline due to the COVID-19 pandemic has led to project cancellations, equipment purchase delays, and employee furloughs, layoffs, and hiring freezes in the transportation sector. For instance, 16 states announced delays or cancellations of major projects valued at $5 billions by July 2020 (Black, 2020). Findings show that dedicating increased state highway use tax and vehicle sales tax to the transportation sector can eliminate revenue shortfalls, making it a more effective solution than relying on motor fuel tax (Hasnat & Bardaka, 2022).

Workforce development is another pressing issue, with a decline in skilled professionals and a need for more interdisciplinary training to keep pace with technological advancements. Research highlights that technological advancements increase work complexity and mental tasks while reducing manual labor, with a simultaneous rise in workload and autonomy. This necessitates the importance of adaptability and the ability to continuously unlearn outdated skills and acquire new ones in the workforce (Beer & Mulder, 2020; Ra et al., 2019). There is a need for continuous vocational education and training to include knowledge about technology, openness to change, and skills for self-management and career development. This can be achieved through flexible learning environments (Beer & Mulder, 2020).

The aging infrastructure requires extensive maintenance and upgrades, which is further complicated by rising costs and insufficient funding. (Little & Fellow, 2012) point out that aging infrastructure with inadequate maintenance and prolonged service life creates hidden vulnerabilities that can significantly weaken systems, making them more susceptible to otherwise survivable events. Environmental impacts necessitate a transition to cleaner transportation modes and climate-resilient infrastructure to reduce greenhouse gas emissions. Studies reveal the need for significant reductions in car use alongside emission-reducing vehicle design changes, and adoption of environmental technologies and renewable energy can significantly reduce CO_2 emissions (Kwilinski et al., 2024; Winkler et al., 2023).

Additionally, the systemic response to technological advancements, such as autonomous vehicles and smart infrastructure, remains inadequate, demanding comprehensive long-term planning and investment. For policy, there is an urgent need to rethink transportation funding models, focusing on alternative revenue sources like vehicle miles traveled taxation and increased state highway use tax to address shortfalls. In practice, there must be a stronger emphasis on workforce development and continuous vocational training to adapt to technological changes and manage aging infrastructure effectively. Future research should explore the impacts of technological advancements on the transportation sector, including the effectiveness of environmental technologies, the integration of autonomous vehicles, and strategies for maintaining and upgrading infrastructure in a climate-resilient manner.

3.6.2. Skillsets and Competencies

The survey highlights several essential skillsets that transportation professionals deem critical for future engineers. Strong communication skills are paramount for engaging a wide range stakeholders and effectively conveying complex information. (Elwy et al., 2022) points out that effectively translating research into practice requires a strategic approach to identifying, categorizing, and involving stakeholders throughout the project process. Collaboration skills are necessary for working across multidisciplinary teams and fostering relationships to achieve cohesive project outcomes. Research reveals that differences in how various fields conceptualize and emphasize collaboration are strongly associated with the success of projects with positive team interactions (Brown et al., 2023; Slade et al., 2023; Urton & Murray, 2021). Emphasis on innovative solutions is vital for addressing evolving transportation challenges and integrating new technologies. (Cascetta & Henke, 2023) points out that transportation systems are currently experiencing a seventh revolutionary phase driven by innovations in energy sources, autonomous vehicles, and smart mobility services, which could significantly impact societal, economic, and environmental sustainability. Mastery of emerging technologies, such as autonomous and electric vehicles, is crucial for modernizing transportation networks and staying ahead of industry advancements.

The automotive industry is on the cusp of a major transformation with the rise of autonomous vehicles (AVs), driven by advancements in technologies like IoT, edge intelligence, 5G, and Blockchain (Biswas & Wang, 2023). Technical skills remain foundational but must now include proficiency in intelligent transportation systems and sustainable practices. Findings show that professionals' technical skills, such as knowledge of machines, tools, and equipment operation, do not always align with employers' requirements; this is a clear indication of a significant mismatch between their knowledge, skills, and abilities (Simkins & Mahjabeen, 2017). Policies should prioritize aligning educational programs with industry needs, emphasizing communication, collaboration, and proficiency in emerging technologies. Practitioners must focus on interdisciplinary teamwork and invest in training that bridges current skill gaps. Future research should explore effective curriculum integration, the impact of technological advancements on industry requirements, and strategies to address the skills mismatch between professionals and employers.

3.6.3. Disciplinary Areas

The survey underscores the importance of interdisciplinary integration in transportation engineering, highlighting several key areas. Bridging engineering with social sciences is crucial for understanding human behavior and ensuring projects meet societal needs and values. For instance, there’s a need for broader social sciences disciplines on automated vehicles beyond public acceptance to fully understand potential impacts on economic structures, land use, and personal well-being (Cohen et al., 2020). It is crucial to recognize that transportation needs and accessibility can differ based on factors such as location and living conditions, as well as the resources available to different groups of people (Levin, 2019). Computer science plays a pivotal role in developing intelligent transportation systems and leveraging data analytics for optimized traffic management and safety. Advanced analytics applied to Big Data can overcome traditional data limitations, offering new insights into crash detection, driving behavior, safety improvements, and intelligent transportation systems (Lian et al., 2020; Montoya-Torres et al., 2021; Phuong Nguyen et al., 2022).

Economic analysis is essential for evaluating the sustainability and financial viability of transportation projects, incorporating innovative funding models and comprehensive cost-benefit analyses. Studies show that when financial resources are scarce, cost-benefit analysis can assist decision-makers in selecting the most efficient allocation of these resources (Jones et al., 2014). Integrating transportation planning with engineering enhances the development of solutions that address safety, land use, and sustainability. Environmental sciences are vital for assessing and mitigating the ecological impacts of transportation projects, promoting long-term sustainability and adherence to regulations. Policy should encourage interdisciplinary integration in transportation engineering to address various aspects such as human behavior, data analytics, and environmental impacts. Practitioners should apply insights from social sciences, computer science, and environmental sciences to develop holistic and sustainable transportation solutions. Future research needs to focus on understanding the broader impacts of transportation innovations, refining financial evaluation methods, and advancing technologies for enhanced safety and sustainability.

3.6.4. Effectively Bridged Disciplinary Areas

For the disciplinary synergies, the top-referenced disciplines related to Civil Engineering (n = 14), Computer Science (n = 12), Transportation Planning (n = 9), Environmental Sciences (n = 6), Social Sciences (n = 6), and Technology Integration (n = 6). Civil Engineering is related primarily to the structural engineering sub-discipline given the close tie with transportation infrastructure; however, survey participants also mentioned the nexus with other sub-disciplines including environmental engineering and the integration of civil engineering technology and modeling. Participant reference to Computer Science related to artificial intelligence and machine learning, enhancing safety, asset management, and real-time traffic solutions. Participants mentioned that this collaboration is evident in the development of intelligent transportation systems (ITS) and the use of robust computer modeling for various transportation disciplines.

For Transportation Planning, participants primarily focused on the policies that mandate robust collaboration and context-sensitive design. Many discussed how transportation planning is evident in university curricula, conference topics, and practical work environments, where planning and civil engineering work closely together to create implementable and human-centered projects. Environmental Sciences related to the minimization of environmental impact from transportation infrastructure. Participants mentioned that environmental sciences are increasingly integrated into transportation planning, focusing on sustainability and reducing the environmental impacts of infrastructure projects. There is notable coordination among design, environmental, and traffic disciplines to address transportation challenges and climate adaptation. Participants also indicated that while there is a growing emphasis on climate resilience, the approaches to adaptation vary significantly depending on geographical areas. Finally, Social Sciences focused on community engagement and assessing social impacts to better address needs and concerns. Participants indicated that there is a shift in focus toward how transportation projects are conceptualized.

3.6.5. Disciplinary Silos

For the disciplinary silos, the top-referenced disciplines related to Social Sciences (n = 17), Economics (n = 11), Computer Science (n = 11), Transportation Planning (n = 8), and Intelligent Transportation Systems (ITS, n = 4). While these top disciplinary silo codes mirror the disciplinary synergies codes, the details provided by survey participants for each discipline – mentioned as a siloed area needing to be bridged – are significantly different (**Table 4**).

For Social Sciences, participants mentioned that bridging social sciences is crucial for developing user-centered and sustainable transportation solutions that consider the diverse needs and values of different communities. They point out that such integration could enhance engineers' soft skills, such as community engagement, public relations, and understanding social determinants of mobility, which are essential for creating holistic transportation networks. Therefore, it is important to integrate practices from social science in transportation planning. This integration of social science practices is crucial but underutilized. Fischer (Fischer, 2011) argues that social sustainability is often overshadowed by environmental and economic factors in transportation decision-making, suggesting opportunities to make this silo more explicit. Some studies have tried to define such a silo. For instance, Trainor et al. (Trainor et al., 2013) propose an interdisciplinary approach to evacuation modeling that merges social science insights with transportation engineering, recognizing the intertwined nature of human behavior and transportation systems. Another example is the work by Jirón Martínez & Lange Valdés (Jirón & Lange, 1969) who emphasize the importance of understanding mobility practices in daily life for urban transport planning, suggesting that studying urban social practices can bridge the gap between dwellers' and planners' perspectives in comprehending city dynamics. The multidisciplinary approach helps address complex societal issues like poverty, mental health, and homelessness, ensuring that transportation policies and infrastructure support all segments of society effectively.

Participants mentioned that Economics is essential for addressing the financial impacts of infrastructure demands and achieving a balance between economic feasibility and long-term sustainability goals. This interdisciplinary approach is about equipping transportation planners and engineers to have a better understanding of funding mechanisms, economic development, and the broader societal value of projects, leading to more informed and proactive decision-making. Additionally, enhancing skills in economic analysis, grant applications, and benefit-cost analysis is crucial for securing funding and effectively communicating the benefits of transportation projects. The integration of economic development practices in transportation planning is crucial for maximizing the benefits of infrastructure investments. Research has shown that transportation projects can stimulate job creation, income growth, and business expansion (Gkritza et al., 2007). However, traditional evaluation methods often overlook these wider economic impacts due to methodological challenges (Gkritza et al., 2007). To address this, some metropolitan planning organizations have successfully incorporated economic development goals into their decision-making processes (Forkenbrock, n.d.). It's important to consider the scale of impact, future economic uncertainties, and social objectives when assessing transportation investments' contributions to economic development (Forkenbrock, n.d.). While large-scale projects typically receive more attention, there's a need to focus on local economic development in disadvantaged communities to ensure distribution is done fairly (Loveless, 2006). Programs like the Transportation and Community Development Initiative demonstrate how targeted investments can revitalize disadvantaged neighborhoods and integrate transportation with economic development planning (Loveless, 2006).

Participants mentioned that Transportation Planning is important for addressing the impacts of land use decisions on transportation systems and promoting proactive solutions. Effective integration requires collaboration between planning, transportation operations, and engineering to balance economic development with the efficient movement of people and goods. They stated that enhancing the understanding of urban planning basics within DOTs and other transportation agencies can help prevent issues and reduce the need for reactive infrastructure development. Therefore, there is a pressing need for a holistic and multidisciplinary approach to transportation planning. Long-term planning should incorporate community vision, public involvement, and realistic financial projections (Lyons et al., 2012). A comprehensive systems perspective is crucial, integrating health considerations into metropolitan area transportation planning (Lyons et al., 2012). This holistic approach should address the complex human aspects of transport systems, linking societal needs, environmental concerns, and economic factors with physical infrastructure (Giannakodakis, 1994). Transportation planning must also consider its broader context, including its influence on community structure, environmental sustainability, and quality of life (Poorman, 2005). The integration of these diverse elements requires a multidisciplinary perspective, acknowledging the interconnectedness of transportation with social, environmental, and economic factors. This comprehensive approach aims to create more effective and sustainable transportation systems that better serve community needs and align with broader societal goals.

Finally, participants indicated that ITS requires close collaboration between software engineers and traffic engineers to integrate and optimize the system effectively. Bridging the gap between ITS and other transportation fields is crucial to maximize the use of existing infrastructure, avoiding the need for new infrastructure and improving overall system performance and maintenance. There is a need for a new breed of ITS engineers who can connect public agencies and private industry sectors, as their educational backgrounds often differ (Sarakki & Land, 1996). ITS solutions should be tailored to meet the diverse travel needs of emerging population groups, such as car-sharing and flexible transit options (Douma, 2004). To effectively transfer ITS research to real-world applications, researchers and practitioners must interact closely, moving from concept development to pilot programs and long-term deployments (Stiller & Barth, 2014). Performance measurement of ITS is crucial for decision-making, but challenges exist, including lack of data, incomparable data formats, and complexity of the process. Improving inter-agency collaboration and developing best practices for benchmarking could enhance ITS performance evaluation across transportation departments (Abedi et al., 2023).

The above analyses reveal two encouraging and complementary findings. While there is a need for further integration of technology, computer science, and social science within transportation planning and management activities, analysis of survey responses showed that many silo disciplines are already in the initial stages of integration. However, survey participants identified barriers to efforts to scale up existing silo integration efforts. For example, a participant mentioned that the integration of Intelligent Transportation Systems (ITS) is hindered by a decline in civil engineering program enrollment and focus, which affects the effective implementation of these technologies despite their significant impact on optimizing transportation networks and improving efficiency. Additionally, institutional barriers and challenges in incorporating new data and perspectives, such as data science, remain significant obstacles. Furthermore, while there is strong support for understanding these aspects, other areas of sociology, such as community dynamics and mental health, are less emphasized in current undergraduate engineering curricula.

These comments, along with our qualitative analysis of survey responses, highlight the need for a two-pronged approach to promote the bridging of disciplinary silos. First, civil and transportation engineering curricula within universities should create space and structure for civil engineering students to take classes in social sciences, computer science, economic analysis, and community or transportation planning. The transportation sector, in turn, should provide opportunities for professionals to engage across disciplines and receive training to effectively combine these fields. While this study does not provide a concrete roadmap for implementing the recommended approach, it shows that the most promising way to begin this process is perhaps to leverage the existing silo integration efforts already taking place organically - namely in the areas of computer science, social sciences, and ITS. This can help build momentum and demonstrate the value needed to further bridge more disparate disciplines, such as those in economics.

4. CONCLUSIONS

Increasingly complex transportation challenges require a multidisciplinary workforce—one that can engage across engineering and non-engineering disciplines to design effective and sustainable solutions. This research project sought a wide range of perspectives from transportation professionals across the U.S. to inform educational institutions about necessary curriculum adjustments and encourage interdisciplinary collaboration. The project identified key challenges, including funding constraints, workforce development gaps, environmental impacts, aging infrastructure, and poor systemic adaptation to technology. Essential skill sets highlighted were communication, collaboration, problem-solving, adaptability to emerging technologies, and foundational technical competencies.

The research findings revealed that disciplinary synergies currently exist between transportation engineering and traditional civil engineering disciplines, such as structural and environmental engineering, as well as in the application of computer science, data science, and environmental sustainability. However, disciplinary silos persist in fields such as social sciences, economics, transportation planning, and advanced computing areas like artificial intelligence and machine learning.

To address these gaps, future research and practice should focus on aligning educational programs with industry needs, addressing skills mismatches, and fostering interdisciplinary approaches. Industry and higher education institutions must collaborate to integrate engineering and non-engineering curricula while expanding workforce training opportunities. By leveraging emerging synergies and actively bridging existing silos, this research project contributes to the development of a holistic, adaptable, and future-ready transportation workforce. The findings provide valuable guidance for educational institutions to refine their curricula, incorporate interdisciplinary perspectives, and equip engineers with the critical skills necessary to tackle evolving transportation challenges.

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