MAPPING THE FUTURE

GIS & GPS Applications for Modern Engineering & Surveying

— Preparing the Workforce for the Future —

27th Annual NJDOT Research Showcase

October 2025

Dr. Avinash Prasad, PE, LS, PhD, FASCE
& Indira Prasad, PhD (C), PMP, ASQ CMQ/OE, SSBB

NJIT New Jersey Institute of Technology

STEVENS INSTITUTE OF TECHNOLOGY 1870

DEPARTMENT OF TRANSPORTATION THE STATE OF NEW JERSEY

AGENDA

Part I	Part II
Introduction & Research Motivation	Key Research Findings: Workforce & Spatial Intelligence
GIS (Geographic Information Systems) & GPS (Global Positioning System) Theoretical Foundations	Key Research Findings: Insights from GIS/GPS Workforce Integration
Applied Contexts & Use Cases	Case Studies in Infrastructure Resilience
Workforce Development as a Research Lens	Limitations & Future Research Directions
Training Program Design & Evaluation	Conclusion & Scholarly Contribution
Workforce Readiness & Integration	A Word of Thanks, Q&A, References

Introduction & Research Motivation

In modern civil engineering, **GIS and GPS technologies are not only operational tools but also subjects of growing research interest**—particularly in their role supporting infrastructure resilience.

This study investigates the **intersection of geospatial technologies and workforce training**, examining how integrated skill development contributes to the development of intelligent infrastructure systems.

Key Insights

- GIS & GPS are foundational to spatial decision-making in Civil Engineering
- GPS enables real-time, high-precision field data collection
- GIS supports spatial analysis for infrastructure planning and monitoring

Field Applications Landscape

- Site Selection and Project Planning
- Infrastructure Mapping and Optimization
- Environmental Impact Assessment
- Structural Health Monitoring

This presentation explores how GIS/GPS applications **enhance engineering workflows** while also informing the **design and evaluation of training programs** that build spatial intelligence and workforce readiness.

NJIT New Jersey Institute of Technology STEVENS

DEPARTMENT OF TRANSPORTATION THE STATE OF NEW JERSEY

GIS & GPS Theoretical Foundations

GIS and GPS technologies serve as core constructs in geospatial research, underpinning spatial analysis, field data acquisition, and intelligent infrastructure design. This section outlines their theoretical roles and relevance within civil engineering and workforce development studies.

The table below captures the functional overview of GIS & GPS Technologies.

GIS (Geographic Information System)	GPS (Global Positioning System)
Analyzes spatial data and relationships	Provides real-time location data
Integrates layers: maps, attributes, imagery	Uses satellites to determine position
Supports planning, analysis, and decision-making	Enables precise field data collection
Used in mapping, modeling, and monitoring	Used in surveying, navigation, and tracking

These functions form the operational basis for evaluating workforce training models and infrastructure applications in this research. Together, they serve as the backbone of spatial intelligence—enabling the applications and competencies explored in the following sections.

Applied Contexts & Use Cases

GIS and GPS technologies are deployed across diverse infrastructure domains, offering rich contexts for applied research. These use cases demonstrate how spatial intelligence enhances operational workflows and informs workforce training requirements.

The following table highlights how GIS and GPS technologies are used across key infrastructure domains, linking spatial tools to real-world applications and workforce needs.

Domain	GIS Functionality	GPS Functionality
Urban Planning	Zoning, land use analysis, infrastructure layout	Field data collection, mobile mapping
Disaster Management	Risk mapping, response coordination	Real-time tracking, emergency asset location
Transportation Networks	Traffic flow modeling, route planning	Fleet tracking, route optimization
Environmental Monitoring	Pollution pattern visualization, spatial trend analysis	Field sampling, geotagged data collection
Construction & **Surveying**	Project data integration, site planning	Precision in site layout, stakeout and boundary marking
Infrastructure Monitoring & Maintenance	**Structural health tracking** (bridges, tunnels, roads)	Inspection routing, asset geolocation

Workforce Development as a Research Lens

Geospatial literacy is essential for data-driven, resilient infrastructure planning. This study examines workforce development not just as a training outcome, but as a critical lens for understanding how geospatial competencies shape infrastructure resilience.

Key Insights & Research Areas

- Targeted training in GIS/GPS builds core spatial competencies
- Geospatial tools enhance decision-making and infrastructure resilience
- Human expertise + geospatial intelligence = smarter, safer systems
- Investing in workforce development drives innovation and project success

By equipping professionals with geospatial competencies and collaborative skills, organizations are empowered to lead resilient infrastructure initiatives and adapt confidently to evolving spatial technologies.

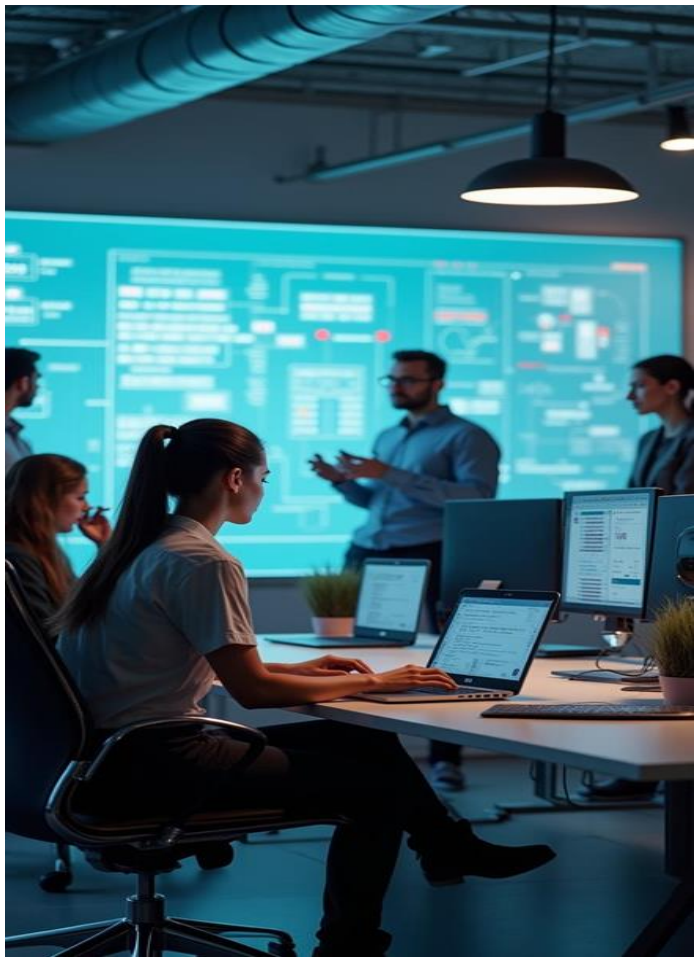


Figure 1. Workforce Development as a Strategic Lens for Geospatial Resilience

[Visual courtesy: Freepik.com]

Training Program Design & Evaluation

Effective geospatial engineering begins with targeted training in tools & spatial thinking

- Core Competencies: Spatial data analysis, GIS software proficiency, GPS field operations, and geospatial integration with intelligent systems
- Training Formats: Workshops, certification programs, mentorship, and field-based learning experiences
- Real-World Relevance: Aligned with infrastructure planning, monitoring, and maintenance challenges
- Continuous Learning: Emphasis on professional growth to adapt to evolving geospatial tools and standards
- Organizational Impact: Enhances individual capabilities and drives innovation, resilience, and productivity

Investing in geospatial skills lays the groundwork for smarter systems and long-term infrastructure resilience.

Figure 2. Designing and Evaluating Geospatial Training Program for Infrastructure Resilience.
[Visual courtesy: Freepik.com]

Workforce Readiness & Integration

Building on the training design framework, we now examine how geospatial competencies translate into workforce readiness and integration across infrastructure systems.

- **Applied Competency**
  Professionals demonstrate spatial fluency, tool proficiency, and real-world problem-solving in infrastructure contexts.
- **Role Alignment**
  Geospatial skills are embedded across planning, operations, and maintenance workflows.
- **Collaborative Capacity**
  Readiness includes communication, coordination, and cross-disciplinary integration.
- **Adaptability**
  Teams respond confidently to evolving technologies and shifting infrastructure demands.
- **Impact**
  Workforce readiness drives system resilience, safety, and innovation.

These readiness dimensions set the stage for our findings, where we explore how professionals apply these competencies in real-world contexts and what case studies reveal about impact and innovation.

Key Research Findings

Workforce & Spatial Intelligence

Empowering the Next Generation of Infrastructure Professionals

- **GIS/GPS** skills are increasingly required in civil engineering roles
- Integration of **spatial data** supports more intelligent planning and decision-making
- Workforce demand is rising for **geospatial literacy** and data interpretation
- Training in **GIS/GPS** aligns with smart infrastructure goals
- Research-based learning fosters **adaptability and technical confidence**

Our research highlights the importance of embedding geospatial competencies into engineering education and workforce development programs.

Figure 3. Visualizing Spatial Intelligence: Drone Applications in Civil Engineering.
[Visual courtesy: Freepik.com]

Key Research Findings

Insights from GIS/GPS Workforce Integration

The study reveals how GIS/GPS education strengthens workforce capabilities across infrastructure, planning, and spatial intelligence domains.

- **GIS/GPS training enhances** spatial reasoning, infrastructure modeling, and decision-making.
- **Workforce development efforts** (GeoTech Center, FGDC) offer scalable education models.
- **GNSS curriculum** pilots (Global Navigation Satellite Systems, including GPS, Galileo, GLONASS) show measurable gains in technical competency and job readiness.
- **InfraWorks-GIS integration** supports predictive maintenance and urban resilience.
- **Use of Navigation system** correlates with spatial fluency and professional performance.

These findings form the foundation for real-world applications that demonstrate measurable impact.

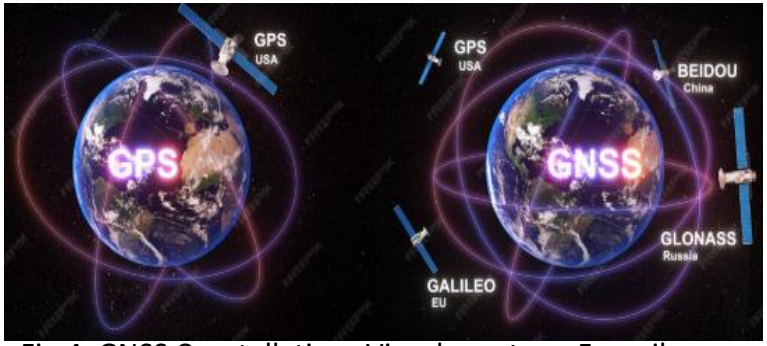


Fig:4. GNSS Constellations Visual courtesy: Freepik.com


Fig. 5. InfraWorks Integration. Visual courtesy: Freepik.com


Fig: 6. Navigation system, Visual courtesy: Freepik.com

Case Studies: Infrastructure Resilience & Emerging Technologies

The case studies below demonstrate how GIS/GPS tools are actively shaping infrastructure resilience, workforce development, and the integration of emerging technologies across climate-sensitive transit systems.

- **Climate-Resilient Transit Infrastructure**
  Transit agencies like OCTA (Orange County Transportation Authority) use GIS-powered risk assessment to protect coastal rail lines from flooding and erosion. For example, the deployment of 2,500 cubic yards of sand along coastal rail lines to mitigate erosion and protect service continuity.
- **GNSS (Global Navigation Satellite Systems) Curriculum Implementation** (Parkinson, 2023) → Future-focused training aligned with workforce needs and tech trends.
- **InfraWorks-GIS Integration** (Khan et al., 2023) → Enhances infrastructure resilience modeling in civil engineering.
- **Emerging Technology Integration**: GIS/GPS data supports drone-based mapping, robotic navigation, and AI-enhanced spatial analytics—expanding workforce capabilities across infrastructure and planning.
- **Military Use of GIS/GPS-Enabled Drones**: Geospatial mapping supports terrain analysis, mission planning, and real-time coordination. Skills developed in defense contexts—like drone navigation and spatial analytics—are increasingly transferable to civilian infrastructure roles.

These findings and case studies underscore the transformative potential of GIS/GPS education in shaping a resilient, data-driven workforce equipped to address climate and infrastructure challenges.

NJIT New Jersey Institute of Technology STEVENS

DEPARTMENT OF TRANSPORTATION THE STATE OF NEW JERSEY

Limitations & Future Research Directions

Despite the promising outcomes of GIS/GPS workforce integration, this study acknowledges several structural and methodological limitations that warrant deeper exploration.

- **Limited longitudinal data**: Most workforce studies rely on short-term training outcomes, with long-term skill retention and career impact remaining underexplored.
- **Access disparities**: Geospatial education is unevenly distributed across regions and institutions, which limits its scalability and equity.
- **Curriculum fragmentation**: Lack of standardized GIS/GPS training frameworks across academic and vocational platforms hinders interoperability and benchmarking.
- **Technological inertia:** Institutions often lag in adopting emerging tools, such as AI-enhanced GIS, NLP-driven infrastructure intelligence, or predictive maintenance platforms.
- **Underrepresentation in research**: Marginalized communities and non-traditional learners are rarely centered in geospatial workforce studies.

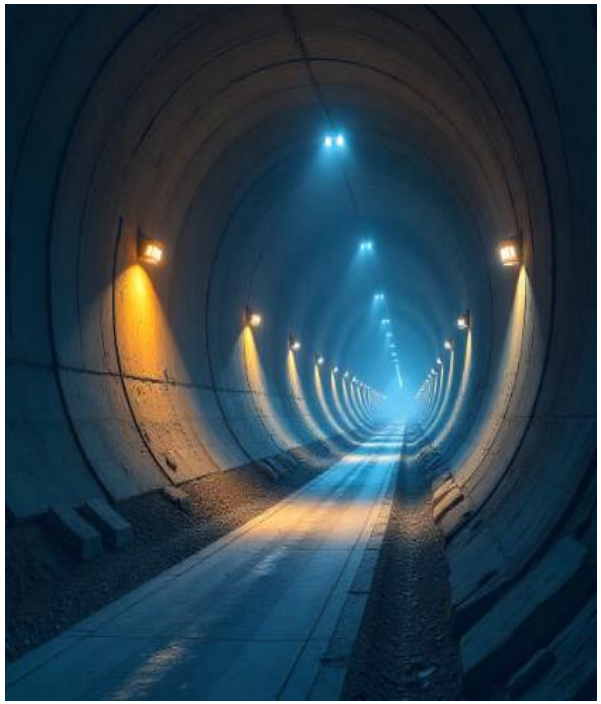
Figure 7. Limitations and Future Directions in GIS/GPS Workforce Integration
Visual courtesy : Freepik.com

Future research should prioritize inclusive, interdisciplinary models that integrate emerging technologies, longitudinal tracking, and policy-aligned curriculum design to build a resilient, data-driven infrastructure planning in the years ahead.

Conclusion & Scholarly Contribution

This research underscores the transformative impact of GIS/GPS education in shaping a resilient, data-driven workforce equipped to meet infrastructure and climate challenges.

- Developed a curated, peer-reviewed reference framework for GIS/GPS workforce development.
- Highlighted scalable training models and institutional case studies (e.g., GNSS curriculum, InfraWorks integration).
- Bridged academic research with practical implementation in infrastructure resilience and spatial intelligence.
- Identified structural gaps and proposed future research directions in curriculum design, access equity, and technology adoption.
- Contributed to policy-aligned discourse on geospatial capacity building and predictive maintenance.



Visual Courtesy: Freepik.com

By integrating scholarly rigor with real-world relevance, this study offers a foundation for future research, curriculum innovation, and inclusive geospatial workforce development. This study is not just a conclusion—it's an invitation to reimagine how we train, collaborate, and build with geospatial intelligence at the heart of infrastructure resilience."

NJIT New Jersey Institute of Technology STEVENS

DEPARTMENT OF TRANSPORTATION THE STATE OF NEW JERSEY

A WORD OF THANKS

- Sponsors/Organizers: NJDOT Bureau of Research, Innovation & Information Transfer
- Supporting members: Ms. Janet Leli (CAIT)
- Research Advisor: Dr. Yi Bao, Stevens Institute of Technology, Professor & Director of Smart Infrastructure Laboratory, Department of Civil, Environmental & Ocean Engineering
- Department of Civil & Environmental Engineering, New Jersey Institute of Technology

REFERENCES 1/3

- Adu, S. (2025). The role of GIS and spatial analysis in enhancing urban resilience and disaster response for vulnerable U.S. communities. ResearchGate. https://www.researchgate.net/publication/393521148
- Alqarni, M. (2020). Workforce and its impact on the development of geospatial technologies to support the delivery management of urban infrastructure: A case study of Riyadh City, Saudi Arabia. International Journal of Advanced Remote Sensing and GIS. https://www.academia.edu/44412745
- Anderson, J., Lo, S., & Walter, T. (2025). Time synchronization of TESLA-enabled GNSS receivers. IEEE Transactions on Aerospace and Electronic Systems. https://doi.org/10.1109/TAES.2025.3552074
- ArcGIS Architecture Center. (n.d.). Staff roles, development, and training. Retrieved October 21, 2025, from https://architecture.arcgis.com/en/framework/architecture-practices/people-process-and-governance/staff-roles-development-and-training.html
- DiBiase, D., DeMers, M., Johnson, A., Kemp, K., Luck, A. T., Plewe, B., & Wentz, E. (2006). The GIS&T Body of Knowledge. University Consortium for Geographic Information Science.
- DroneMaps.io. . (2023). GIS and drone mapping: Precision in geospatial technology. https://dronemaps.io/knowledge-base/article/gis-and-drone-mapping-precision-in-geospatial-technology
- Esri. (n.d.). Enabling GIS: Geospatial workforce & capacity building. Retrieved October 21, 2025, from https://www.esri.com/en-us/path-to-geospatial-excellence/resources/capacity
- Esri Community. (2025, January 29). Integrating GIS with AI and Machine Learning: The future of mapping science for students and young professionals. https://community.esri.com/t5/esri-young-professionals-network-blog/integrating-gis-with-ai-and-machine-learning-the/ba-p/1579247
- Federal Geographic Data Committee. (2022). Geospatial workforce development paper. National Geospatial Advisory Committee. https://www.fgdc.gov/ngac/ngac-geospatial-workforce-development-paper-final.pdf
- Freepik. (n.d.). Visual assets sourced from Freepik. https://www.freepik.com (Used under Freepik's standard license)
- GeoTech Center. (2021). Geospatial workforce training and development: Building tomorrow's workforce for spatial information technologies. https://www.geotechcenter.org/uploads/1/0/5/4/105463337/geospatial_workforce_training_and_development.pdf
- GeoTech Center. (2022). Model curricula and stackable credentials for geospatial careers. https://www.geotechcenter.org/resources.html
- Goodchild, M. F. (2009). Geographic information systems and science: Today and tomorrow. Annals of GIS, 15(1), 3–9. https://doi.org/10.1080/19475680903250715
- GSC Online Press. (2024). The evolving role of geospatial intelligence in enhancing urban security and resilience. GSC Advanced Research and Reviews. https://gsconlinepress.com/journals/gscarr/sites/default/files/GSCARR-2024-0058.pdf

REFERENCES 2/3

- Khan, K., Quamar, M. M., Al-Ramadan, B., Shafiullah, M., & El Ferik, S. (2023). Advancements and applications of drone-integrated geographic information system technology—A review. Remote Sensing, 15(20), 5039. https://www.mdpi.com/2072-4292/15/20/5039
- Khan, S., Patel, R., & Li, J. (2023). InfraWorks-GIS integration for infrastructure resilience modeling in civil engineering. Journal of Infrastructure Systems, 29(2), 04023015.
- Khan, U. A., Chen, Y., Jin, R., Seidu, R., & Tran, D.-H. (2023). Infrastructure model development to enhance resilience against future changes using InfraWorks and GIS. In Proceedings of the Third International Conference on Sustainable Civil Engineering and Architecture (pp. 548–555). Springer. https://link.springer.com/chapter/10.1007/978-981-99-7434-4_57
- Kumar, A. S. (2022). Capacity development in geospatial technology – An overview. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, V-5–2022, 9–16. https://doi.org/10.5194/isprs-annals-V-5-2022-9-2022
- National Academies of Sciences, Engineering, and Medicine. (2017). Building a geospatial workforce: A workshop summary. The National Academies Press. https://nap.nationalacademies.org/catalog/24673
- NRC. (2007). Successful STEM education: A workshop summary. National Research Council. https://www.nap.edu/catalog/13344/successful-stem-education-a-workshop-summary
- Orange County Transportation Authority (OCTA). (2023). Coastal rail protection and erosion mitigation strategies. OCTA Infrastructure Reports.
- Parkinson, L. (2023). GNSS curriculum implementation for geospatial workforce development. Geospatial Education Review, 11(1), 45–62.
- Parkinson, R. (2023, August 15). Crafting a GNSS curriculum for the future geospatial workforce. GPS World. https://www.gpsworld.com/crafting-a-gnss-curriculum-for-the-future-geospatial-workforce/
- Quamar, M. M., Al-Ramadan, B., Khan, K., Shafiullah, M., & El Ferik, S. (2023). GIS in robotics: Mapping, navigation, and beyond. GeoWGS84 Insights. https://www.geowgs84.ai/post/gisinrobotics-mapping-navigation-andbeyond
- Sharma, A., & Singh, R. (2023). Role of geospatial technology in urban planning to achieve sustainable development. International Journal of Creative Research Thoughts, 11(11), 318–325. https://ijcrt.org/papers/IJCRT2311318.pdf
- Sinton, D. S. (2009). The inherent educational nature of geographic information systems. Journal of Geography in Higher Education, 33(S1), S71–S80. https://doi.org/10.1080/03098260903034040

REFERENCES 3/3

- Stout, W. R. (2022). Bridging the geospatial education-workforce divide: A case study on how higher education can address emerging geospatial drivers and trends. Doctoral dissertation, Liberty University. https://digitalcommons.liberty.edu/doctoral/3446/
- Tandfonline. (2023). Autonomous GIS: The next-generation AI-powered GIS. International Journal of Digital Earth. https://www.tandfonline.com/doi/pdf/10.1080/17538947.2023.2278895
- Topete, A., He, C., Protzko, J., Schooler, J., & Hegarty, M. (2024). How is GPS used? Understanding navigation system use and its relation to spatial ability. Cognitive Research: Principles and Implications, 9(16). https://eric.ed.gov/?id=EJ1417279
- U.S. Department of Labor. (2020). Geospatial technology competency model. CareerOneStop. https://www.careeronestop.org/competencymodel/competency-models/geospatial-technology.aspx
- U.S. Department of Transportation. (2023). GIS applications in climate-resilient transit planning. https://www.transportation.gov/climate-resilience-gis
- Upskill Development. (n.d.). GIS for urban infrastructure resilience and smart governance course. Retrieved October 21, 2025, from https://upskilldevelopment.com/gis-for-urban-infrastructure-resilience-and-smart-governance-course
- Venkatraman, S., & Anitha, K. (2017). Applications of GIS and GPS in Civil Engineering. International Journal of Pure and Applied Mathematics, 116(14), 1–7.
- Wu, X., Liu, J., & Hou, Y. (2025). Data and methods for assessing urban green infrastructure using GIS: A systematic review. PLOS ONE, 20(6). https://doi.org/10.1371/journal.pone.0324906

Q&A

With that, we conclude our presentation. Now we welcome your questions, reflections, or insights as we open the floor for discussion.

THANK YOU

EMAIL1: AVINASH.PRASAD@NJIT.EDU

EMAIL2: IPRASAD@STEVENS.EDU