

Inspection Technologies for Construction and Maintenance of Highway Infrastructure – Review and Analysis

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Introduction

High-quality highway infrastructure is the backbone of safe and efficient transportation. As technology evolves, state Departments of Transportation (DOTs) are increasingly turning to cutting-edge tools to enhance their inspection practices, with a specific focus on optimizing operational efficiency and reducing costs. Advances in inspection technologies, such as unmanned aerial vehicles (UAVs), augmented and virtual reality (AR/VR), building information modeling (BIM), and light detection and ranging (LiDAR), offer promising opportunities to streamline inspection processes, improve data accuracy, and identify maintenance needs proactively. Yet, the full potential of these emerging technologies for highway inspections remains largely untapped and not well understood. This research aims to address these gaps by investigating the current landscape of adoption and application of UAVs, AR/VR, BIM, and LiDAR technologies within DOTs. This research addresses this objective by asking the following question: What are the potential applications of these emerging

technologies for highway infrastructure construction and maintenance inspection? Ultimately, the findings of this research aim to guide state agencies in adopting a more technologically advanced, data-centered approach to highway infrastructure construction and maintenance inspection, laying the groundwork for developing guidance to better adoption of emerging technologies at the state DOTs.

Study Methods

This study conducted an extensive literature review (of a total of 96 publications) and content analysis exploring the current landscape of emerging technologies in highway infrastructure inspection. The methodology follows a structured approach, including data collection, screening, and qualitative content analysis. NVIVO software was employed to facilitate the analysis, enabling a structured and in-depth examination of the collected materials. Keywords such as “highway inspection,” “infrastructure construction inspection,” and “emerging technologies”

guided the literature review. These keywords guided the search and selection process, helping identify a diverse array of sources, including research reports, academic journal articles, industry manuals, technical reports, and publications from state Departments of Transportation (DOTs). This approach enables a comprehensive overview of the state of practice in using these technologies, offering a comparative perspective across state DOTs. These materials provided valuable insights into the usage of major emerging inspection technologies: Remote Sensing and Monitoring - Unmanned Aerial Systems (UAS) and Light Detection and Ranging (LiDAR), Building Information Modeling (BIM), and Augmented Reality/Virtual Reality (AR/VR) for inspection purposes, thus contributing to a deeper understanding of how DOTs can leverage these technologies to improve efficiency, safety, and cost-effectiveness in highway infrastructure construction and maintenance.

Findings

The key findings of the research are the following:

- All 50 states in the US have implemented at least one emerging technology for highway infrastructure inspection. While most DOTs adopt some form of new technology, only 18% (or 9 out of 50) have fully integrated all four technologies explored in this study: UAS, LiDAR, BIM, and AR/VR.
- Adoption rates for UAS and LiDAR are particularly high, at 92% and 94%, respectively. These technologies are commonly applied in structural inspections, and progress monitoring inspections due to their efficiency in collecting accurate, real-time data.
- By contrast, BIM is used by just over half (52%) of state DOTs, while AR/VR adoption is notably low, with only 20% of DOTs employing it. BIM is primarily applied in quantity estimation verification and aiding in the coordination and documentation of infrastructure projects inspection.
- AR/VR, though underutilized, has the substantial potential in the future to perform remote inspections and train construction inspectors more efficiently in a cost-effective manner.

This disparity in adoption rates across technologies highlights an opportunity for increased exploration and implementation of BIM and AR/VR to enhance

inspection practices. As demonstrated by the success of UAS and LiDAR in inspection tasks, these advanced technologies can yield considerable benefits if adopted more widely.

Policy/Practice Recommendations

This study advocates for increased exploration and adoption of advanced inspection technologies by state DOTs. By harnessing these tools' diverse capabilities, the state DOTs can enhance inspection efficiency, improve data accuracy, and maximize the benefits of their transportation investments. Leveraging these innovations can thus optimize inspection procedures, better allocate resources, and ultimately contribute to safer, more resilient transportation infrastructure for the communities they serve.

About the Principle Investigator

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Dr. Tummalapudi is an Assistant professor in the Department of Construction Management at California State University, Fresno, and also a faculty fellow at Fresno State Transportation Institute. Mani holds a M.S. with Civil Engineering emphasis from Bradley University and Ph.D. with Construction Management emphasis from Colorado State University. Dr. Tummalapudi's research interests include transportation project delivery, transportation workforce development, construction finance, emerging technologies in construction, transportation equity, and construction education.

To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/2357



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