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

Manideep Tummalapudi, PhD  Prem Raj Timilsena

CSUTC California State University Transportation Consortium

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# Executive Summary

The quality of highway infrastructure is crucial for ensuring safety and efficiency in transportation systems. To achieve and maintain high-quality standards, efficient inspection practices are essential. In the digital age, state Departments of Transportation (DOTs) increasingly use emerging technologies to enhance the inspection processes. However, there is limited understanding of the various emerging technologies utilized for highway infrastructure inspection.

This research paper investigates the implementation of emerging technologies by state DOTs for construction and maintenance inspection purposes. The study focuses on Remote Sensing and Monitoring Technologies (such as Unmanned Aerial Systems (UAS) and Light Detection and Ranging (LiDAR)), Building Information Modeling (BIM), and Augmented Reality/Virtual Reality (AR/VR).

Through an extensive literature review and analysis of technical documents, the research reveals varied levels of adoption among state DOTs. Technologies like UAS and LiDAR have achieved significant usage, with 92% of state DOTs employing UAS and 94% utilizing LiDAR. In contrast, BIM and AR/VR adoption rates are notably lower, with 52% of state DOTs using BIM and only 20% employing AR/VR. This gap highlights a significant opportunity for state DOTs to expand the use of these technologies to improve inspection processes.

The findings also identify the applications and potential benefits of adopting a wider range of advanced inspection technologies. State DOTs can enhance efficiency, effectiveness, and innovation by embracing these tools fully. Moreover, the research also identifies the importance of strategic planning for effectively implementing emerging inspection technologies.

In conclusion, this study advocates for increased exploration and adoption of advanced inspection technologies by state DOTs. Leveraging these innovations can optimize inspection procedures, better allocate resources, and ultimately contribute to safer, more resilient transportation infrastructure for the communities they serve.

# 1. Introduction

The development of cost-effective methods to enhance the long-term benefits of transportation investments, particularly through the practical implementation of emerging technologies in highway infrastructure construction and maintenance, is an important priority for state Departments of Transportation (DOTs). Inspection during the construction and maintenance phases is critical to ensuring compliance with plans, specifications, and material requirements—factors that significantly influence the overall life cycle of transportation projects.

State DOTs aim to construct high-quality infrastructure that meets or exceeds established standards for the communities they serve. A key component of this effort is the inspection of highway infrastructure. However, these inspections consume substantial time, resources, and funding. For instance, nearly 8% of the Caltrans maintenance budget is dedicated to inspections (Caltrans Report 2015-120), as the agency oversees the maintenance and inspection of 25,000 bridges. The adoption of emerging technologies in inspection processes offers significant opportunities for productivity gains, time savings, and cost reductions—critical advantages amid a shortage of skilled inspection personnel.

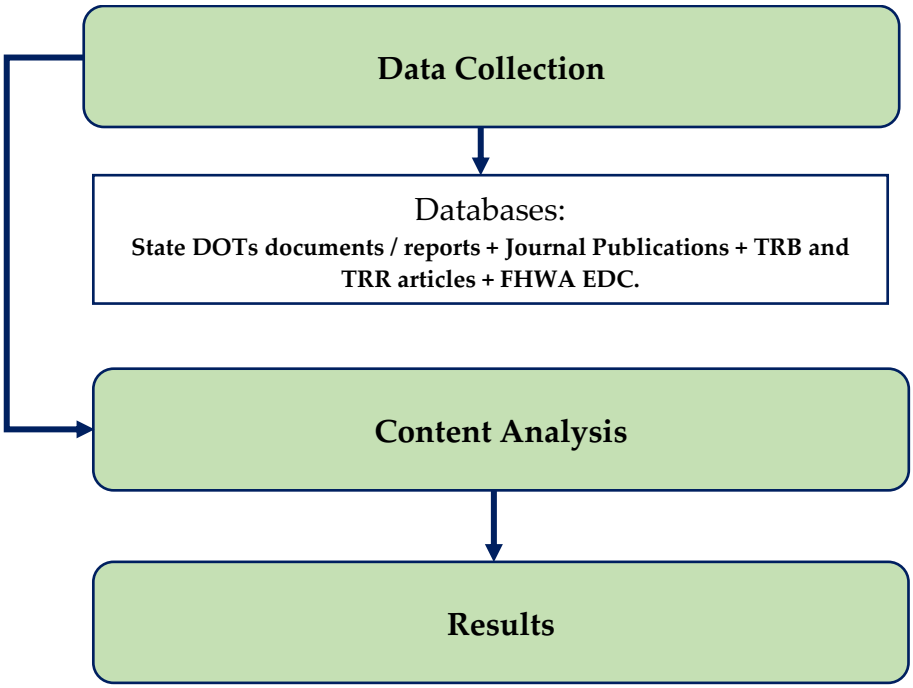
Accurate and timely bridge evaluations are essential for maintaining a safe and reliable bridge network, optimizing repair costs, and minimizing overall expenditures (Kim et al., 2013). Various emerging technologies, including geospatial tools, 3D/4D/5D modeling, Unmanned Aerial Systems (UAS), E-ticketing, Ground Penetrating Radar (GPR), LiDAR, GIS, and Augmented/Virtual Reality (AR/VR), have demonstrated efficiency in construction inspection processes (National Academies of Sciences, Engineering, and Medicine, 2022). Despite their potential, full-scale adoption of these technologies across state DOTs remains limited, resulting in an estimated annual cost of $1.3 billion to state DOTs nationwide (Zulifqar et al., 2014). Notably, Caltrans reported savings of $200,000 in 2021 from the effective use of UAS technology alone (Caltrans Efficiency Report 2020-21), indicating that broader implementation of other technologies could yield even greater savings.

This study seeks to assess the current state of emerging technologies adoption at state DOTs and explore the potential applications for highway construction and maintenance inspections, marking the first step in identifying effective strategies for improving their implementation. By investigating the current state of emerging technologies use in highway infrastructure construction and maintenance, state DOTs can gain valuable insights into what other agencies are implementing and learn from each other's experiences. This collaborative understanding is the first step toward identifying effective strategies for improving the adoption and integration of emerging technologies, ultimately enhancing inspection processes and maximizing the long-term benefits of transportation investments.

# 2. Research Methodology

This study aims to explore the emerging technologies that are being used and their current and potential applications for the construction and maintenance inspection of highway infrastructure. Accordingly, the study followed the approach as shown in Figure 1.

Figure 1. Research Methodology




First, the researchers developed the following research question that serves as a guide to accomplishing the research objective.

## Research Question

What are the potential applications of relevant emerging technologies for highway infrastructure construction and maintenance inspection?

## Data Collection

A comprehensive literature review was conducted, encompassing 96 publications, including academic research articles, technical reports, research reports, publications, manuals, and various documents from state Departments of Transportation (DOTs). The focus of this review was placed on the following key emerging technologies:

- Remote Sensing and Monitoring Technologies: Unmanned Aerial System (UAS) and Light Detection and Ranging (LiDAR)

- Building Information Modeling (BIM)
- Augmented Reality/Virtual Reality (AR/VR)

The authors collected 20 academic research articles (published between 2011 and 2022), five research reports (from NCHRP research publications), and 71 documents (from various state DOTs). The authors then performed content analysis to identify emerging areas of application and specific tasks that the emerging technologies can help with in highway infrastructure construction and maintenance inspection. The methodology involved three steps: (1) establishing selection criteria, searching, collecting, and selecting high-impact journals to review relevant research articles; (2) searching and collecting the relevant research reports and technical documents from State DOTs; and (3) screening the results and conducting a content analysis of selected articles, reports, and technical documents.

The authors selected academic journals in the areas of construction engineering and management, and transportation, with a Scopus Cite Score of 1.0 and above. For the research reports, the authors used two criteria: (1) the report is published based on federal research projects on highway construction inspection; and (2) the report involves discussing emerging technologies utilized in highway construction inspection. For state DOT technical reports, the authors used the criterion: (1) reports discussing applications and usage of emerging technologies for highway inspection purposes. The authors used keywords such as "highway inspection," "infrastructure construction inspection," and "emerging technologies in highway inspection" to identify the relevant articles. Then, after rigorous review and synthesis of several publications, the authors selected 20 research articles, five research reports, and 71 state DOT technical documents for further analysis.

Content Analysis

Once the research articles, research reports, and technical documents were identified, a detailed content analysis was conducted. Qualitative content analysis using NVIVO was conducted to identify the emerging technologies and their applications for highway infrastructure construction and maintenance inspections. Content analysis is a method for analyzing the content of a variety of data. It enables the reduction of phenomena or events into defined categories so as to better analyze and interpret the data. Content analysis can be both qualitative, usually in the developmental stages of research, and quantitative, where it is applied to determine the frequency of phenomena (Harwood and Tony, 2003). This study utilized both approaches, in order to quantify the current state of practice of emerging technology usage and to qualitatively understand applications of these emerging technologies. These methodological steps collectively form the foundation of the research's mission to shed light on the changing landscape of inspection technologies within the context of construction and maintenance, providing valuable insights for transportation agencies and construction inspection professionals.

# 3. Findings & Discussion

This section presents the results of the content analysis. The findings include inspection work types and activities related to the select emerging technologies, including: (a) Remote Sensing and Monitoring Technologies: Unmanned Aerial System (UAS) and Light Detection and Ranging (LiDAR); (b) Building Information Modeling (BIM); and (c) Augmented Reality/Virtual Reality (AR/VR). The number of discussed articles in paragraphs or tables to the total number of articles (i.e., 96 articles) is expressed as a percentage.

## 3.1 Findings

### *3.1.1 Highway Construction Inspection Activities Utilizing Emerging Technologies*

This section identifies the major highway construction and maintenance inspection activities that use emerging technologies mentioned in the reviewed publications. The inspection activities include construction progress monitoring, documentation of inspection results, comparing installed work with plans and specifications, job site safety inspections, training of highway construction inspectors, and others.

Table 1. Inspection Activities Utilizing Emerging Technologies

| Inspection Activity | Number of Publications |
|---|---|
| Construction Progress Monitoring | 55 |
| Comparing installed work with Plans, Specifications, Pay Quantities | 21 |
| Structural Inspections | 31 |
| Job site Safety Inspections | 17 |
| Training of Highway Construction Inspectors | 6 |

### *3.1.2 Highway Construction Work Types Using Emerging Technologies for Inspection*

This section examines the primary highway construction types of work that were mentioned in the research publications that utilized emerging technologies for inspection purposes. These include Earthwork, Bridges, Culverts, and Paving (both Hot Mix Asphalt (HMA) and Concrete Paving). The findings indicate that the highest number of articles mention the use of emerging technologies by state DOTs for the construction and maintenance of bridges (40%), followed by paving (35%), earthwork (15%), and subgrade (10%).

Table 2. Work Types Using Emerging Technologies

| Work Types | Number of Publications |
|---|---|
| Bridges | 38 |
| Paving – HMA & Concrete | 34 |
| Earthwork | 15 |
| Subgrade | 9 |

*3.1.3 Emerging Technologies Utilization at State DOTs for Inspection*

The findings indicate that all 50 states of the U.S. were found to have used at least one of these emerging technologies for inspection purposes. Moreover, only 18% of DOTs (9 out of 50) were utilizing all three types of select emerging technologies (Table 3).

Table 3. Emerging Technologies Used for Construction Inspection by State DOTs

| State DOTs | Remote Sensing and Monitoring | | BIM | AR/VR |
|---|---|---|---|---|
| | UASs | LiDAR | | |
| Alabama | X | X | X | |
| Alaska | X | X | X | X |
| Arizona | X | X | | |
| Arkansas | X | X | | |
| California | X | X | X | X |
| Colorado | X | X | X | X |
| Connecticut | X | X | X | |
| Delaware | | X | | |
| Florida | X | X | X | X |
| Georgia | X | X | | |
| Hawaii | | X | X | |
| Idaho | X | X | | |
| Illinois | X | X | | |
| Indiana | X | X | X | X |
| Iowa | X | | X | |
| Kansas | X | X | | |
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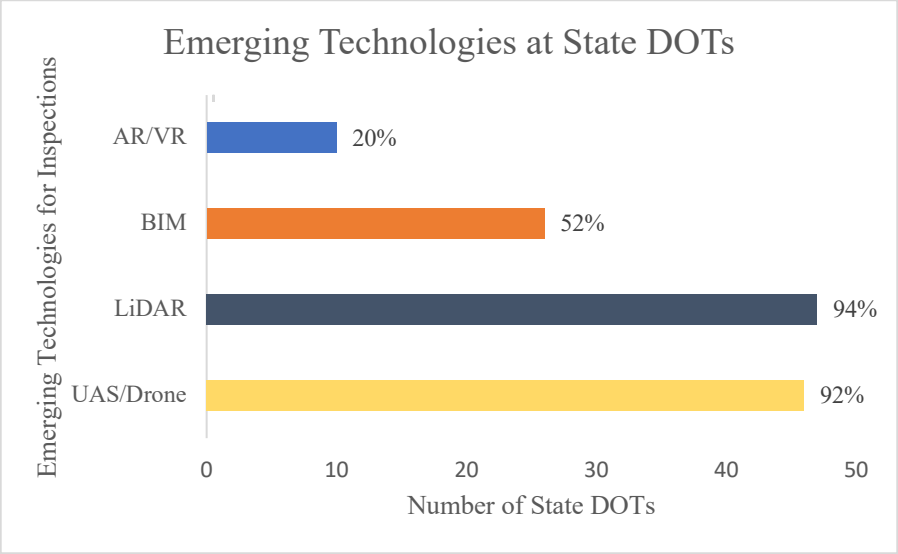
| Mississippi | X | X | | |
| Missouri | | X | | |
| Montana | X | X | X | |
| Nebraska | X | X | | |
| Nevada | X | X | | |
| New Hampshire | X | X | | |
| New Jersey | X | X | X | X |
| New Mexico | X | | | |
| New York | X | X | X | |
| North Carolina | X | X | | |
| North Dakota | X | X | | |
| Ohio | X | X | X | |
| Oklahoma | X | X | X | |

| State DOTs | Remote Sensing and Monitoring | | BIM | AR/VR |
|---|---|---|---|---|
| | UASs | LiDAR | | |
| Oregon | X | X | | X |
| Pennsylvania | X | X | X | X |
| Rhode Island | X | X | X | |
| South Carolina | X | X | | |
| South Dakota | X | | | |
| Tennessee | X | X | X | |
| Texas | X | X | X | X |
| Utah | X | X | X | |
| Vermont | X | X | X | |
| Virginia | X | X | X | X |
| Washington | X | X | | |
| West Virginia | X | X | | |
| Wisconsin | X | X | X | |
| Wyoming | X | X | | |

Also, the analysis of the various publications revealed that 92% (46 out of 50) of state DOTs had either deployed or explored UAS applications within their operations. Similarly, 94% (47 out of 50) of state DOTs were actively employing LiDAR technology for various inspection purposes. Moreover, BIM technology was in use by 52% (26 out of 50) of the state DOTs, while AR/VR technology had been implemented by 20% (10 out of 50) (Figure 2).

Figure 2. Emerging Technologies Implementation for Inspections at State DOTs



It has become evident that state Departments of Transportation (DOTs) have increasingly embraced using UASs, incorporating them into a diverse range of operational activities. This analysis has also revealed distinct categories of UAS applications and their associated uses within the domain of state DOTs, providing valuable insights into the evolving landscape of inspection technology. These categories and their corresponding applications are presented in Table 4.

Table 4. Applications of UASs at State DOTs for Inspections

| Category | Use/Application |
|---|---|
| Structural Inspection | Bridge inspection, powerline inspection, structural inspection |
| Surveying / Mapping | Surveys of construction sites, topographical surveys, aerial mapping |
| Progress Monitoring Inspection | Monitoring the progress of construction projects, engineering works, quality inspections, and control |
| Safety Inspections | Monitor for safety hazards for compliance with regulations |
| Traffic Monitoring and Inspections | Analyzing traffic flow, surveillance, and congestion for traffic management |
| Other Uses | Incidence response, delivery service, agricultural monitoring, documenting |

The widespread adoption of UAS technology by state DOTs highlights its versatility and effectiveness in enhancing inspection practices. Structural inspections, including bridge and powerline inspections, stand out as the most prevalent applications, indicating the critical role of UASs in ensuring the safety and integrity of transportation infrastructure.

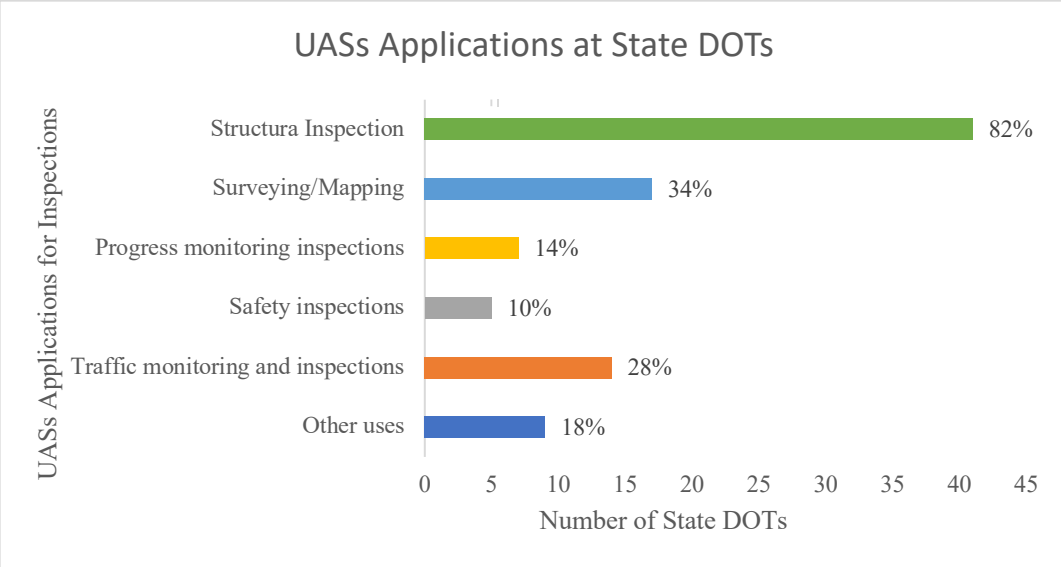
Surveying and mapping tasks also benefit significantly from UAS deployment, facilitating efficient data collection and analysis for construction site surveys, topographical mapping, and aerial mapping projects. Moreover, using UASs for progress monitoring inspections enables real-time monitoring of construction projects, enhancing project management and quality control efforts.

Regarding safety inspections, UASs offer a proactive approach to identifying safety hazards and ensuring compliance with regulations, thereby contributing to overall safety improvements on transportation networks. Additionally, the utilization of UASs for traffic monitoring and inspections aids in traffic management by providing valuable insights into traffic flow, congestion patterns, and surveillance of critical transportation corridors.

Beyond these traditional applications, state DOTs have explored innovative uses of UASs, including incidence response, delivery services, agricultural monitoring, and documentation tasks. These emerging applications highlight the adaptability of UAS technology to diverse operational needs within transportation agencies.

Among the 46 DOTs that have deployed UASs in their operations, the most common usage was for structural inspections/monitoring, employed by 41 state DOTs. In addition, drones were used for surveying/mapping by 17 state DOTs, while 14 states used them for traffic monitoring and inspections. Seven state DOTs found value in using UASs for progress monitoring and inspection documentation, with five and nine states utilizing them for safety monitoring and other purposes, respectively (Figure 3).

Figure 3. Deployment of UASs at State DOTs for Various Inspection Applications




Also, the analysis revealed the uses of LiDAR, as shown in Table 5.

Table 5. Applications of LiDAR at State DOTs for Inspections

| Category | Use/Application |
|---|---|
| Structural Inspection | Bridge inspection, infrastructure inspection |
| Surveying, Mapping, and Inspections | Surveys of construction site, precise topographical mapping, aerial mapping, digital elevation model (DEM) |
| Quantity Takeoff for Inspections | Volume and mass calculation, inventory takeoff |
| Asset Management Inspections | Collect asset (bridge, roadway, highway, railroad, etc.) inventory data for inspection purposes |
| Construction Progress Tracking for Inspections | Construction site monitoring, project timeline tracking, identifying deviations and percentage of completion for inspection documentation |
| Other Uses | Incidence response, agricultural monitoring, and inspection |

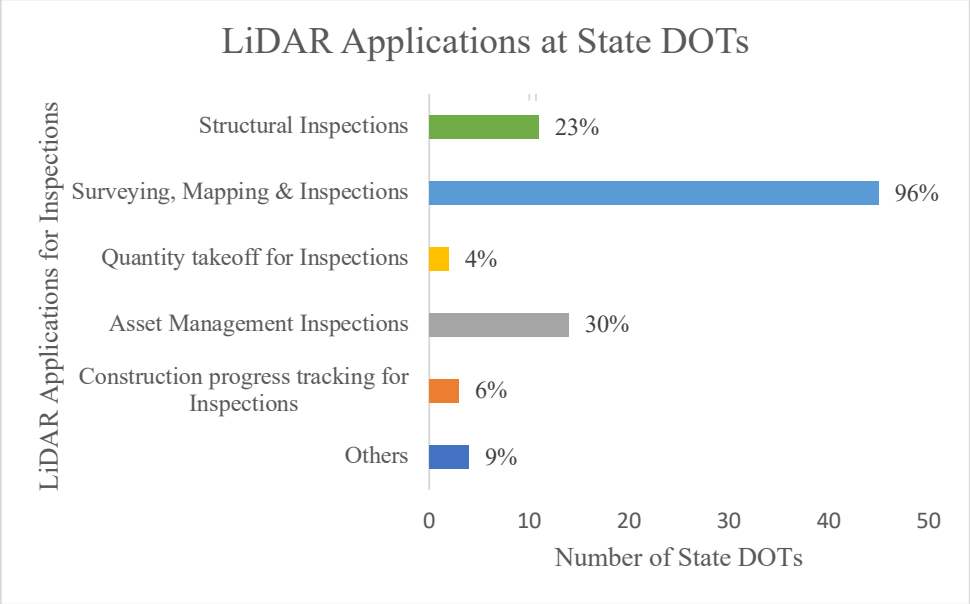
The use of LiDAR for surveying, mapping, and digital elevation modeling highlights its important role in facilitating precise data collection and analysis for various infrastructure projects.

Moreover, integrating LiDAR into asset management inspections enables state DOTs to collect and manage asset inventory data efficiently, contributing to effective infrastructure maintenance and management practices. Applying LiDAR in structural inspections further emphasizes its importance in ensuring the safety and integrity of transportation infrastructure, particularly in identifying potential structural defects and vulnerabilities.

Using LiDAR for construction progress tracking also provides state DOTs with valuable insights into project timelines and completion percentages, facilitating effective project management and documentation processes. Beyond these primary applications, state DOTs have explored innovative uses of LiDAR, including incidence response, agricultural monitoring, and other inspection tasks, demonstrating its adaptability to diverse operational needs within transportation agencies.

Among the 47 state DOTs incorporating LiDAR technology, the primary applications included surveying, mapping, and digital elevation modeling, adopted by 45 of these state DOTs. Asset management inspection purposes utilized LiDAR in 14 state DOTs, while structural inspection benefited from LiDAR in eleven states. Furthermore, LiDAR was applied by three states for construction progress tracking for inspections, while an additional four state DOTs used it for various other purposes, as illustrated in Figure 4.

Figure 4. Deployment of LiDAR at State DOTs for Various Inspection Applications




Moreover, the use of BIM was categorized under the following categories, as shown in Table 6.

Table 6. Applications of BIM at State DOTs for Inspections

| Category | Use/Application |
|---|---|
| Clash Detection / Coordination | Detection of clashes and conflicts in design plans, enhancing coordination and collaboration among stakeholders |
| Quantity Takeoff / Estimation | Material estimation, cost analysis, and budgeting for pay applications that will be used for inspection documentation |
| Inspection of Infrastructure | Develop inspection plans, assessment and analysis of infrastructures like bridges, roadways, highways, buildings, etc., and collect observations and measurements from BIM models for inspection documentation |
| Plan / Modeling for Inspection Purposes | Develop plans and models for construction inspection, prioritizing inspection tasks using a risk-based approach |
| Others | Operations management and storing as-built data for inspection and close-out documentation |

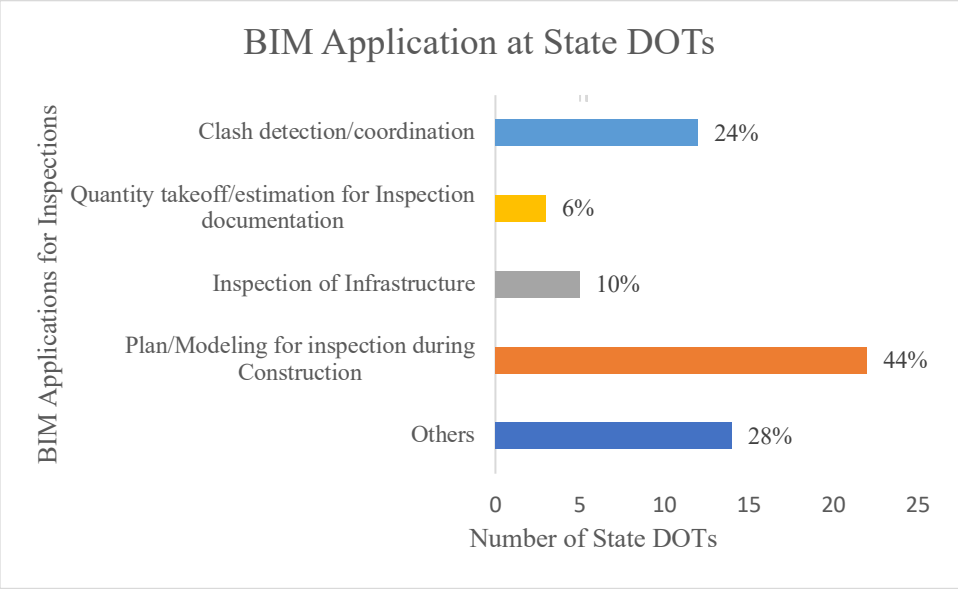
The predominant use of BIM for construction, design, and modeling purposes highlights its pivotal role in facilitating efficient project planning and execution, directly contributing to improved inspection practices throughout the project life cycle.

Moreover, the application of BIM for clash detection and coordination demonstrates its capability to enhance collaboration among project stakeholders, thereby reducing the likelihood of design conflicts and delays during construction. Additionally, using BIM for infrastructure inspection purposes enables state DOTs to develop comprehensive inspection plans and conduct thorough assessments of critical infrastructure assets, ensuring their safety and longevity.

Furthermore, integrating BIM into quantity takeoff and estimation tasks streamlines cost analysis and budgeting processes, providing state DOTs with accurate and reliable data for inspection documentation and pay applications. Beyond these primary applications, state DOTs have leveraged BIM for operations management, maintenance, and storing as-built data, showcasing its adaptability to diverse operational needs within transportation agencies.

Among the 26 state DOTs implementing Building Information Modeling (BIM) technology, 22 predominantly utilized it for construction, design, and modeling activities. These models were employed for inspection purposes across pre-construction, construction, and post-construction phases. 14 DOTs applied BIM for operations management and maintenance, while 12 used it for clash detection and coordination. Additionally, five DOTs utilized BIM for infrastructure inspection purposes, and three employed it for quantity takeoff and estimation tasks that can be used for inspection documentation, as illustrated in Figure 5.

Figure 5. Deployment of BIM at State DOTs for Various Inspection Applications




Similarly, the categories for the use of AR/VR are classified as shown in Table 7.

Table 7. Applications of AR/VR at State DOTs for Inspections

| Category | Use/Application |
|---|---|
| Plan/Design/Visualize for Inspections | Planning and designing of structures, visualization of models that can be used for inspections during the construction phase |
| Progress Monitoring for Inspection Documentation | Tracking construction progress and identifying defects/clashes for inspection purposes and documentation |
| Automated Inspection | Automated inspection of construction sites and infrastructure using AR/VR |
| Remote/Virtual Inspection | Conduct virtual/remote inspection, remote collaboration for highway construction and maintenance inspection |
| Virtual Inspection Training and Skill Development | Training workers in a virtual environment for infrastructure inspections, safety inspection training, and skill development training |

The use of AR/VR for planning, design, and visualization underscores its effectiveness in facilitating the conceptualization and communication of project plans, enabling stakeholders to visualize structures and identify potential issues before construction begins.

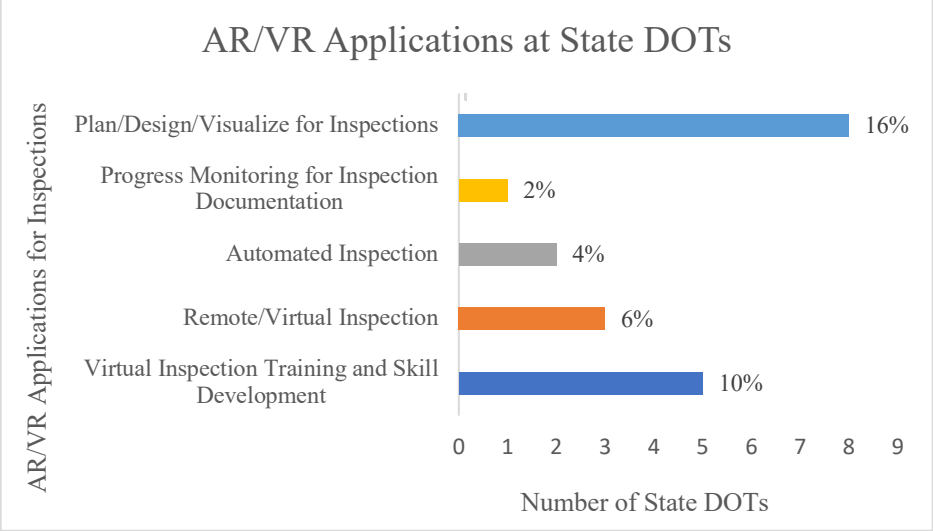
Furthermore, adopting AR/VR for inspection training and skill development enhances workforce proficiency and safety awareness within transportation agencies. By providing workers with immersive training experiences in a virtual environment, state DOTs can improve inspection efficiency and accuracy while minimizing on-site risks and errors.

Additionally, using AR/VR for remote inspections and collaboration demonstrates its utility in overcoming geographical barriers and facilitating real-time communication among project teams. Moreover, the application of AR/VR for automated inspection processes streamlines inspection procedures, enabling state DOTs to conduct comprehensive assessments of construction sites and infrastructure assets with greater efficiency and precision.

While the adoption of AR/VR for progress monitoring remains limited, its potential to revolutionize construction progress tracking and defect identification holds promise for future applications within transportation agencies.

Among the 10 state DOTs using AR/VR technology, eight primarily utilized it for planning, design, and visualization purposes that can be later used for inspection. Five of them employed AR/VR for inspection training and skill development within a virtual environment. Additionally, three state DOTs used AR/VR for remote inspections, while two adopted it for automated inspection processes. Lastly, only one state DOT was identified as using AR/VR for progress monitoring, as shown in Figure 6.

Figure 6. Deployment of AR/VR at State DOTs for Various Inspection Applications




## 3.2 Discussion

The findings of this study highlight the growing adoption of emerging technologies among state Departments of Transportation (DOTs) for highway infrastructure inspection, with notable variations in the degree and scope of technology use. The widespread deployment of technologies such as Unmanned Aerial Systems (UAS) and Light Detection and Ranging (LiDAR) demonstrates that state DOTs are recognizing the value of these tools for enhancing the efficiency and accuracy of inspections. However, the lower adoption rates of technologies like Building

Information Modeling (BIM) and Augmented Reality/Virtual Reality (AR/VR) suggest that there is still significant untapped potential for improving inspection practices across the nation.

The analysis indicates that UAS and LiDAR are predominantly used for structural inspections, surveying, and progress monitoring—critical activities for ensuring the safety and quality of highway infrastructure. UAS, in particular, is widely adopted, with 92% of state DOTs either deploying or exploring its use. This technology's versatility in structural inspections, surveying, and even traffic monitoring highlights its potential to streamline inspection operations and reduce costs. Similarly, the widespread use of LiDAR technology (94% of state DOTs) underscores its importance in precise surveying and mapping, as well as its applications in asset management and construction progress tracking inspections.

Despite these successes, the study reveals a significant gap in the adoption of BIM and AR/VR technologies. With BIM used by only 52% of state DOTs and AR/VR by just 20%, there remains substantial room for growth. BIM's applications for inspecting clash detections, verifying pay quantities with actual quantity takeoff, and other inspections are crucial for improving not just inspections but also project coordination. However, the limited adoption suggests that state DOTs may face challenges in integrating BIM fully into their workflows, possibly due to resource constraints or a lack of skilled personnel trained in these technologies.

The even lower adoption of AR/VR technologies is perhaps the most striking finding, given the potential of these tools for remote inspections, progress monitoring, and virtual training. AR/VR offers innovative solutions for overcoming geographical barriers and enhancing workforce development through immersive training. The limited use of AR/VR (20% of state DOTs) indicates that while the potential is recognized, further efforts are needed to facilitate its integration into routine inspection activities.

The study also underscores the importance of cross-agency learning and collaboration. By sharing insights and experiences, state DOTs can accelerate the adoption of emerging technologies and overcome common barriers. For instance, agencies that have successfully implemented UAS or LiDAR could provide valuable guidance on best practices and lessons learned, enabling others to replicate their success. Similarly, the broader adoption of BIM and AR/VR could be supported by sharing knowledge on effective implementation strategies, including addressing the technical and organizational challenges that may hinder wider usage.

Overall, the findings highlight both the progress made and the opportunities that remain for state DOTs to fully leverage emerging technologies in highway construction and maintenance inspections. Increased adoption of BIM and AR/VR, in particular, could yield significant benefits, including enhanced project coordination, cost savings, and improved safety outcomes. Moving forward, strategic planning, training, and inter-agency collaboration will be key to ensuring that all state DOTs can take full advantage of these technological advancements, maximizing the long-term benefits of transportation investments.

# 4. Conclusions

This study provides a comprehensive overview of the current state of emerging technology adoption by state Departments of Transportation (DOTs) for highway infrastructure construction and maintenance inspections. The research identified Unmanned Aerial System (UAS), Light Detection and Ranging (LiDAR), Building Information Modeling (BIM), and Augmented Reality/Virtual Reality (AR/VR) as four major emerging inspection technologies being implemented at state DOTs. Of the identified technologies, only 18% (9 out of 50) of the state DOTs were using all four. Also, 92% of state DOTs were using UASs, 94% were using LiDAR technology, 52% were using BIM, and only 20% of state DOTs were using AR/VR technology.

The research highlights the substantial progress made with technologies like Unmanned Aerial Systems (UAS) and Light Detection and Ranging (LiDAR), which have been widely implemented across the country. These technologies are revolutionizing key inspection activities, such as structural inspections, surveying, and progress monitoring, offering significant improvements in efficiency, accuracy, and cost savings.

However, the study also reveals that technologies such as Building Information Modeling (BIM) and Augmented Reality/Virtual Reality (AR/VR) are underutilized, with adoption rates significantly lower than those of UAS and LiDAR. This presents a critical opportunity for state DOTs to explore and expand the use of these technologies, which have the potential to greatly enhance project coordination, cost estimation, and inspection processes. AR/VR, in particular, offers promising applications in remote inspections and training, areas that can address workforce shortages and improve safety.

The findings of this research underscore the importance of strategic planning, training, and inter-agency collaboration to overcome the barriers to wider adoption of these advanced technologies. By sharing experiences and best practices, state DOTs can accelerate the integration of BIM and AR/VR into their operations and maximize the benefits of their transportation investments.

In conclusion, while significant strides have been made in the adoption of emerging technologies, there remains considerable potential for further advancements. To fully realize the benefits of these tools, state DOTs must continue to innovate, collaborate, and invest in the implementation of cutting-edge inspection technologies. Doing so will not only enhance the efficiency and effectiveness of their inspection processes but also contribute to the development of safer, more resilient infrastructure for the future.

# Abbreviations & Acronyms

| | |
|---|---|
| AR | Augmented Reality |
| BIM | Building Information Modeling |
| Caltrans | California Department of Transportation |
| DEM | Digital Elevation Model |
| DOT | Department of Transportation |
| EDC | Every Day Counts |
| FHWA | Federal Highway Administration |
| GIS | Geographic Information System |
| GPR | Ground Penetrating Radar |
| LiDAR | Light Detection and Ranging |
| SB 1 | Senate Bill 1 |
| TRB | Transportation Research Board |
| TRR | Transportation Research Record |
| UAS | Unmanned Aerial System |
| UAV | Unmanned Aerial Vehicle |
| VR | Virtual Reality |

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