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Assessing Building Information Modeling (BIM) Maturity and Identifying Barriers to Implementation among Transportation Agencies in Region 6

Southern Plains Transportation Center

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16. Abstract Despite the significant benefits of Building Information Modeling (BIM) in the transportation sector, its widespread adoption faces several challenges. Key barriers include technological limitations, such as integrating BIM with legacy systems, and organizational issues, like resistance to change and a lack of skilled personnel. The fragmented nature of transportation projects, involving numerous stakeholders and diverse project phases, further complicates BIM implementation. The absence of a unified framework for BIM adoption and implementation has led to inconsistent maturity levels across Departments of Transportation (DOTs), hindering effective evaluation and improvement of digital delivery practices. This research was conducted to develop a systematic BIM implementation framework aligned with the FHWA National Strategic Roadmap for regional DOTs, with a focus on Region 6. Although many State DOTs in the region have adopted data-collection technologies for specific project phases, there is a gap in integrating and utilizing data across the project lifecycle. The project research goals were to (1) review literature to develop BIM competency metrics, (2) collect and analyze data on the current state of BIM implementation in Region 6, and (3) create an actionable BIM implementation framework based on the maturity assessments in Region 6. Data was collected through a survey and follow-up discussions with each State DOT in the region, offering valuable insights into their BIM practices and maturity levels. The resulting framework outlines practical steps for advancing BIM adoption in alignment with the FHWA National Strategic Roadmap, addressing key barriers and supporting the evolution of BIM practices across the region.		
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ASSESSING BUILDING INFORMATION MODELING (BIM) MATURITY AND IDENTIFYING BARRIERS TO IMPLEMENTATION AMONG TRANSPORTATION AGENCIES IN REGION 6

FINAL REPORT
SPTC Project Number: CY1-UTEP-03

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List of Abbreviations and Acronyms

3D ______________Three Dimensional
AEC ______________Architecture, Engineering and Construction
AMG ______________Automated Machine Guidance
AVL ______________Automated Vehicle Location
ARDOT ___________Arkansas Department of Transportation
BEOP____________ BIM Excellence Online Platform
BIM ______________Building Information Modeling
CAD ______________Computer-aided Design
CPIx______________CPIx BIM Assessment Form
DBO ______________Design, Build, and Operate
DOT ______________Department of Transportation
EPISD ____________El Paso Independent School District
IFC ______________Industry Foundation Classes
IRB_______________Institutional Review Board
FHWA ____________Federal Highway Administration
GIS ______________ Geographic Information Systems
LIDAR ____________Light Detection and Ranging
LDOT_____________Louisiana Department of Transportation
DBO ______________Design, Build, and Operate
MMSAQ___________Maturity Matrix: Self-Assessment Questionnaire
MPO _____________ Metropolitan Planning Organization
NBIMS ____________National Institute of Building Sciences
NMDOT ___________New Mexico Department of Transportation
ODOT ____________Oklahoma Department of Transportation
OBA ______________Organizational BIM Assessment
O & M ____________Operation and Maintenance
ROI ______________Return on Investment
TxDOT ___________ Texas Department of Transportation
TRIP _____________Transportation Research Immersive Program
UAVs_____________Unmanned Aerial Vehicles

Executive Summary

The integration of Building Information Modeling (BIM) in transportation projects has emerged as an innovative force capable of significantly enhancing efficiency and data-driven decision-making across the entire project lifecycle. As a collaborative, data-rich 3D platform based on open standards, BIM has the unique potential to seamlessly connect design, construction, and operational data. In particular, the transportation sector, which has historically lagged behind industries such as architecture and construction in adopting BIM, stands to gain substantial benefits from the broader use of this technology. By utilizing BIM, transportation projects can improve coordination, reduce errors, and optimize resource allocation, leading to faster project delivery and lower overall costs. Moreover, BIM's capacity to provide real-time data analysis and predictive insights can play a pivotal role in enhancing performance by informing decisions that reduce waste, energy consumption, and other impacts throughout a project's lifecycle.

Despite the considerable advantages, the systematic and consistent adoption of BIM within the transportation sector presents a range of challenges. These include technological barriers, such as the integration of BIM with legacy systems, and organizational hurdles, such as resistance to change and a lack of trained personnel. Additionally, the fragmented nature of transportation projects, often involving numerous stakeholders, complex regulatory requirements, and diverse project phases, can complicate the smooth implementation of BIM processes. While the potential for BIM to revolutionize the sector is clear, overcoming these obstacles requires a concerted effort across industry stakeholders, including policymakers, technology developers, and practitioners, to establish frameworks, standards, and training programs that support widespread adoption. Historically, one of the most significant barriers to realizing the full potential of BIM in the transportation sector is the lack of a unified, systematic framework for implementation. The absence of such a framework has resulted in inconsistent BIM maturity levels across Departments of Transportation (DOTs), making it difficult to evaluate the progress and identify key areas for improvement in digital delivery practices

The overarching purpose of this project is to provide a systematic BIM implementation framework to regional DOTs at the organizational level based on a comparative BIM maturity assessment across the region. Within Region 6, many State DOTs have embraced various data-collection technologies for specific project phases. However, there remains a considerable gap in achieving systematic and life cycle data collection and utilization. The challenge lies in consolidating and integrating data from different phases to establish a comprehensive and collaborative project ecosystem that maximizes the benefits of digitalization. To overcome these obstacles, a concerted effort is needed to document the state of BIM adoption in Region 6 and provide a comprehensive overview of the potential barriers to systematic implementation. Specific project objectives are as follows:

- RO1: Review existing literature to construct BIM competency metrics

- RO2: Collect and analyze data to understand the current BIM implementation status within Region 6 DOTs
- RO3: Prepare a BIM implementation framework based on BIM maturity assessment

To assess the BIM maturity levels across various State DOTs in Region 6, data were collected through the regional survey. The process began with a thorough review of relevant documents and the determination that the survey did not need to be submitted for Institutional Review Board (IRB) approval as the respondents were providing factual responses on behalf of an agency. The survey was distributed to representatives from the digital delivery teams at each regional DOT, who were tasked with providing insights into their organizations' BIM practices and maturity levels.

A BIM implementation framework was crafted based on the insights gathered from the regional survey and the BIM maturity assessment. It clearly outlined actionable steps that each DOT can undertake to advance its BIM capabilities in alignment with the FHWA National Strategic Roadmap.

Key Insights:

- Transportation agencies in Region 6 struggle to achieve higher levels of BIM maturity without having a clearly defined mission, vision, goals, and objectives. These foundational elements are critical for guiding the integration of BIM across various stages of project delivery. Without a clear strategic framework, many agencies are unable to establish effective guidelines for their employees.
- BIM tools must also be regularly updated and compatible with new hardware to ensure that the technology remains effective and efficient. All the Region 6 DOTs agree that organizational support is crucial, especially in maintaining system and server operations, as well as in supporting the use of BIM tools across the agency.
- Employee acceptance of new, integrated design methods is essential. This requires providing education and training opportunities for those who will be working directly with BIM tools. Moreover, most of the Region 6 State DOTs emphasized that data collection methods need to be standardized across the agency to ensure that data is interoperable with BIM environments and can be easily shared with external stakeholders, such as contractors and consultants.
- One of the most significant challenges identified by the Region 6 State DOTs is the lack of standardization in BIM terminology and practices across transportation agencies. This lack of uniformity in terms, processes, and methodologies has created confusion and fragmentation, hindering the effective adoption of BIM at scale. Overcoming this challenge will require concerted efforts from all involved agencies, including the development of common standards and the sharing of best practices and lessons learned.

Chapter 1. Introduction

Background

Initially a tool for design, BIM has transformed into a comprehensive platform that integrates design, construction, and operations data throughout the life cycle of an infrastructure asset (Davis 2007; Augenbroe 2009; Boon & Prigg 2012; RICS 2015; Aziz 2017; PricewaterhouseCoopers 2018; Pirdavani et al. 2023). BIM Level 2 Benefits Measurement Introductory note: Approach and benefits framework). This digital conduit allows project teams to virtually construct projects before actual construction, mitigating traditional errors and enhancing productivity. The integration of BIM data across the design, build, and operate (DBO) supply chain benefits all stakeholders, providing a reliable digital record for the asset's entire life span. BIM's focus on connecting project and asset data is crucial, but its true value lies in its ability to integrate with other project delivery dimensions such as scheduling, productivity, and operations.
This integration, coupled with advancements in cloud storage and mobile technology, has expanded BIM's potential, making it a multidimensional tool that supports process optimization and data interoperability.

According to a 2017 report by Dodge Data & Analytics, the top benefit of BIM is its ability to educate younger staff on project assembly, leading to fewer errors (Laquidara-Carr 2017). Successful BIM implementation requires foundational changes in both technical and non-technical aspects of project delivery, operations, and maintenance (Figure 1). On the technical side, the core components of BIM include 3D computer-aided design (CAD), intelligent models, and effective information management systems. These tools enable teams to visualize the project in greater detail, enhance accuracy, and ensure that all relevant data is seamlessly integrated and easily accessible.

However, the technical foundation alone is not enough. Equally critical are the non-technical elements that support BIM’s effectiveness. These include fostering a condition of synchronous collaboration, where all project stakeholders, from architects and engineers to contractors and owners, work together, sharing insights and making decisions based on a single, unified model. Coordinated work practices are also vital to ensuring that all team members are aligned and that their efforts are harmonized throughout the project lifecycle.

In addition, institutional and cultural frameworks play a key role in enabling successful BIM adoption. This includes the development of organizational policies that support BIM processes, along with a culture that encourages innovation, transparency, and continuous learning. These factors help create the conditions for effective BIM deployment and ensure that the technology is fully leveraged to improve outcomes.

The BIM integration in transportation projects has emerged as a transformative tool with the potential to enhance efficiency and data-driven decision-making throughout the entire project lifecycle. BIM, a collaborative 3D platform based on open standards, has the potential to enable the seamless integration of design, construction, and operational data, allowing for more effective project planning, execution, and management (Chong et al. 2016; Costin et al. 2018; Biancardo et al. 2020; Castañeda et al. 2021; Laquidara-Carr 2017). The transportation sector, historically slow in adopting BIM compared to other industries like architecture and construction, stands to gain significantly from the widespread adoption of this technology. However, despite the promising potential of BIM, the systematic and consistent implementation of BIM in the transportation sector remains a challenge.

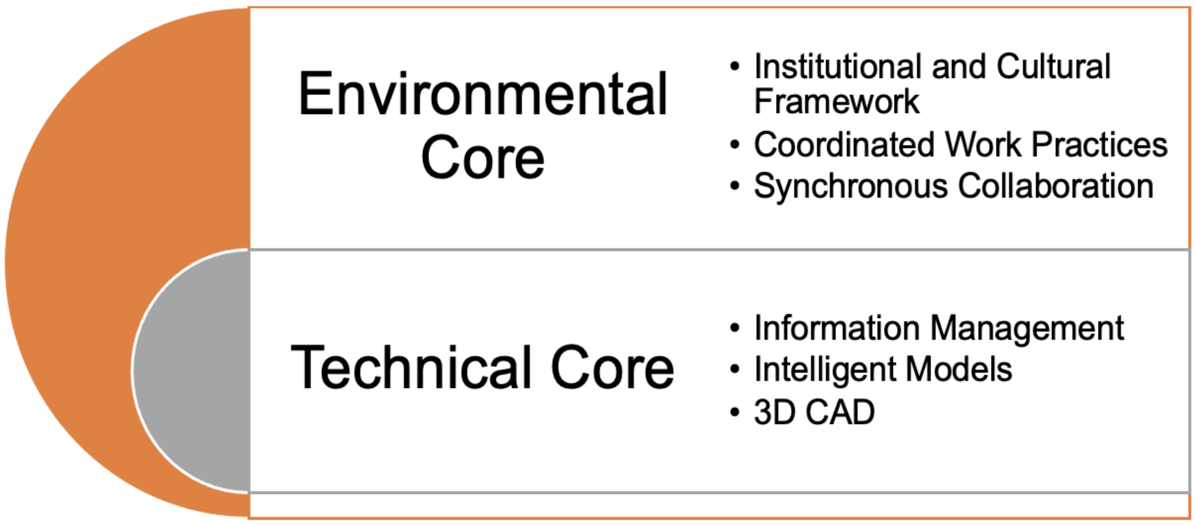


Figure 1 Environmental and Technical Components of BIM (Adapted from Wood 2020)

Despite the increasing interest in BIM, the transportation sector's adoption has been hindered by several barriers, including fragmented data collection, inconsistent application of BIM standards, and a lack of integrated workflows across different phases of a project (Costin et al. 2018; Moreno et al. 2020). Many state DOTs have embraced advanced data collection tools such as geographic information systems (GIS), automated vehicle location (AVL) systems, unmanned aerial vehicles (UAVs), LIDAR (light detection and ranging) mobile mapping systems, automated machine guidance (AMG), and construction management software for specific phases (Mallela et al. 2018; Fuller et al. 2019; Martin et al. 2020; Jahanger 2023). However, these tools often operate in silos, limiting their potential for creating a cohesive, data-driven approach that can inform decisions throughout the entire project lifecycle (Costin et al. 2018; Djuedja et al. 2019; Patel et al. 2021).

Historically, one of the most significant barriers to realizing the full potential of BIM in the transportation sector is the lack of a unified, systematic framework for implementation. The absence of such a framework has resulted in inconsistent BIM maturity levels across DOTs, making it difficult to evaluate the progress and identify key areas for improvement in digital delivery practices. Furthermore, despite the availability of national BIM guidelines and roadmaps, many regional DOTs are still grappling with the complexities of translating these guidelines into actionable, context-specific strategies (NIBS 2015; O'Brien et al. 2016; Costin et al. 2018)

Research Objectives

The overarching purpose of this project is to provide a systematic BIM implementation framework to regional DOTs at the organizational level based on a comparative BIM maturity assessment across the region. Within Region 6, many State DOTs have embraced various data-collection technologies for specific project phases. However, there remains a considerable gap in achieving systematic and life cycle data collection and utilization. The challenge lies in consolidating and integrating data from different phases to establish a comprehensive and collaborative project ecosystem that maximizes the benefits of digitalization. To overcome these obstacles, a concerted effort is needed to document the state of BIM adoption in Region 6 and provide a comprehensive overview of the potential barriers to systematic implementation. Specific project objectives are as follows:

- RO1: Review existing literature to construct BIM competency metrics
- RO2: Collect and analyze data to understand the current BIM implementation status within Region 6 DOTs
- RO3: Prepare a BIM implementation framework based on BIM maturity assessment

To achieve these objectives, the project has leveraged survey-based data collection and conducted comparative data analysis. The research team has collaborated with Region 6 DOTs to gather insights into current BIM practices and implementation challenges.

Research Tasks

This project consists of four tasks (Figure 2):

Task 1: Review the literature to construct competency matrices for each of the essential components required to attain BIM maturity. For the study, the team has focused on the competency elements specified in the national BIM roadmap, including *skills, tools and technologies, data and standards, and policies and procedures.*

Task 2: Collect data through a regional survey to establish the BIM maturity levels of various DOTs. The survey was submitted for the IRB review process at UTEP before it was shared with the regional DOTs (representatives of digital delivery efforts at each State DOT). Leveraging the data collected through the regional survey, the team has drawn comparisons in BIM usage across various state DOTs, identifying trends, strengths, and gaps.

Task 3: Assessment of BIM maturity levels. Each competency element was assessed using the levels described in the FHWA Roadmap (L0 – Document Oriented, L1 – Object Oriented, L2 – Federated Object Models and Databases, and L3 – Integrated Lifecycles) to promote a standard method of assessment that the FHWA seeks to implement. The assessment for each regional DOT was compiled in a graphical color color-coded format to make comparisons for each competency element. The implementation gaps and priority areas were highlighted for improvement at the organizational level.

Task 4. Develop a BIM Level 2 implementation framework. The final task involved the development of a BIM Level 2 implementation framework, completed with prioritized action items. This framework was crafted based on the insights gathered from the regional survey and the BIM maturity assessment.

Structure of Report

This report has seven chapters:

- Chapter 1 provides an introduction to the project background, project objectives, research tasks, and limitations.
- Chapter 2 presents a review of existing research on BIM adoption, maturity models, and implementation challenges for transportation agencies.
- Chapter 3 describes the research design, survey development, and data collection
- Chapter 4 documents the data analysis and discusses the results
- Chapter 5 summarizes the study's contributions and offers recommendations for future research and practice.
- Chapter 6 discusses the benefits of implementing the findings and recommendations from this research.
- Chapter 7 provides an overview of the community engagement and outreach activities performed for the underserved student population in El Paso as a result of this study.

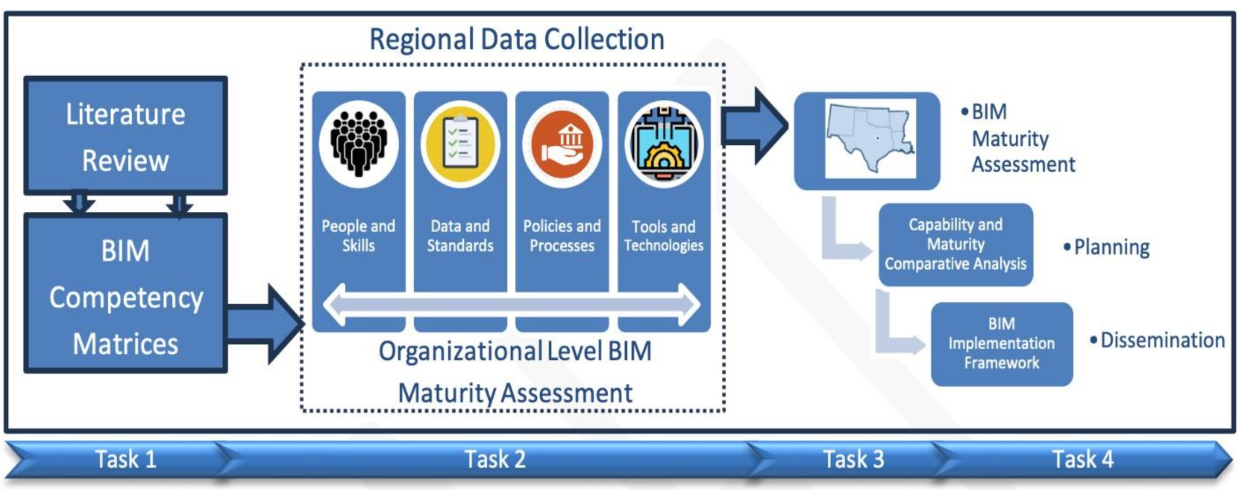


Figure 2 Research Tasks

Chapter 2. Literature Review

BIM maturity refers to the ongoing journey of improvement, evolution, and refinement within the realm of BIM implementation. It signifies a commitment to enhancing several key aspects, namely quality, repeatability, and predictability, all of which are intricately tied to an organization's BIM capability. The competency metrics are integral to shaping a holistic organizational structure and encompass a wide array of critical elements.

Building Information Modeling (BIM)

Building Information Modeling is widely used by the Architecture, Engineering, and Construction (AEC) industry to elevate the quality of work in the planning, design, construction, and operation and maintenance (O&M) of infrastructure (Mitchell et al. 2022). BIM is a modern, model-based approach that encourages all people involved in a project to share their work in a common space to optimize the phase times and decrease the overall cost of a project by capturing errors before construction begins and delivering more accurate calculations. Although BIM has a fair share of benefits, its implementation has proven to be a challenge in the AEC sector (Abumoeilak & Beheiry, 2023) due to the non-standardization of its nature in its current form in the United States. Many agencies have adopted, to some degree, digitalizing their work in the design and construction phases, but that alone is only a small portion of the holistic view of a project (Shou et al. 2015).

BIM Capability and Maturity Levels

To better understand the components that define BIM Maturity Levels, it is essential to first grasp the concept of BIM Capability. BIM Capability represents the baseline competency required by an organization to achieve a quantifiable level of performance in BIM. This capability is assessed through three BIM stages, as illustrated in Figure 3.

- *Stage 1*: This stage characterizes organizations that have begun to use some form of 3D modeling software. At this level, the organization demonstrates foundational digital modeling practices, which serve as a starting point for more advanced BIM processes.
- *Stage 2*: This stage highlights the collaborative mechanisms within the organization that allow stakeholders to work together using information from the model. Although the shared data might not yet be fully interoperable, tools are in place to facilitate teamwork and interaction around a common model, ensuring a more integrated workflow.
- *Stage 3*: This stage reflects the organization’s ability to adopt network-based solutions for sharing object-based models seamlessly. At this level, models from various sources use standardized definitions and objects, enabling full interoperability. This advanced capability reduces inefficiencies, significantly improving the speed and accuracy of the design process (Succar, 2010).

Understanding these stages is fundamental, as they provide the framework for evaluating an organization's progression in leveraging BIM effectively. Proficiency of these capabilities paves the way for achieving higher levels of BIM maturity, ultimately fostering efficiency and innovation in construction workflows.

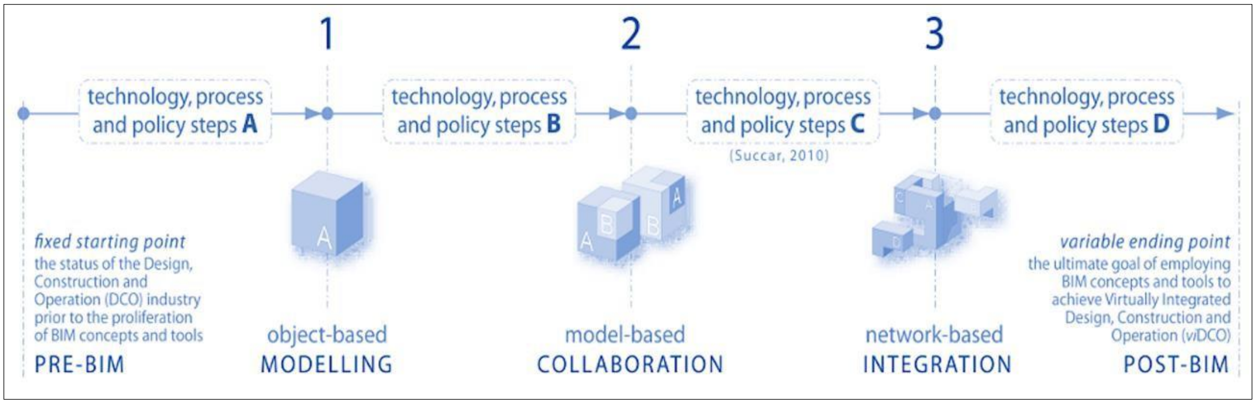


Figure 3 Stages of BIM for Capability Assessment (Succar, 2010)

BIM Maturity represents an organization's level of quality, excellence, and repeatability in its application of BIM practices. This concept, illustrated visually in Figure 4, highlights the progression from foundational competency to highly refined and consistent performance. While *BIM Capability* defines the foundational ability of an organization to implement BIM, *BIM Maturity* evaluates the degree to which that ability has been refined and standardized to deliver consistent and high-quality outcomes. The benchmarks for assessing BIM Maturity are defined by performance levels that organizations aim to achieve. As an organization advances in its maturity, it gains better control over the discrepancies between its performance targets, established during the pre-design phase, and actual project outcomes. Increased maturity reflects an organization's growing competency to minimize variations and optimize processes by leveraging insights and lessons learned from previous projects. This approach enhances performance, improves accuracy, and leads to better cost management. Moreover, as organizations strive for greater maturity, they prepare to tackle more complex challenges with increasing efficiency and effectiveness, ultimately driving their pursuit of excellence (McCormack et al., 2008).

The levels of BIM Maturity, as shown in Figure 4, are commonly categorized into five stages, a framework widely adopted in European countries. It starts from a rudimentary "Ad-hoc" stage to culminate in an "Optimized" stage. Each stage represents a level of sophistication in how BIM is implemented and utilized within a construction project or organization.

- *Ad-hoc*: BIM is used in an isolated or experimental manner, often limited to specific tasks or departments. There may be a lack of clear standards or procedures for BIM usage.
- *Defined*: Basic standards and processes are established for BIM usage. There is a growing awareness of BIM's potential benefits, but implementation may still be inconsistent.

- *Managed*: BIM processes are formalized and integrated across different project phases. There is a focus on data quality and consistency.
- *Integrated*: BIM is fully integrated into the project lifecycle, enabling seamless information exchange and collaboration among stakeholders.
- *Optimized*: BIM is used strategically to optimize project performance, improve decision-making, and achieve significant business value. Continuous improvement and innovation are emphasized.

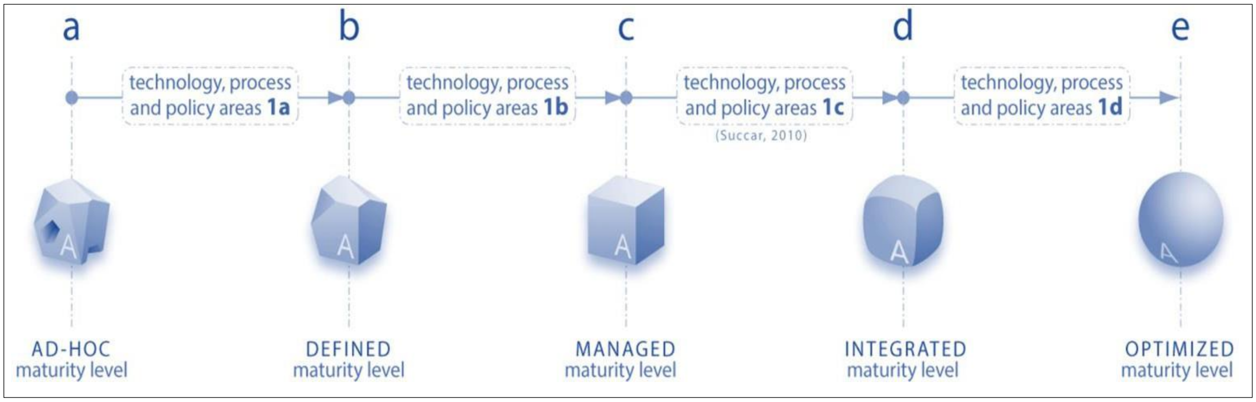


Figure 4 BIM Maturity Levels (Succar, 2010)

Methods and Tools to Analyze BIM Maturity

In recent years, the methods for analyzing BIM maturity and evaluating its benefits have significantly expanded. This growth can be attributed to the increasing recognition of BIM as a powerful tool for enhancing project delivery quality and providing strategic guidance for successful BIM implementation within organizations (Kassem et al., 2020). Despite these advancements, many existing tools have yet to be extensively applied in the domains of infrastructure and asset management. Consequently, there is limited evidence to demonstrate their effectiveness in assessing BIM maturity for these specific areas. This gap highlights the need for further exploration to determine the applicability and value of these tools in broader contexts. Maturity tools and methods differ in their application and functionality when evaluating BIM maturity levels (Table 1):

- *Maturity Tools*: These typically come with dedicated platforms to facilitate accessibility and usability for organizations. Examples include online surveys and interactive Excel workbooks, which allow users to systematically assess maturity levels by following pre-defined criteria and metrics. These platforms provide a structured and repeatable means of gathering data, analyzing results, and generating insights.
- *Maturity Methods*: In contrast, maturity methods often lack a standardized or widely available platform for conducting assessments. While they may offer valuable conceptual frameworks and methodologies, their effectiveness depends on the organization’s ability to manually implement these methods, which may result in inconsistencies and limited scalability.

Table 1 Existing Methods and Tools to Analyze BIM Maturity (Adapted from Kassem et al., 2020)

Tool	**Researchers/Developers**	**Type**	**Application**
Owner's BIMCAT (Competency Assessment Tool)	Brittany Giel and Raja R. A. Issa	Maturity method	Organization
BIM Maturity Assessment Tool	Department for Transport	Maturity method	Organization
Building Information Modeling Cloud Score (BIMCS)	Jing Du, Rui Liu and Raja R. A. Issa	Maturity method	Organization
Organizational BIM Assessment Profile	Pennsylvania State University	Maturity method	Organization
BIM Excellence Online Platform	ChangeAgents AEC	Maturity tool	Organization, Project
BIM Online Maturity Assessment	National Federation of Builders (NFB)/CITB	Maturity tool	Organization
BIM Supporters' BIM Compass	BIM Supporters	Maturity tool	Organization
CPIx BIM Assessment Form	Construction Project Information Committee	Maturity tool	Organization
Maturity Matrix: Self-Assessment Questionnaire	Project 13 - Institute of Civil Engineers	Maturity tool	Organization
NBIMS Capability Maturity Model	National Institute of Building Sciences	Maturity tool	Organization
Organizational BIM Assessment	Pennsylvania State University	Maturity tool	Organization
SFT's BIM Compass	Scottish Futures Trust	Maturity tool	Organization
Supply Chain BIM Capability Assessment	Wates Group	Maturity tool	Organization
Vico BIM Scorecard	Vico Software	Maturity tool	Organization
BIM Maturity Assessment Tool (BMAT)	ARUP/University of Cambridge	Maturity tool	Project
BIM Working Group BMAT	Public Sector Working Group	Maturity tool	Project
Dstl BIM Maturity Assessment Tool	Defense Science and Technology Laboratory (Dstl)	Maturity tool	Project
VDC Scorecard	Centre for Integrated Facility Engineers, Stanford University	Maturity tool	Project

Business Case of Using BIM for Infrastructure

A report titled Project TFRS-02, "Lifecycle BIM for Infrastructure: A Business Case for Project Delivery and Asset Management," underscores the critical role of Return on

Investment (ROI) analysis that enables businesses and organizations to quantify the value of BIM implementation in financial terms. This approach establishes a solid business case for adopting BIM in infrastructure projects and highlights how applying BIM at an organizational level can improve efficiency and yield benefits throughout the lifecycle of a project, encompassing design, construction, and asset management phases. The ROI analysis outlined in the report involves several components categorized into inputs, outputs, and outcomes:

Inputs: These are the initial investments required to facilitate BIM adoption. Examples include:

- Software installation or upgrading to support BIM functionalities.
- Staff training programs to ensure employees are equipped with the necessary skills to use BIM tools and procedures effectively.

- Development of new standards and processes to align project management with modern, BIM-driven methodologies.

Outputs: These represent the immediate results achieved from the investments made. For example:

- Staff members are gaining expertise in using BIM software and engaging in enhanced modeling processes.
- The organization adopts standardized workflows that streamline collaboration and data sharing across teams.

Outcomes: These are the longer-term benefits of BIM implementation, which ROI analysis evaluates against the inputs. Notable outcomes include:

- Cost savings are realized through reduced time spent on design iterations and avoiding costly change orders during construction.
- Increased project efficiency and accuracy by mitigating errors and optimizing resource allocation.
- Improved decision-making capabilities through enhanced data integration and access across the project lifecycle.

To provide a thorough evaluation, the study employs the concept of use cases as a key mechanism for identifying and mapping the specific advantages associated with BIM in infrastructure projects. Use cases served as detailed examples of how BIM technologies and methodologies were applied in real-world scenarios, enabling researchers to link technological applications with measurable outcomes and tangible benefits.

One significant finding from these use cases is the effectiveness of 3D modeling in capturing existing site conditions. By leveraging advanced 3D scanning and modeling techniques, project teams can create accurate, comprehensive digital representations of physical sites. These detailed models provide a virtual snapshot of current conditions, drastically reducing the need for labor-intensive and time-consuming physical inspections. As a result, organizations benefit from expedited planning processes, reduced costs, and a minimized risk of inaccuracies during subsequent phases of project delivery.

Beyond the immediate application of 3D modeling, the study highlights how use cases provide a structured means of analyzing and categorizing BIM's broader impacts. The research team drew explicit connections between the technical capabilities offered by BIM tools and the resulting organizational advantages, such as enhanced project coordination, increased efficiency, and improved decision-making. For example, use cases demonstrate how centralizing data within BIM environments streamlines communication among stakeholders, enabling smoother integration of interdisciplinary inputs. Also, virtual modeling allows organizations to anticipate potential construction conflicts and optimize designs before physical implementation, reducing costly change orders.

The study also identifies several key challenges that hinder the full optimization of BIM’s benefits, including management changes and institutional inertia, industry buy-in, and limited experience among contractors (Richter & Director 2022). These factors often create roadblocks to seamless BIM implementation and the realization of its potential advantages in project delivery and asset management.

- *Change Management and Institutional Inertia*: A major obstacle to BIM adoption is the slow pace of change inherent in shifting from traditional project delivery methods to more technologically advanced, BIM-driven approaches. Introducing new management processes and moving forward with initiatives that embrace modern methods often require significant time, effort, and resources. This delay can stall progress, as stakeholders may struggle to adapt to unfamiliar workflows or feel hesitant about transitioning away from established practices. Leadership buy-in and consistent commitment to driving change are critical for overcoming this inertia.

- *Geographical Variations in Digital Delivery*: The study also points out that the adoption and application of BIM can vary widely depending on geographic and regional factors. For example, in New York State, Automated Machine Guidance (AMG) is widely utilized in upstate regions where expansive open land provides the ideal conditions for its use. However, in urban areas like New York City, where space is constrained and the construction landscape is more complex, AMG adoption is much less common. These regional differences highlight how localized considerations can influence the adoption of BIM and related technologies, requiring tailored strategies to maximize relevance and effectiveness.

- *Industry Buy-In*: Achieving industry-wide acceptance and support for BIM presents another challenge. While shared object models within organizations are a significant accomplishment, external stakeholders such as subcontractors, vendors, and collaborating agencies may lack familiarity with BIM applications and their potential benefits. This lack of awareness or understanding can result in resistance to its adoption and limit the interoperability that is essential for maximizing BIM's value.

- *Contractor Experience and Traditional Practices*: Another barrier lies in the varying levels of BIM proficiency among contractors. Some contractors may lack the necessary experience or resources to effectively use BIM tools, which can diminish its benefits during project execution. Additionally, in some cases, state DOTs have not mandated the use of BIM models for contract bidding. Instead, they allow contractors to rely on traditional signed and sealed plans to complete work. This practice perpetuates reliance on conventional methods and undermines efforts to modernize and streamline project delivery through BIM.

To address these challenges, the study emphasizes the importance of fostering education and training across all levels of the industry. Comprehensive training programs can help contractors and external agencies better understand and utilize BIM technologies. Additionally, encouraging DOTs to incorporate BIM requirements into contract bidding processes could promote broader adoption among contractors and create incentives for aligning with modern standards. Building stakeholder confidence and highlighting the long-term benefits of BIM, such as improved efficiency, cost savings, and reduced project risks, are also crucial for achieving industry buy-in. Addressing geographical disparities in BIM adoption may require customized strategies, ensuring that tools and processes are relevant to the specific needs and constraints of each region. With these efforts, organizations and agencies can accelerate the transition to BIM-driven practices, enhancing productivity and collaboration across the construction industry.

Digital transformation occurs through four critical "tipping points": technology, individuals, businesses, and public policy (Figure 5). Although BIM technology is mature, its effectiveness is ultimately shaped by the skills and willingness of individuals, as well as the business conditions in which they operate. A key challenge in deploying BIM for infrastructure is aligning these stakeholders and motivating them to embrace the technology. Moreover, the role of public policy cannot be underestimated. Governmental support for BIM adoption, including relevant incentives and regulations, is essential for accelerating its integration into infrastructure projects. However, such policy changes are often slow, and influenced by various economic, political, and societal factors. Technological advancements in mobile devices, cloud computing, and business intelligence have significantly enhanced BIM’s potential for infrastructure projects. As these technologies converge, the question for DOTs and their external partners may no longer be if BIM should be adopted, but when and how it will be implemented to maximize value across the project lifecycle. The challenge now lies in identifying key stakeholders, understanding their motivations, and creating a condition conducive to the widespread deployment of BIM.

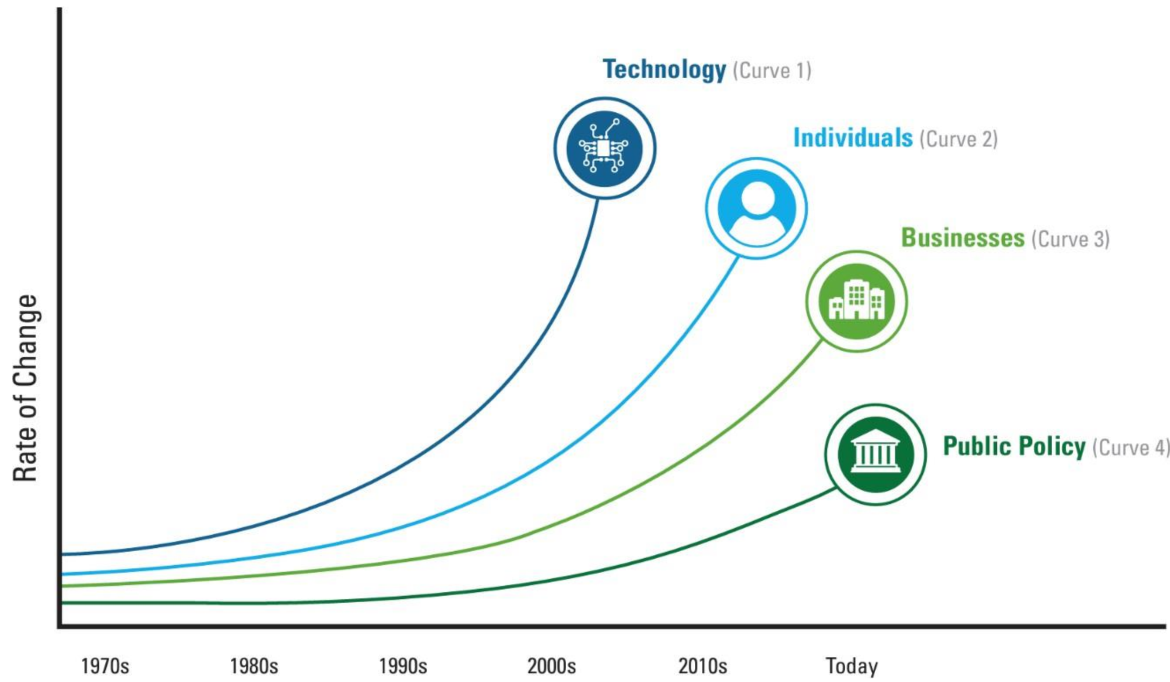


Figure 5 Digital Transformation through Four Separate "Tipping Points" (Bersin et al. 2017)

National Strategic Roadmap

The Federal Highway Administration (FHWA) defines BIM for infrastructure as "*a collaborative work method for structuring, managing, and using data and information about transportation assets throughout their lifecycles*." This definition captures BIM's essential role in enhancing data organization, sharing, and usage across all stages of a transportation asset's lifecycle, from design and construction to maintenance and eventual decommissioning.

- *The VISION is to digitalize project delivery, operations, and maintenance for the Nation's highway infrastructure and make information available to anyone who needs it when they need it.*
- *The GOAL is for State DOTs to adopt BIM for Infrastructure as a standard practice.*

To advance BIM adoption nationwide, the FHWA introduced a comprehensive 10-year roadmap designed to unify efforts among the FHWA, state DOTs, and industry partners (Mallela and Bhargava 2021). The roadmap's primary objective is to elevate BIM maturity to Level 2 standards across the country. Level 2 maturity signifies the widespread use of collaborative BIM processes, including the effective exchange of data between multiple stakeholders and improved integration of 3D modeling tools for project delivery.

Currently, U.S. highway infrastructure lags behind several European nations, which have embraced BIM more broadly and earlier. These countries, benefiting from proactive government mandates and industry-wide collaboration, have set a high bar in terms of BIM maturity and its associated benefits. For example, in 2020, nations that had already adopted BIM at an advanced level reported annual savings of 5 to 20 percent in their construction budgets. These savings were driven by increased efficiency, reduced waste, and the early identification and mitigation of design conflicts, enabled by robust BIM implementation (Meerkerk & Koehorst, 2017).

Recognizing the success of BIM in other countries, the FHWA's roadmap aims to position the U.S. as a global competitor in infrastructure design, delivery, and asset management. By fostering collaboration among DOTs, contractors, and industry stakeholders, the FHWA seeks to leverage BIM not only as a design tool but also as a platform for achieving long-term cost efficiencies and innovation across the nation's transportation networks. The adoption of BIM lifecycle design and analysis would allow U.S. projects to achieve:

- Higher Cost Predictability: Reducing budget overruns by accurately estimating costs across all project phases.
- Enhanced Data Integration: Enabling seamless information sharing across disciplines and agencies.
- Performance Goals: Optimizing design and construction to minimize adverse impacts and extend asset lifespans.

The FHWA's 10-year roadmap categorizes BIM for Infrastructure into four foundational elements: policies and processes, people and skills, data and standards, and tools and technologies (Figure 6). Together, these elements create a framework for achieving higher levels of BIM maturity and are aligned with commonly used BIM metrics across industries. Each element represents a critical aspect of BIM adoption and integration, working in parallel to facilitate the seamless implementation of BIM practices in infrastructure projects. By focusing on these elements, the roadmap seeks to create a unified vision for BIM adoption that aligns with the goals of the FHWA, DOTs, and industry partners.

1. *Policies and Processes*: This element focuses on establishing structured procedures and governance frameworks for managing BIM workflows throughout the lifecycle of transportation assets. It includes:
    - The creation, storage, and movement of data across design, construction, operations, and maintenance phases.
    - Developing policies that define how data is captured, shared, secured, and updated.
    - Implementing frameworks that align with organizational and project-specific goals to optimize the use of BIM.

Effective policies and processes ensure consistent management of BIM-related activities while fostering collaboration across various teams and agencies. For instance, by formalizing how information is transferred from design to construction and later to asset management, this element reduces inefficiencies and data silos.

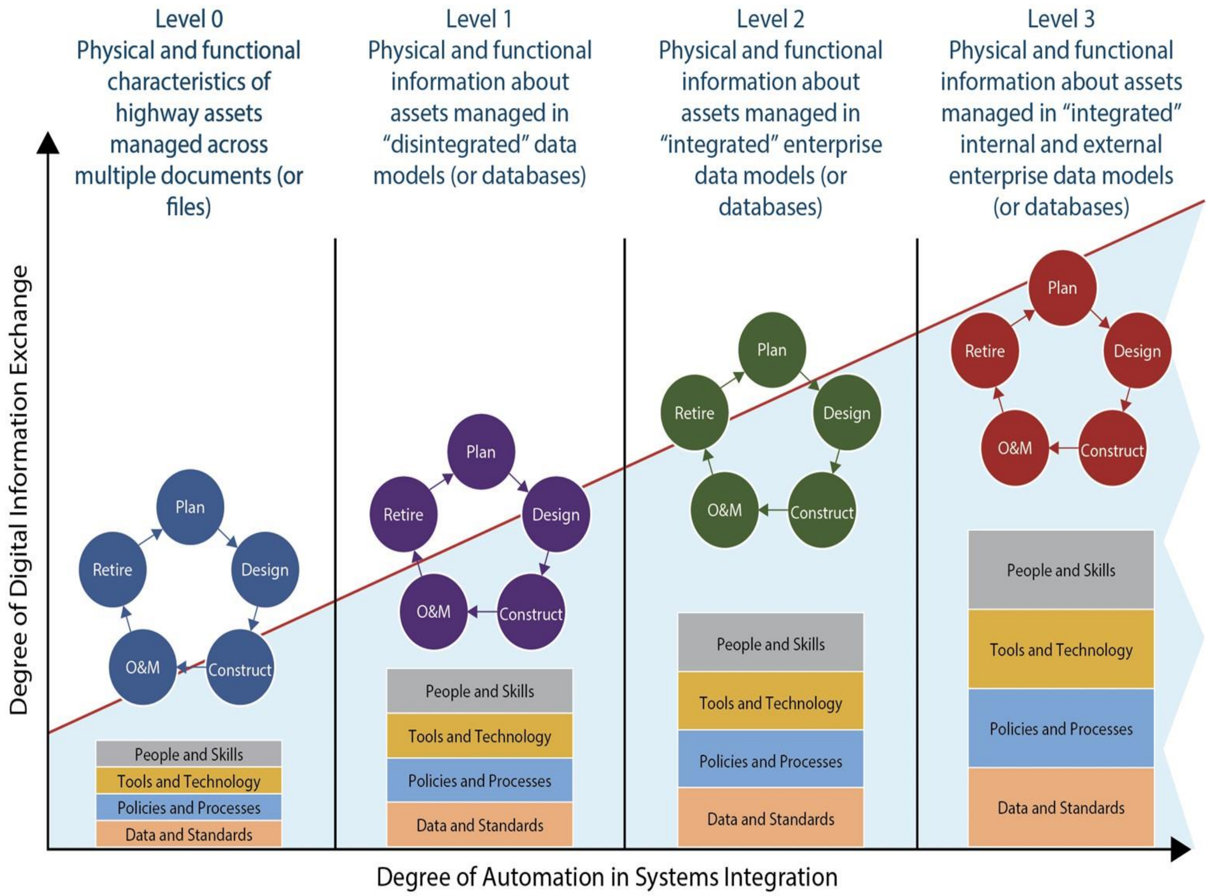
2. *People and Skills:* The success of BIM heavily depends on the people responsible for managing and executing the system. This element emphasizes the human aspect of BIM integration, including:
    - Identifying and supporting key roles, such as BIM managers, coordinators, and operators, who oversee the implementation and application of BIM processes.
    - Providing comprehensive training and skill development programs to equip staff with the knowledge required to use BIM tools effectively.
    - Encouraging a cultural shift within organizations to embrace digital transformation and collaborative practices.
    - Training is particularly critical, as the rapid pace of BIM advancement requires ongoing education to keep teams up to date with the latest technologies and standards.

- *Data and Standards:* Standardization is essential to ensure the seamless exchange and interoperability of data across the multiple phases of an asset's lifecycle. Adhering to standardized practices also helps minimize miscommunication and inconsistencies, providing a common language for all parties involved. This element includes:
    - Establishing rules and guidelines for data collection, storage, and usage, such as adopting open standards (e.g., Industry Foundation Classes or IFC).
    - Ensuring that data structures are compatible with a range of BIM tools, facilitating efficient collaboration among stakeholders.
    - Leveraging standardized data to improve workflow efficiency, reduce project phase times, and enhance decision-making accuracy.

3. *Tools and Technologies*: This element focuses on the digital and physical infrastructure required to support BIM processes. It includes:
    - Software solutions such as 3D modeling tools, data management platforms, and simulation programs, which are central to creating, managing, and analyzing BIM models.
    - Hardware components like servers, sensors, and mobile devices that facilitate real-time data sharing and field integration.

- Advanced systems such as web applications, reporting portals, and dashboard tools to monitor project performance and ensure transparency across workflows.

These tools and technologies not only enhance the precision of design and construction but also streamline operations and maintenance (O&M) processes. For instance, a well-integrated BIM environment can enable real-time updates to a digital twin, supporting proactive asset management and reducing lifecycle costs.



Source: FHWA.

Note: This phase includes asset management of facilities as well as facility maintenance management.

Figure 6 BIM for Infrastructure Maturity Model and Maturity Levels (Source: FHWA 2021)

However, to standardize the assessment of BIM maturity across regions, FHWA employs a modified structure comprising four distinct levels of maturity (Appendix A):

- L0-Document-Oriented BIM: This initial level focuses on traditional document-centric practices with minimal integration of BIM principles.
- L1-Object-Oriented BIM: At this stage, organizations begin employing BIM tools to develop 3D object-based models, improving data coordination and visualization.
- L2-Federated Object Models and Databases: This level introduces the use of integrated models that enable improved collaboration and centralized data management among stakeholders.
- L3-Integrated Lifecycle BIM: This advanced stage merges the capabilities of federated object models and databases to achieve full lifecycle integration, supporting seamless collaboration from project inception through operations and maintenance.

As organizations aim to move through these stages, their focus on reducing variability and enhancing efficiency positions them to meet evolving industry demands and achieve long-term performance goals in their operations.

Chapter 3. Research Methodology

The project was structured around four key tasks, as illustrated in Figure 7. These tasks are interconnected and collectively serve to provide a comprehensive analysis of the current state of BIM implementation in Region 6, identify gaps, and propose actionable strategies for systematic implementation.

Task 1-Comparison of BIM Maturity Assessment Tools

The project commenced with a thorough review of the existing literature to develop comprehensive competency matrices for each of the core components essential for achieving BIM maturity. BIM maturity refers to the continuous process of improvement, adaptation, and refinement that organizations undergo as they integrate and expand BIM practices. This concept signifies more than just the adoption of BIM tools; it reflects an ongoing commitment to enhancing several vital dimensions, including quality, repeatability, and predictability. These elements are deeply interwoven with an organization's overall BIM capability, influencing its capacity to deliver successful projects and drive innovation.

The competency matrices play a crucial role in defining the required knowledge, skills, and processes that contribute to organizational BIM maturity. These matrices serve as benchmarks for measuring an organization's proficiency in key BIM domains and are foundational in shaping a well-rounded, robust organizational structure. For this study, the team focused on the competency areas outlined in the national BIM roadmap. These areas include skills development, tools and technologies, data management and standards, as well as policies and procedures. Each of these elements is critical for fostering a mature BIM environment, and together they provide a framework for organizations to build their BIM capabilities systematically.

As part of the literature review conducted, existing tools and methods for assessing BIM maturity at the organizational level were explored. The goal was to consolidate and evaluate these tools, identify their strengths and weaknesses, and adapt their findings to create a standardized framework for assessing BIM maturity in state transportation agencies. From this review, a comparison matrix was developed to condense the number of sub-elements identified across the various maturity tools. This matrix was designed to group similar sub-elements under the four core categories outlined in the FHWA BIM Roadmap: Policies and Processes, People and Skills, Data and Standards, and Tools and Technology.

Out of the ten BIM maturity tools identified in the literature, six were operational or had documented use cases. These tools were included in the comparison matrix, and the names of the tools have been abbreviated for ease of reference throughout the study. The tools included in the comparison are:

- Organizational BIM Assessment (OBA)
- BIM Excellence Online Platform (BEOP)
- BIM Supporters' BIM Compass (Compass)
- CPIx BIM Assessment Form (CPIx)

- Maturity Matrix: Self-Assessment Questionnaire (MMSAQ)
- NBIMS Capability Maturity Model (NBIMS)

To organize the sub-elements from these various maturity tools, a matrix was created that mapped each sub-element to the four key categories in the FHWA roadmap. A matrix similar to OBA's was used, where each row represents a sub-element, and each column corresponds to the definitions of that sub-element from the different maturity tools. This method allowed for a direct comparison of definitions and helped consolidate overlapping sub-elements. Initially, 102 distinct terms were identified from the six tools, which were later refined through a comparison process.

The first step in this process was to compare the definitions of sub-elements across the tools. The comparison was structured so that the names of the tools appeared as columns, with the definitions of each sub-element displayed as rows. This allowed for the identification of similar definitions, enabling the grouping of sub-elements that were essentially describing the same concept. This step reduced the number of unique sub-elements to 43.

In some cases, sub-elements did not have overlapping definitions across the tools. These were carefully examined to determine whether they were relevant to the study's purposes. If a sub-element was found to be essential to the BIM maturity framework, it was retained; otherwise, it was excluded. The second round of evaluation streamlined the list further by focusing on sub-elements that had at least three similar definitions across the tools. This evaluation resulted in a final list of 24 sub-elements, with eight in Policies and Processes, four in People and Skills, seven in Data and Standards, and five in Tools and Technology.

Task 2-Survey Development and Data Collection

Once the sub-elements were consolidated, they were used to create an assessment questionnaire for transportation agencies. The survey was designed using a Likert scale, allowing respondents to self-assess their agency's level of BIM integration across each sub-element (Appendix C). The Likert scale used in the questionnaire aligned with the levels in the FHWA BIM Roadmap.

Each of the four elements from the FHWA roadmap was introduced with a brief definition, followed by the relevant sub-elements, which were displayed in a table format. Respondents were asked to rate their organization's maturity level in each sub-element based on their current practices. The survey also included open-response questions to capture insights into challenges, plans for BIM implementation, and any digital delivery plans or strategies currently in place. These open-ended questions provided qualitative data to complement the quantitative assessments.

To assess the BIM maturity levels across various State DOTs, data was collected through the regional survey. The process began with a thorough review of relevant documents and the determination that the survey did not need to be submitted for IRB approval as the respondents were providing factual responses on behalf of an agency.

This step was essential to ensure ethical standards were upheld in the collection and handling of data. The survey was distributed to representatives from the digital delivery teams at each regional DOT, who were tasked with providing insights into their organizations' BIM practices and maturity levels.

The primary goal of this data collection was to gain a clear and accurate understanding of the current state of BIM implementation within different DOTs. By capturing information on the use of BIM tools, processes, and technologies, the survey aimed to paint a comprehensive picture of how BIM is being adopted, integrated, and utilized across various transportation agencies. The responses from the survey were crucial in identifying the specific challenges, opportunities, and levels of success each DOT has experienced in its BIM-based processes.

Task 3-Assessment of BIM Maturity Levels

With the data collected, the project team undertook a comparative analysis of BIM usage across the different state DOTs. This comparison revealed a range of trends, strengths, and gaps in the implementation of BIM. By identifying common themes and discrepancies in BIM adoption, the team was able to draw valuable conclusions about the factors influencing BIM maturity at the regional level. These insights were essential for informing future strategies and best practices, offering actionable recommendations to help DOTs advance in their BIM implementation and reach higher levels of maturity.

Each competency element was assessed using the levels described in the FHWA Roadmap (L0 – Document Oriented, L1 – Object Oriented, L2 – Federated Object Models and Databases, and L3 – Integrated Lifecycles) to promote a standard method of assessment that the FHWA seeks to implement.

- Level 0-Document Oriented: Reliance on traditional 2D drawings and documents, and paper documentation without digital collaboration or integration. Terms, objects, and attributes are inconsistent across the organization.
- L1 – Object Oriented: Introduction to 3D models for design and documentation. Data exchanges and specific projects are targeted as BIM early pilot projects. Stakeholders are aware of BIM processes, policies, standards, tools, and systems.
- L2 – Federated Object Models: Standard templates for data exchange within the organization between asset lifecycle phases are developed, which are then used to automate information exchanges. Information requirements and delivery specifications are clearly defined.
- L3 – Integrated Lifecycles: Full integration and collaboration among all project participants during the entirety of the project lifecycle. Data are available to both the internal and external stakeholders through automated systems.

The assessment of each regional DOT was conducted using these maturity levels and compiled into a graphical, color-coded format. This visualization enabled a straightforward comparison across the various competency elements and DOTs, providing a clear and immediate view of where each DOT stands in terms of its BIM maturity. These charts graphically represent the maturity of each agency across the four elements, with each element being assessed from Level 0 (innermost ring, indicating no BIM use) to Level 3 (outermost ring, indicating high BIM integration). The radar charts allow for a clear comparison of BIM maturity levels across agencies and highlight the areas where agencies have made significant progress, as well as those requiring further development.

Each element's radar chart was accompanied by a detailed analysis of the sub-elements, where agencies with higher BIM integration levels in specific areas were identified and discussed in greater detail. The results from the survey provided valuable insights into the current state of BIM adoption across the participating transportation agencies, highlighting both the successes and the challenges they face as they move toward greater BIM integration.

In addition to the maturity levels, the assessment also highlighted key implementation gaps and priority areas that required attention. These areas were pinpointed for improvement at the organizational level, providing clear guidance on where to focus efforts to advance BIM practices. This assessment was particularly significant because, to the best of the research team's knowledge, no such prior efforts had been made to map BIM maturity directly aligning the results with the national BIM roadmap.

Task 4-Development of BIM Level 2 Implementation Framework

The final task involved the development of a BIM Level 2 implementation framework, with prioritized action items. This framework was crafted based on the insights gathered from the regional survey, and the BIM maturity assessment. It clearly outlined actionable steps that each DOT can undertake to advance its BIM capabilities in alignment with the national roadmap.

The prioritization of these steps was determined by considering factors such as the DOT's current maturity level, available resources, and strategic objectives. The framework will serve as a practical guide, assisting DOTs in their journey towards achieving BIM Level 2 maturity and fostering collaboration and innovation within the transportation sector. While developed for implementation in Region 6, the framework underpinning the roadmap is transferable to other states and regions.

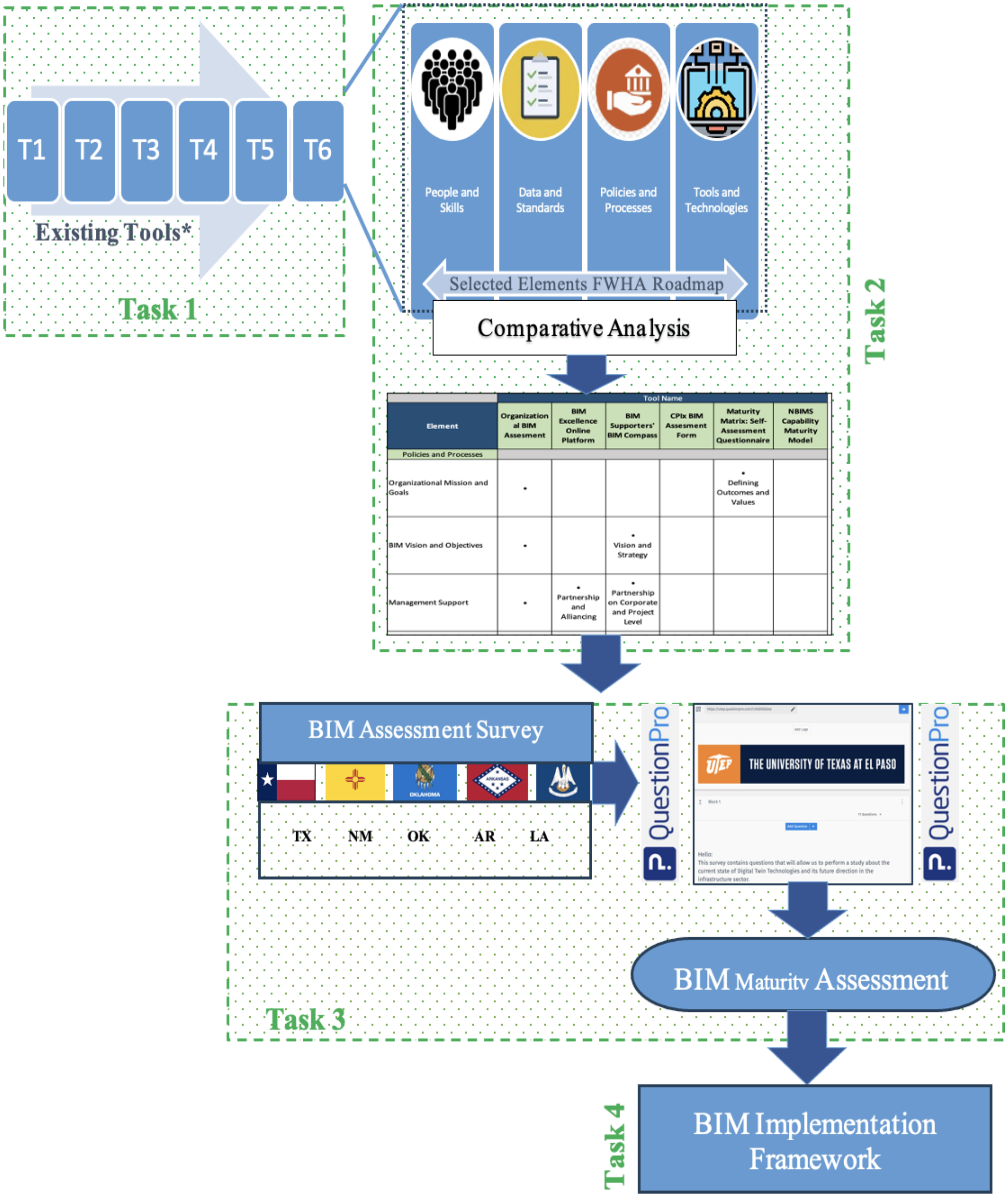


Figure 7 Research Methodology

*T1: Organizational BIM Assessment; T2: BIM Excellence Online Platform; T3: BIM Supporters' BIM Compass; T4: CPIx BIM Assessment Form; T5: Maturity Matrix-Self-Assessment Questionnaire; T6: NBIMS Capability Maturity Model

Chapter 4. Results and Discussions

Comprehensive Comparison of BIM Maturity Assessment Tools

Table 2 presents a detailed matrix comparing six existing BIM Maturity Assessment tools. Each tool is represented with a highlighted identifier and listed with its abbreviated name for easy reference. From an initial pool of fifteen tools identified in the literature (Appendix B), only six were operational or provided enough information to be evaluated for their role in assessing BIM integration at an organizational level. The remaining four tools identified in previous studies either no longer exist, lack active links, or have insufficient documentation to support their inclusion.

Table 2 Existing Tools for BIM Maturity Assessment

Selected Tools	Overview
Organizational BIM Assessment (OBA)	A spreadsheet-based maturity tool that evaluates organizations using **five levels of integration**, offering a structured approach for measuring BIM practices.
BIM Excellence Online Platform (BEOP)	A comprehensive questionnaire customizable to assess BIM integration at either the **project** or **organizational level**, allowing for tailored insights.
BIM Supporters' BIM Compass (Compass)	A **self-assessment survey** with four sections, providing results directly to users or through a certified consultant who conducts in-person evaluations.
CPIx BIM Assessment Form (CPIx)	A tool focused on **qualitative assessment**, helping organizations evaluate their BIM maturity in less rigid, more narrative-driven terms.
Maturity Matrix Self-Assessment Questionnaire (MMSAQ)	A self-assessment tool based on **five core areas**, offering insights into an organization's BIM adoption and readiness levels.
NBIMS Capability Maturity Model (NBIMS)	A robust spreadsheet-based tool that examines organizations across **eleven dimensions**, enabling a more granular analysis of BIM maturity.

The tools were analyzed based on the four key elements of the FHWA Roadmap: Policies and Processes; People and Skills; Data and Standards and Tools and Technologies. Each maturity tool's sub-elements were mapped to these categories, showing 43 unique sub-elements across the six tools (Table 3). The matrix compared sub-element definitions based on terms, themes, and language to identify overlapping concepts. An analysis of BIM maturity tools revealed interesting patterns in their emphasis on different organizational elements. All the tools studied included sub-elements within the domains of Policies and Processes and Data and Standards, emphasizing their critical role in assessing and improving BIM integration. However, there were notable gaps in the coverage of People, Skills, and Tools and Technology. Interestingly, no sub-elements were found to have consistent definitions across all six tools, showcasing diverse methodologies and perspectives in evaluating BIM implementation. However, one sub-element, "BIM Champion", emerged as the most common across the tools. Defined as technically skilled employees who facilitate adoption, improve processes, and manage resistance to change, the BIM Champion was universally regarded as a critical factor in achieving effective BIM implementation.

OBA is a maturity tool that evaluates BIM integration across five distinct levels, providing organizations with a structured spreadsheet format for self-assessment. Each level reflects the degree of BIM adoption, from early stages of integration to advanced, full-scale implementation. BEOP offers a more detailed, customizable questionnaire that can be tailored to either a project or organizational level. This tool provides deeper insights into an organization's readiness for BIM adoption and can be adjusted based on specific project requirements or overall organizational goals. Compass is a self-assessment that divides its evaluation into four sections, providing users with private results. Alternatively, a certified consultant can conduct the assessment through on-site visits, offering personalized feedback on the organization's BIM maturity. CPIx is another questionnaire-based tool, which is less structured and allows for more qualitative insights into an organization's BIM integration. MMSAQ is a self-assessment survey that examines BIM integration across five key areas, helping organizations identify their strengths and weaknesses in BIM adoption. Lastly, NBIMS is a spreadsheet-based tool that evaluates BIM integration using eleven specific areas of interest, offering a comprehensive view of an organization's current BIM capabilities.

To streamline the sub-elements used to create the evaluation survey at the organizational level, only those sub-elements with three or more similar definitions across the six tools were selected. Sub-elements with similar themes were merged, while those with fewer similarities underwent a thorough review to determine their relevance and importance to the study. This approach ensured that only the most pertinent sub-elements were included in the final survey tool. The definitions from each tool were consolidated into comprehensive new definitions that captured the central themes of the overlapping sub-elements, providing clarity and consistency for the evaluation process. The comparative analysis revealed that most BIM maturity tools emphasize the critical role of Policies and Processes in advancing BIM adoption within organizations. These tools suggest that organizations must establish clear, standardized policies that govern BIM practices. Additionally, ensuring that all personnel are familiar with these policies and the standards used within the organization is essential to improving the quality of data collected for future projects.

In terms of the People and Skills category, the comparison highlighted that only three sub-elements were considered critical. These included the importance of clearly defined roles and responsibilities at all organizational levels, the necessity for personnel to accept changes to their working methods to adopt more complex BIM processes, and the need for ongoing education and training to ensure that employees can work effectively with BIM technologies.

For the Data and Standards and Tools and Technology categories, four and five sub-elements were identified, respectively. The tools collectively emphasized that data collection methods must be standardized to ensure interoperability with BIM systems, facilitating collaboration with external stakeholders. Additionally, the need for regular updates to BIM tools and their compatibility with new hardware was emphasized, ensuring that transportation agencies can continue to operate efficiently as technology evolves. Furthermore, organizational support for maintaining systems and servers is essential to ensure the seamless operation of BIM applications.

The analysis of these sub-elements underscored the importance of strengthening the foundational elements within transportation agencies. Policies and Processes are crucial for setting the stage for BIM integration, while People and Skills, Data and Standards, and Tools and Technology require continuous development and refinement to ensure successful BIM adoption. These elements may require more detailed questions in future assessments to better understand the intricacies of their respective sub-elements, particularly for People, Skills and Tools and Technology, which may be more complex to evaluate.

Once the comparison matrix was established and sub-elements were identified, the next step was to develop an assessment questionnaire that utilized a Likert scale. This scale converted the responses from each agency into maturity levels for each BIM element. The goal was to provide a clear and standardized evaluation method aligned with the FHWA's strategic BIM implementation roadmap, enabling agencies to assess their progress in BIM adoption and identify areas for improvement.

Table 3 Comparison Matrix for Existing BIM Maturity Tools

Tools	T1	T2	T3	T4	T5	T6
Elements	Organizational BIM Assessment	BIM Excellence Online Platform	BIM Supporters' BIM Compass	CPIx BIM Assessment Form	Maturity Matrix: Self-Assessment Questionnaire	NBIMS Capability Maturity Model
Policies and Processes						
Organizational Mission and Goals	•	•				• Defining Outcomes and Values
BIM Vision and Objectives	•	•		• Vision and Strategy		
Management Support		•	• Partnership and Alliancing	• Partnership on Corporate and Project Level		
BIM Champion		•				• Performance Benchmarking
BIM Planning Committee	•	•	• Strategic Planning			

Survey Results

The survey questionnaire was organized into four distinct sections, each corresponding to a major element outlined in the FHWA BIM Roadmap. Within each section, the questions were designed to address specific sub-elements, providing a detailed assessment of the various aspects of BIM maturity as identified in the roadmap (Figure 8). The survey tool was distributed to five representatives from transportation agencies involved in digital delivery initiatives. For the purpose of this study, the agencies are anonymized and referred to as DOT1 through DOT5. These organizations differ significantly in terms of their size and scope, which are determined by various factors, including the total miles of public roads and bridges they manage. Specifically, DOT2 oversees the smallest network of public roads, while DOT5 manages the largest network, reflecting a broad disparity in their infrastructural responsibilities.

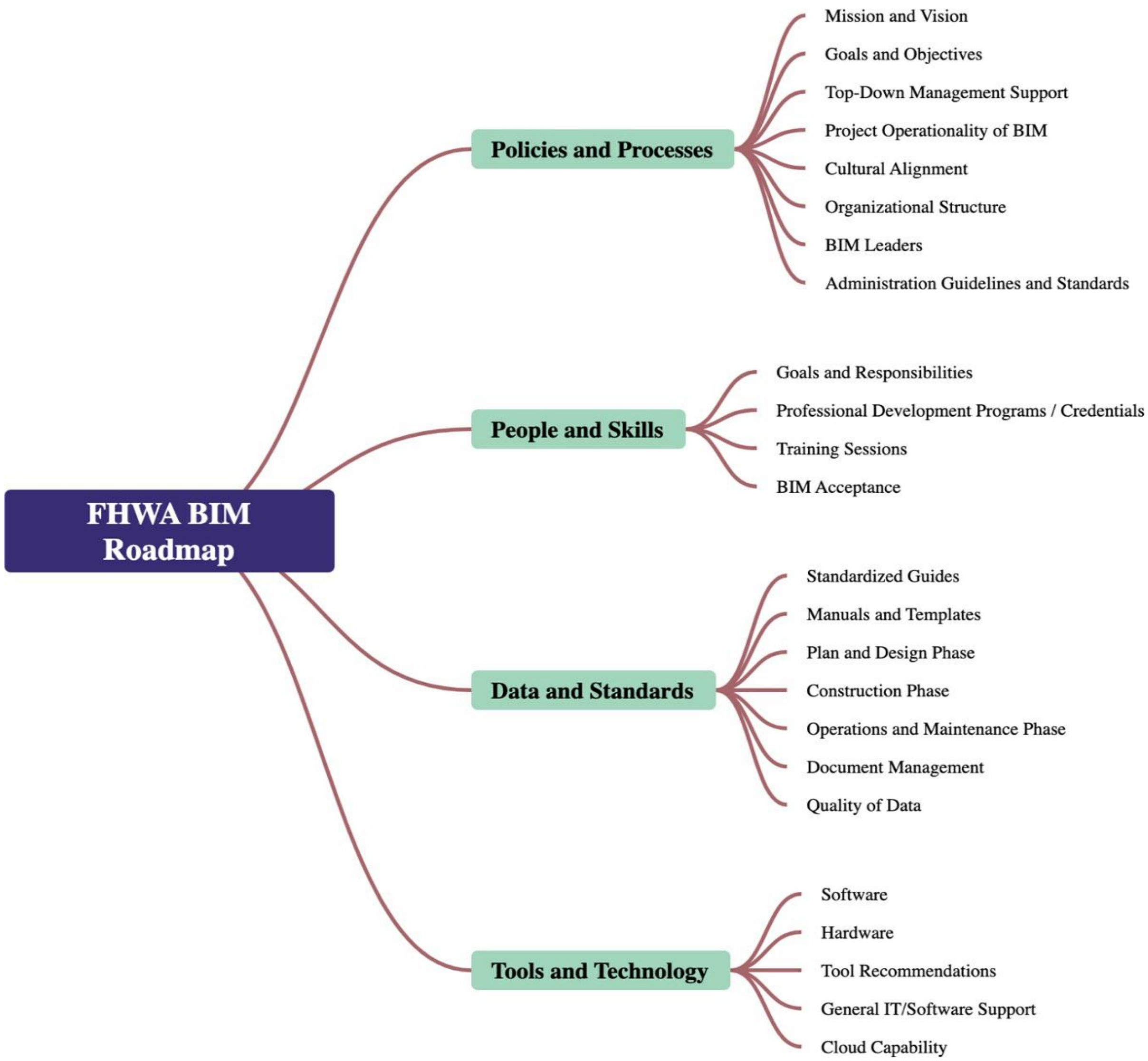


Figure 8 Elements and Sub-Elements of the Survey

In addition to differences in road and bridge management, the agencies also vary in the number of Metropolitan Planning Organizations (MPOs) they are responsible for. DOT4, for example, has jurisdiction over the fewest MPOs, while DOT5 is responsible for the highest number. These variations in jurisdictional scope and the complexity of governance structures underscore the diversity of the agencies' operations and the potential challenges they face in adopting and implementing digital delivery and BIM technologies. As such, each agency's experience and perspective on BIM implementation may differ based on the scale of their infrastructure, the number of MPOs they manage, and the specific organizational challenges they encounter.

Elements Summary

DOT5 and DOT4 demonstrated the highest levels of BIM integration across the agencies surveyed, with DOT5 exhibiting a comprehensive implementation of BIM, achieving Level 1 or higher across all assessed elements (Figure 9). DOT4, while slightly behind DOT5 in terms of overall integration, has established a strong foundation for BIM adoption. Notably, DOT4 reported significant progress in developing policies and processes to support BIM, with 54% of the necessary steps toward achieving Level 3 maturity in this area already completed (Table 4). This indicates a strategic effort to lay the groundwork for full BIM implementation.

In contrast, DOT2 showed minimal progress in preparing for BIM integration, particularly within its workflow. The agency reported only a small degree of BIM usage in the "Data and Standards" category, and no BIM adoption was reported for any of the other elements assessed. This suggests that DOT2 has yet to fully embrace the foundational aspects of BIM, and significant efforts are needed to bridge the gap toward more comprehensive integration.

Across all five organizations, the two elements that showed the most widespread progress were "Policies and Processes" and "Tools and Technology." This trend highlights the importance of these areas as the initial building blocks of BIM implementation. A clear and supportive policy framework, alongside the right tools and technology, is essential for launching BIM initiatives. As organizations mature in their BIM adoption, these elements provide the structural support necessary to guide employees in developing skills and following standardized procedures, which are crucial for maintaining long-term success with BIM.

Table 4 presents a more granular view of the progress reported by each transportation agency, offering detailed percentages for every element assessed. These figures provide a clearer picture of how each agency is advancing toward full BIM integration and highlight the varying levels of maturity and readiness across the different elements.

Table 4 Elements Summary as a Percentage of Level 3 Score

Elements	DOT1	DOT2	DOT3	DOT4	DOT5
Policies and Processes	25%	0%	21%	54%	42%
People and Skills	25%	0%	8%	33%	33%
Data and Standards	38%	10%	10%	0%	33%
Tools and Technology	13%	0%	20%	20%	53%

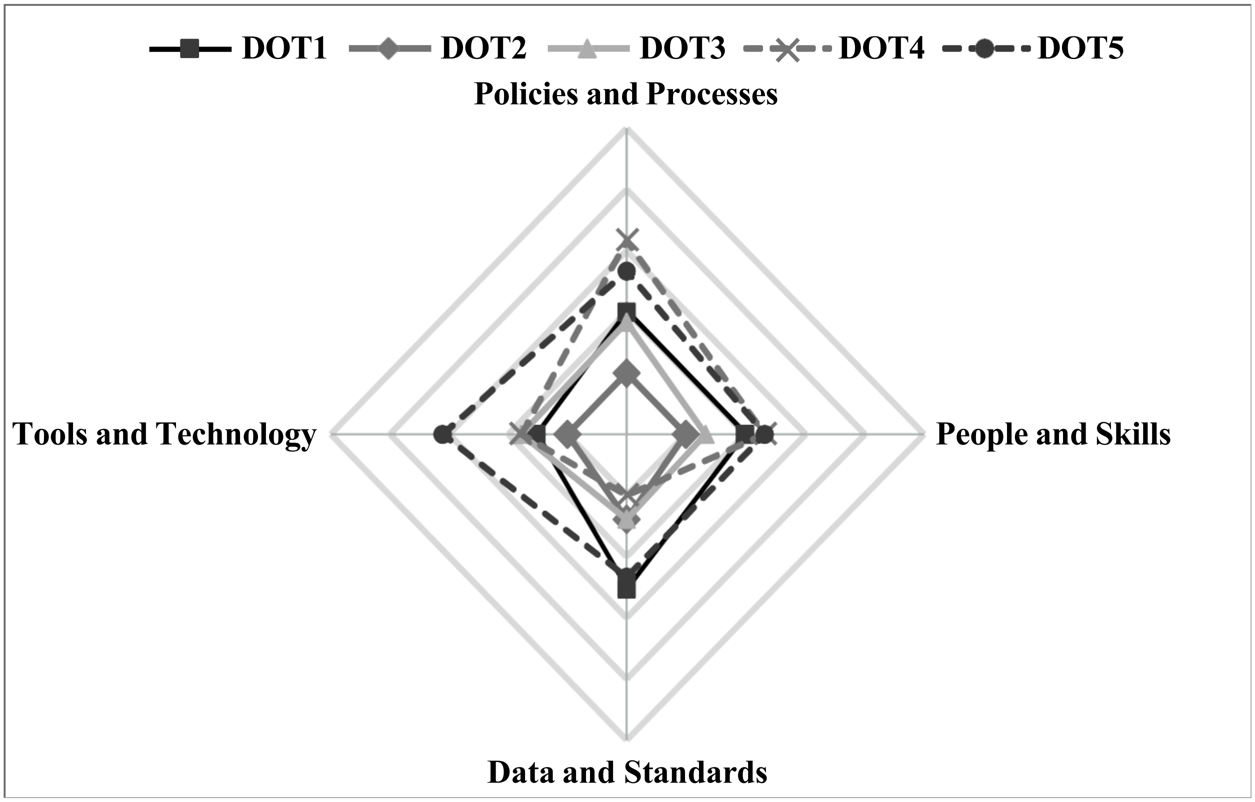


Figure 9. Elements Summary

Figure 9 Elements Summary

E1: Policies and Processes

In terms of Policies and Processes, DOT4 and DOT5 were the only transportation agencies to report achieving Level 3 in at least one sub-element of the BIM implementation framework (Figure 10). Both organizations have made notable strides toward comprehensive BIM integration, but they are at different stages of development and maturity in their respective BIM journeys.

DOT4 has demonstrated significant efforts to establish a strong foundation for BIM adoption. The agency has clearly articulated its mission, vision, goals, and objectives, providing a strategic roadmap for BIM implementation. Additionally, DOT4 has focused on building a robust management structure and leadership team to oversee and drive the successful execution of these plans. These initiatives underscore a thoughtful and deliberate approach to implementing BIM at a systemic level. However, since DOT4 is still in the early stages of integrating BIM into its operations, the agency has not yet developed formal guidelines or standards for employees to follow, resulting in a Level 0 rating for organizational structure and BIM operations. This suggests that while DOT has laid the groundwork for BIM, it has yet to establish the standardized processes and frameworks that would fully support its operationalization across the workforce.

In comparison, DOT5, while further along in some areas of BIM adoption, is still in the process of refining its internal structures. The agency achieved Level 1 in all sub-elements, except for top-down management support, where it scored higher. This indicates that DOT5 is beginning to implement key processes and practices but is not yet fully standardized in its approach. Notably, DOT5 places significant emphasis on securing leadership support for BIM, recognizing that top-down management buy-in is critical to fostering organizational commitment and driving the adoption of BIM technologies and practices.

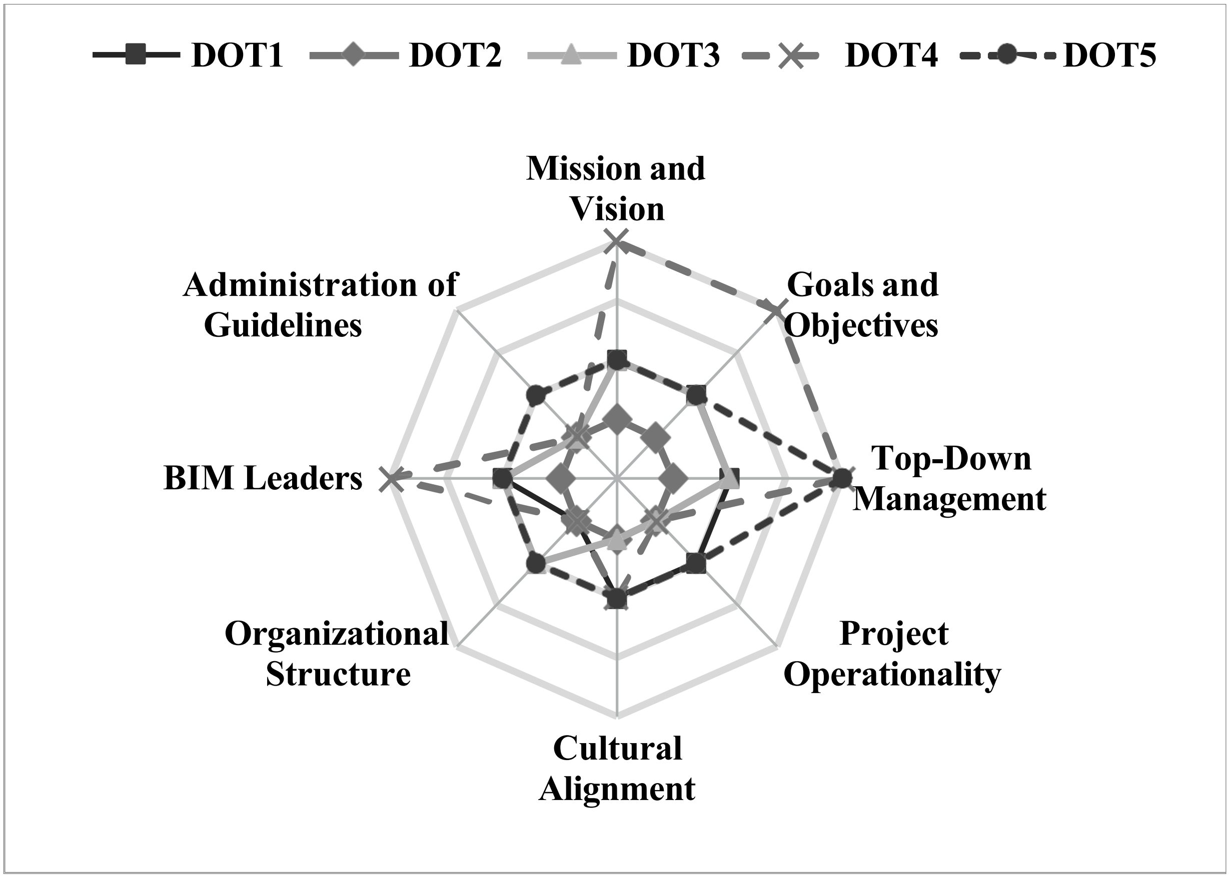


Figure 10 Policies and Processes

On the other hand, DOT2 lags significantly in its efforts to integrate BIM into its operations, particularly in the area of Policies and Processes. The agency reported no efforts or initiatives in any of the sub-elements, signaling a considerable gap in its approach to digital transformation and BIM adoption. This lack of effort suggests that DOT2 is not yet prioritizing or actively working on the foundational elements necessary for BIM implementation, which may hinder future progress if not addressed.

E2: People and Skills

DOT4 was the only state transportation agency to report achieving above Level 1 in any sub-element within this category (Figure 11). As previously highlighted, DOT4 has made significant strides in establishing a clear and well-defined set of goals and objectives for BIM implementation. This clarity, along with the agency's commitment to ensuring that all members of the organization understand and adhere to these goals, is reflected in their self-assessment of Level 3 for goals and responsibilities. This high level of maturity suggests that DOT4 has not only outlined strategic objectives but has also embedded them into the organizational culture, ensuring alignment at all levels of operation. The agency's success in this area reflects a top-down approach to leadership and management, where the importance of BIM adoption is communicated effectively, fostering a shared vision for the future.

In comparison, DOT5 has made initial progress toward BIM adoption, reporting Level 1 across all sub-elements. While the agency has not yet reached the same level of maturity as DOT4, DOT5's efforts indicate a goal-oriented approach to BIM integration. Specifically, DOT5 is encouraging its employees to use innovative BIM tools for future projects, which is a critical step in fostering a culture of continuous improvement and technological adoption. Additionally, DOT5 is investing in the professional development of its workforce by offering training and certification programs. Employees are actively utilizing these resources to enhance their skills and apply BIM tools to their projects. This suggests that DOT5 is in the early stages of creating a skilled workforce capable of leveraging BIM for improved project outcomes, even though it has not yet achieved the level of organizational integration seen in DOT4.

In contrast, DOT2 and DOT3 remain in the document-oriented phase of BIM adoption, with limited efforts to advance beyond basic digital practices. These agencies reported no initiatives focused on educating or certifying employees in BIM. As a result, both DOT2 and DOT3 are still primarily reliant on traditional methods of data management and project documentation, which hinders their ability to fully capitalize on the advantages offered by BIM technologies. Without a clear focus on training and professional development, these agencies may struggle to integrate BIM into their workflows, delaying the realization of its potential benefits.

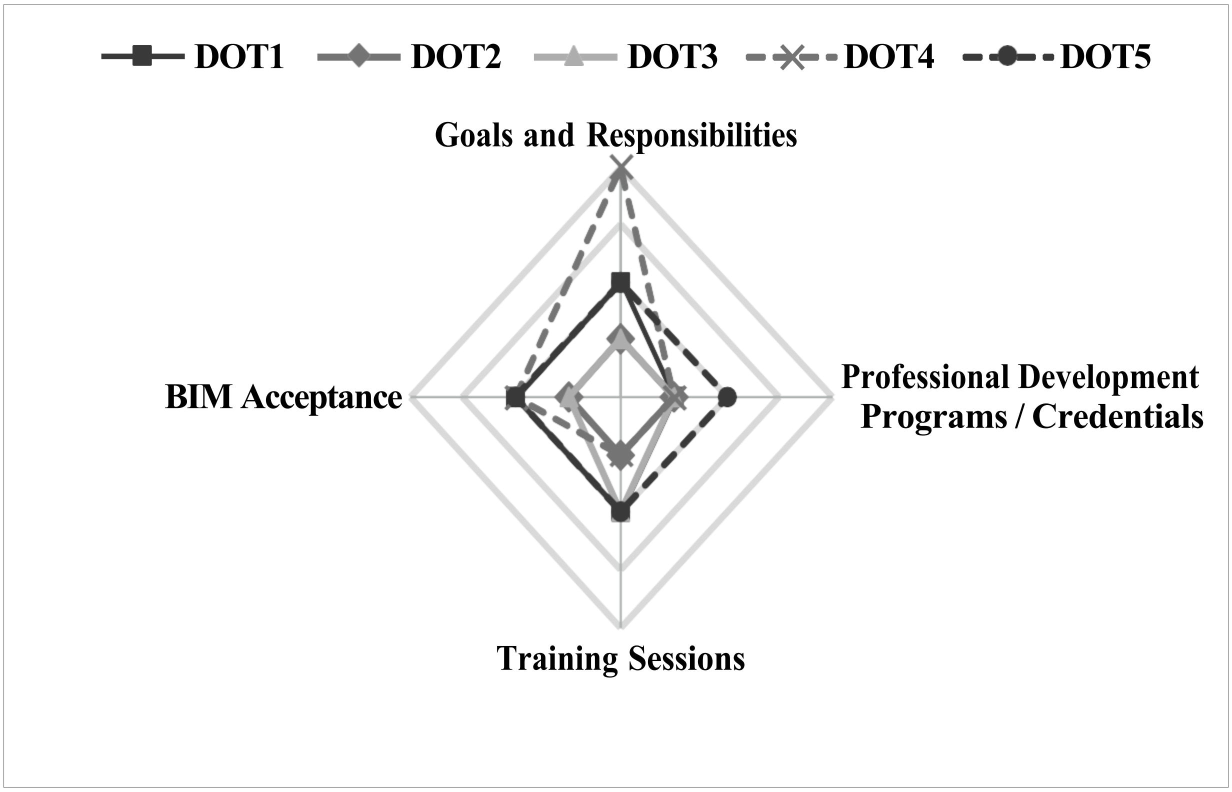


Figure 11 People and Skills

DOT1, while similar to DOT5 in its approach, reported a notable gap in the area of professional development, achieving no rating for this sub-element. This indicates that although DOT1 has made progress in adopting digital tools and encouraging innovation, it has not yet prioritized or invested in training its workforce on BIM-related skills and certifications. This lack of professional development could limit the effectiveness of BIM adoption at DOT1, as employees may not have the necessary expertise to fully utilize the available technology or contribute to more advanced stages of BIM integration.

Overall, the survey results demonstrate a clear distinction between the agencies in terms of their commitment to professional development and the integration of BIM into their organizational structures. DOT4 stands out for its comprehensive approach, while DOT5 is making promising early efforts. DOT2, DOT3, and DOT1, on the other hand, face significant challenges in building the necessary infrastructure and workforce capabilities to support the successful implementation of BIM. Moving forward, these agencies will need to focus on developing and certifying their employees' skills to realize the full potential of BIM and digital delivery in infrastructure projects.

E3: Data and Standards

In contrast to the other elements previously discussed, DOT1 has made notable progress in transitioning from a document-oriented approach to a more standardized method of recording project information and data throughout all phases of its projects (Figure 12). This shift marks a significant step in adopting more structured, data-driven practices, which are essential for effective BIM integration. DOT1 and DOT5 were the only agencies to report achieving Level 1 across all sub-elements in this area, signaling that both organizations have begun to embrace digital tools and standardized processes for managing project data.

For DOT1, the planning and design phase stands out as the area with the highest level of BIM integration, particularly in vertical construction projects. This phase is progressing more quickly toward adopting high-level BIM practices compared to other stages of the project lifecycle. This shift towards BIM in the planning and design phase is crucial, as it lays the foundation for smoother transitions into later phases such as construction and operations. The agency's focus on improving data management and integration at the outset of projects suggests that DOT1 is prioritizing the role of BIM in enhancing collaboration and decision-making early on, a critical factor for achieving long-term success in infrastructure projects.

However, DOT4 reported no BIM use in managing and standardizing its data. This indicates that while DOT4 has made significant strides in establishing a foundation for BIM, its progress in digitizing and standardizing data management across project phases remains limited. Without robust data management practices in place, the agency may face challenges in fully leveraging BIM's potential to improve project efficiency, reduce errors, and enhance overall outcomes.

Meanwhile, DOT2 and DOT3 reported relatively low levels of digital data collection, particularly in the planning and design phase. Both agencies noted that they had only implemented basic digital tools, such as converting documents from paper to PDF (Level 1 for document management) and using manuals and templates to standardize data entry (Level 1 for templates). These efforts, while helpful, reflect more basic steps toward digital transformation and suggest that both agencies are still in the early stages of adopting BIM and digital delivery tools. Without further investment in standardized data management systems and more comprehensive digital workflows, DOT2 and DOT3 may face obstacles in realizing the full benefits of BIM integration in their infrastructure projects.

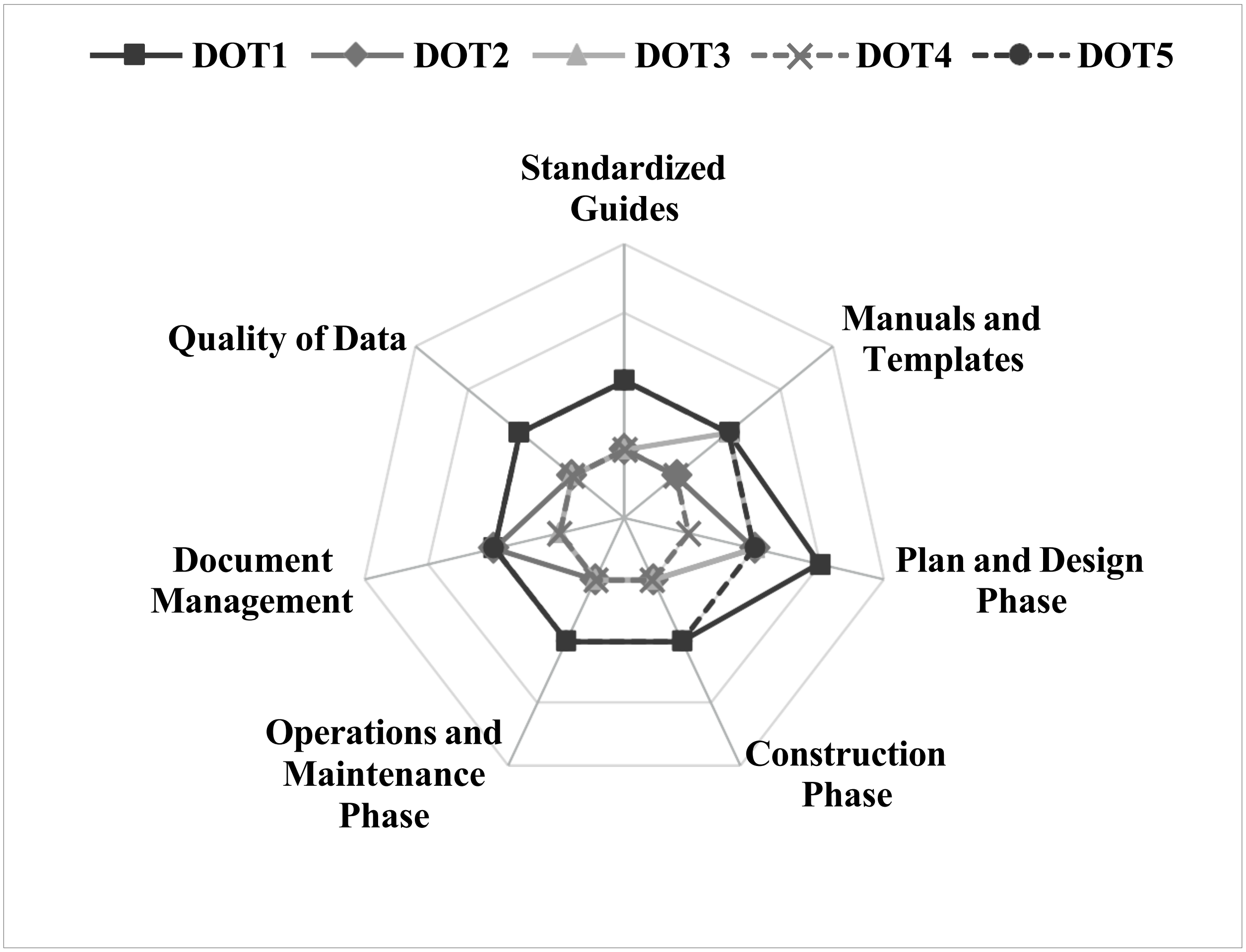


Figure 12 Data and Standards

Overall, the findings suggest that while there is a clear trend toward digital data management across various transportation agencies, the pace and depth of adoption vary significantly. DOT1 and DOT5 are leading the way in standardizing data management and integrating BIM into their project workflows, while DOT2, DOT3, and DOT4 still have substantial gaps to address in their efforts to adopt and implement these digital practices effectively.

E4: Tools and Technology

Based on the analysis, it was seen that DOT5 is leading the efforts to acquire new software and provide technology for their projects (Figure 13). DOT5 has also shifted from traditional paper documents to a cloud-based server for storing their data and documentation (level 2 integration). DOT1, DOT3, and DOT4 reported level 1 in some sub-elements, showing initial efforts to improve their digital use, whereas DOT2 reported no current effort for digitizing their project and using applications for the lifecycle of the project.

DOT5 emerges as the leader in efforts to acquire new software and integrate advanced technologies into its infrastructure projects (Figure 13). The agency has demonstrated significant progress in adopting digital tools, particularly in transitioning from traditional paper-based documentation to a more modern, cloud-based system for storing project data and documentation. This shift to cloud-based storage marks a substantial move toward *Level 2 integration*, which signifies a more sophisticated approach to data management and project collaboration. By utilizing cloud services, DOT5 has improved accessibility, data sharing, and collaboration across teams, setting the foundation for more streamlined workflows and enhanced efficiency in project execution.

While DOT5 leads the way in adopting and implementing digital technologies, DOT1, DOT3, and DOT4 have made more modest strides, reporting *Level 1* integration in certain sub-elements. These agencies have initiated basic steps to improve their digital practices, such as digitizing documents and exploring early-stage software tools, but have not yet advanced to the more integrated and systematic use of technology seen at DOT5. The adoption of digital tools by these agencies appears to be in the early phases, focused primarily on digital documentation and basic data management, rather than comprehensive, cloud-based systems or more advanced software solutions. These efforts reflect a growing recognition of the need for digital transformation, though the full implementation of these technologies is still in progress.

In contrast, DOT2 reported no active efforts to digitize its project management processes or utilize digital tools across the project lifecycle. The absence of any reported initiatives for adopting digital documentation, software applications, or technology integration suggests that DOT2 is still heavily reliant on traditional, paper-based methods. This lack of progress in digital adoption may hinder the agency's ability to improve efficiency, reduce errors, and capitalize on the potential benefits offered by modern technologies such as BIM and cloud-based collaboration tools. Without a concerted push towards digitization, DOT2 may struggle to keep pace with other agencies that are already advancing toward more integrated, data-driven project delivery methods.

Overall, the findings highlight a significant variation in the level of technological adoption across the agencies. DOT5 stands out as the most advanced, leveraging cloud-based solutions and new software to enhance its project management capabilities. DOT1, DOT3, and DOT4 are taking initial steps toward digital integration, but their efforts remain at a more foundational level. DOT2, however, faces a significant gap in its approach to digital transformation, requiring a substantial shift in strategy to ensure it does not fall further behind in the digital era of infrastructure development.

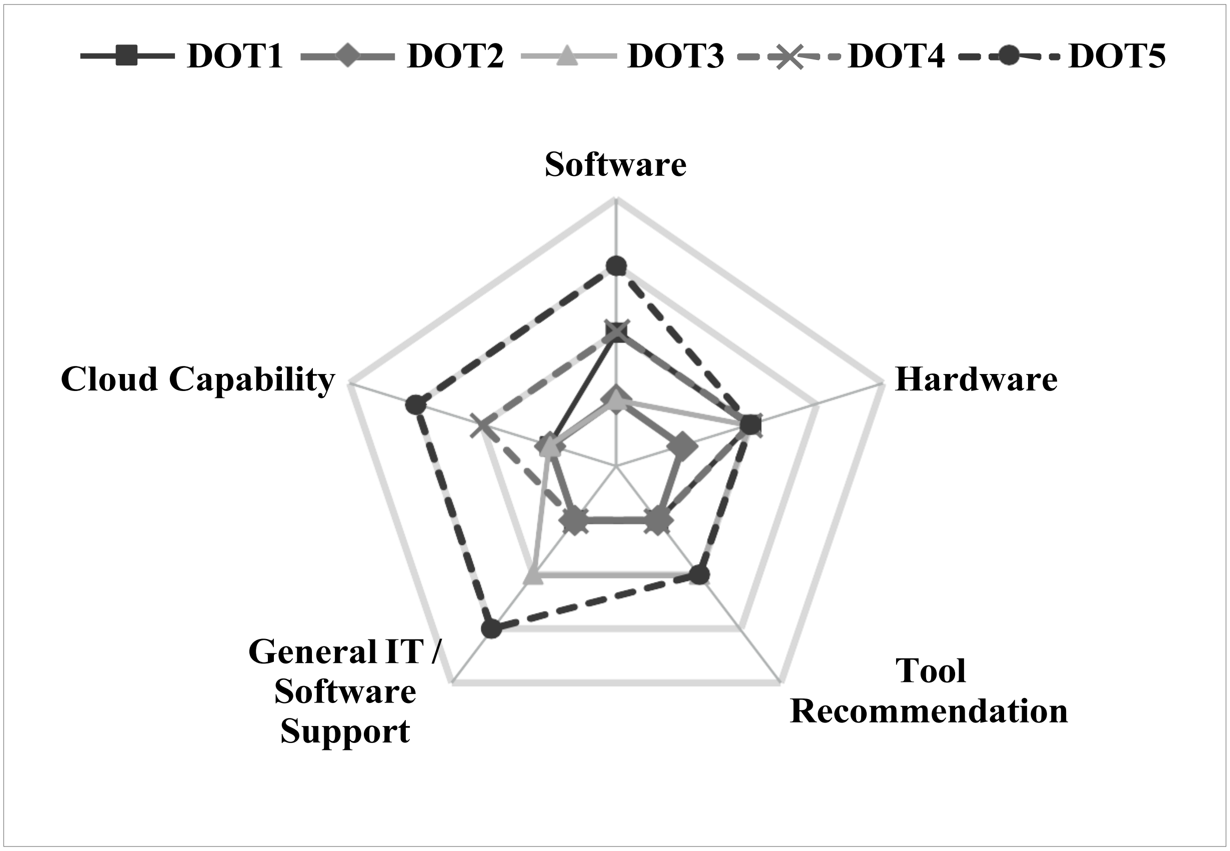


Figure 13 Tools and Technology

Open-Ended Responses

In addition to the Likert scale portion of the survey, respondents were provided the opportunity to provide open-ended responses to share their experiences, challenges, and insights regarding the implementation of BIM in their organizations. A common theme that emerged across all transportation agencies was the challenge of change readiness among employees. Respondents universally noted that integrating new software and digital tools into existing workflows is not a straightforward process. This shift from traditional, paper-based methods to a more digitally driven approach requires the development of new workflows, which have not always been clearly defined or communicated by organizational leadership. As a result, many agencies anticipate that the implementation of BIM will progress slowly and face significant hurdles before it can reach a level of maturity that significantly improves infrastructure project delivery.

DOT1 and DOT3 are currently in the process of developing their strategic plans for BIM adoption, working to define the necessary steps and resources for integrating BIM into their operations. However, these plans are still in the early stages, and both agencies are grappling with the challenge of aligning their organizational structures, workflows, and employee capabilities with the requirements of BIM. Meanwhile, DOT5 is further along in the process, with its BIM plan currently under final review. While DOT5 has made strides in its adoption of digital tools and BIM technologies, the agency highlighted a particular challenge related to the scalability of BIM use due to the large geographic area it covers. This issue underscores the complexities that agencies face in deploying standardized BIM practices across diverse regions and varied infrastructure projects.

DOT2, while it has made some progress, has only reached Level 1 in its digital documentation efforts by converting paper-based documents into PDFs. However, the agency continues to rely heavily on physical documents for managing its projects, indicating that it is still in the early stages of digital transformation. This reliance on paper documents may limit the agency's ability to fully realize the benefits of BIM and digital workflows. On the other hand, DOT3 and DOT4 both identified standardization as a key challenge, specifically the difficulty of establishing uniform BIM standards and practices among all stakeholders. This lack of consistency in BIM usage disrupts existing workflows and impedes smooth collaboration across different teams, contractors, and departments. For these agencies, overcoming this fragmentation is critical to achieving seamless BIM implementation and maximizing its potential to improve project efficiency and outcomes.

DOT4, however, provided a detailed and well-defined strategy for BIM implementation in future projects. This plan reinforces the agency's earlier responses in the Policies and Processes category, where DOT4 outlined a clear vision for integrating BIM into its operations. The agency plans to fully incorporate BIM into the design phase of its projects and is exploring various digital tools to enhance project delivery in all phases, from planning and design to construction, maintenance, and operations. DOT4's public digital delivery plan aims to pilot projects using 3D models in the planning, design, and construction phases by 2025, with full integration into the operations and maintenance (O&M) phase by 2027. This plan aligns closely with the FHWA Strategic Roadmap for BIM implementation and standardization, reflecting the agency's commitment to improving the efficiency and quality of infrastructure projects through digital technologies.

Despite these advancements, DOT4 also acknowledged several challenges that could impede the successful scaling of BIM within the agency. Among the primary obstacles are the need for extensive education and training, a prevailing fear of the unknown within the industry, and the lack of sufficient standardization across both internal and external stakeholders. These issues are critical barriers that need to be addressed if the agency hopes to achieve BIM maturity levels beyond Level 1 and fully realize the benefits of digital transformation in infrastructure projects. Overall, DOT4's proactive approach to BIM adoption, combined with a clear plan for future integration, demonstrates its commitment to overcoming these challenges and advancing the use of BIM across the project lifecycle.

In summary, while several agencies have made notable progress toward BIM adoption, all are confronting common challenges related to change management, scalability, standardization, and workforce development. DOT4's detailed implementation plan, along with its ongoing efforts to address these challenges, provides a promising model for other agencies as they work to integrate BIM into their operations. However, the pace of BIM adoption will depend on each agency's ability to overcome these hurdles, particularly in terms of employee readiness, the standardization of practices, and the effective use of digital tools across the entire project lifecycle.

Discussion

The survey conducted for this study was designed to assess the BIM maturity of Region 6 DOTs across four distinct elements. These elements were carefully chosen to capture a comprehensive picture of each agency's progress in adopting and implementing BIM technologies. The survey responses for each element offered valuable insights into the current state of BIM adoption within the Region 6 DOTs, highlighting both areas of strength and opportunities for improvement.

The data analysis for the *Policies and Processes* element showed that transportation agencies struggle to achieve higher levels of BIM maturity in other sub-elements without having a clearly defined mission, vision, goals, and objectives. These foundational elements are critical for guiding the integration of BIM across various stages of project delivery. Without a clear strategic framework, many agencies are unable to establish effective guidelines for their employees. Notably, DOT5 is the only agency reporting the presence of object-oriented guidelines, a crucial step toward standardizing BIM practices within the organization. This highlights the importance of having well-defined standards and strategies in place to ensure that BIM adoption is not only planned but also systematically executed. The open-ended responses from survey participants further emphasized challenges within the sub-elements related to People, Skills and Tools, and Technology. A recurring theme was the need for sufficient education and training to help employees become proficient in new technologies. Without these resources, BIM implementation will face resistance, and employees may struggle to adopt and use these tools effectively.

All agencies reported low levels of maturity in the Data and Standards sub-element, suggesting that a lack of standardized data protocols and practices is a significant hurdle in BIM implementation. Notably, the agencies that reported scores above Level 0 in certain sub-elements had already begun implementing standardized guidelines for their workflows. This step has been a key driver in their efforts to integrate BIM across the entire project lifecycle, rather than focusing only on the planning and design phases, as seen in agencies that have made less progress.

DOT5, in particular, stands out for its leadership in the Tools and Technology element. The agency has made significant investments in both software and hardware, ensuring that its staff is equipped with the necessary tools to perform their tasks efficiently. This proactive approach has positioned DOT5 as a leader in BIM adoption among the selected agencies, enabling them to implement advanced digital tools and technologies that improve project delivery. However, despite these achievements, DOT5 has expressed concerns about the scalability of BIM use due to the large geographic area it serves and the number of employees who require training in emerging technologies. This challenge underscores the complexities that larger organizations face in implementing BIM at scale. Achieving Level 2 maturity in certain sub-elements will be more challenging for DOT5 compared to smaller agencies due to the larger scope of projects and the scale of workforce education required.

The relationship between agency size and BIM adoption is also reflected in the survey data. DOT5, the largest agency in terms of both miles of public road and the number of Metropolitan Planning Organizations (MPOs), reported achieving at least Level 1 for all sub-elements—a milestone not yet reached by the other agencies. DOT1 and DOT4, the second and third largest agencies, also reported notable progress across the four elements of the BIM framework. These agencies, though still in the early stages of BIM implementation, are making strides in integrating BIM into their operations, which aligns with their larger-scale project requirements.

In contrast, smaller agencies, such as DOT2 and DOT3, have been slower to adopt BIM. These agencies, which manage fewer miles of public road, reported lower maturity levels in almost all sub-elements. DOT2, for example, only reported Level 1 for the planning and design phase as well as document management, a common starting point for agencies in the early stages of digital transformation. This aligns with prior research suggesting that smaller infrastructure agencies tend to lag behind vertical construction sectors in BIM adoption. Interestingly, DOT2 and DOT3 also reported the poorest road conditions according to the Bureau of Transportation Statistics (2022), which may indicate that these agencies are not yet feeling the pressure to adopt more advanced technologies like BIM. Their traditional methods have not posed significant operational challenges, which could explain their slower transition to digital tools.

On the other hand, DOT1 and DOT4, which are beginning to implement BIM, have some of the best road conditions among the selected agencies. This could suggest that these agencies are more proactive in seeking out innovative tools, like BIM, to improve project delivery methods and manage their infrastructure assets effectively. DOT5, despite reporting the highest BIM maturity levels across all elements, ranks third in road conditions. This could imply that the scale of its operations, combined with the complex challenges of managing a large geographic area, requires a higher level of BIM integration to achieve the same results that smaller agencies may see more quickly.

The analysis also underscores the importance of clearly defined roles and responsibilities within the organization. Agencies that are implementing BIM successfully recognize that employee acceptance of new, more complex design methods is essential. This requires providing education and training opportunities for those who will be working directly with BIM tools. Moreover, data collection methods need to be standardized across the agency to ensure that data is interoperable with BIM conditions and can be easily shared with external stakeholders, such as contractors and consultants. BIM tools must also be regularly updated and compatible with new hardware to ensure that the technology remains effective and efficient. Organizational support is crucial, especially in maintaining system and server operations, as well as in supporting the use of BIM tools across the agency. These three elements: education, standardization, and technological support, may require more focused assessment and refinement, as they are foundational to the success of BIM adoption within an agency.

Ultimately, the success of BIM implementation across transportation agencies depends on the acceptance and support of all members within the organization. While agencies can invest in the most advanced BIM tools and develop comprehensive guidelines for their use, without buy-in from both leadership and staff, BIM integration will not reach its full potential. The key to successful implementation lies in fostering a culture of support for digital transformation at all levels of the organization. Given that many other countries have already adopted advanced BIM technologies, the FHWA may face significant challenges in achieving Level 2 BIM maturity across all U.S. transportation agencies within the next decade. Conducting a nationwide BIM maturity assessment for all transportation agencies is therefore essential to identify areas for improvement, assess the potential return on investment, and develop tailored strategies for advancing BIM implementation in U.S. infrastructure projects.

BIM Implementation Framework

The final phase of this study involved the creation of a comprehensive BIM Level 2 Implementation Framework, complete with prioritized action items. This framework was developed using the valuable insights gathered from the regional survey, along with the findings from the BIM maturity assessment conducted across various DOTs (Figure 14). The goal of the framework is to provide a clear, step-by-step guide for advancing BIM adoption and integration, aligning with the overarching national roadmap for BIM implementation in infrastructure projects.

To ensure the framework is both actionable and relevant, the prioritization of each action item was carefully determined. Key factors considered in this process included the current BIM maturity level of each DOT, the availability of resources (such as staff, funding, and technology), and each agency's strategic objectives for the near and long-term future. This thoughtful prioritization ensures that DOTs can begin implementing practical and achievable steps that reflect their unique starting points and organizational needs.

The BIM Level 2 Implementation Framework is designed to provide tangible, actionable steps for DOTs, helping them progress towards achieving BIM Level 2 maturity—a level that emphasizes the integration of Federated Object Models and Databases, and aligns with the broader goals of improved project delivery, data management, and lifecycle management. By following this framework, DOTs can foster greater collaboration and innovation within the transportation sector, ensuring that new technologies and methodologies are effectively embraced across all stages of infrastructure projects.

Although specifically crafted for the DOTs in Region 6, the framework is designed with scalability and flexibility in mind. Its core principles, strategies, and action items are transferable to other states and regions, making it a useful tool for any transportation agency looking to advance its BIM capabilities. This broader applicability ensures that the framework can serve as a nationwide model, guiding DOTs across the United States as they strive to meet the goals outlined in the FHWA's BIM Strategic Roadmap.

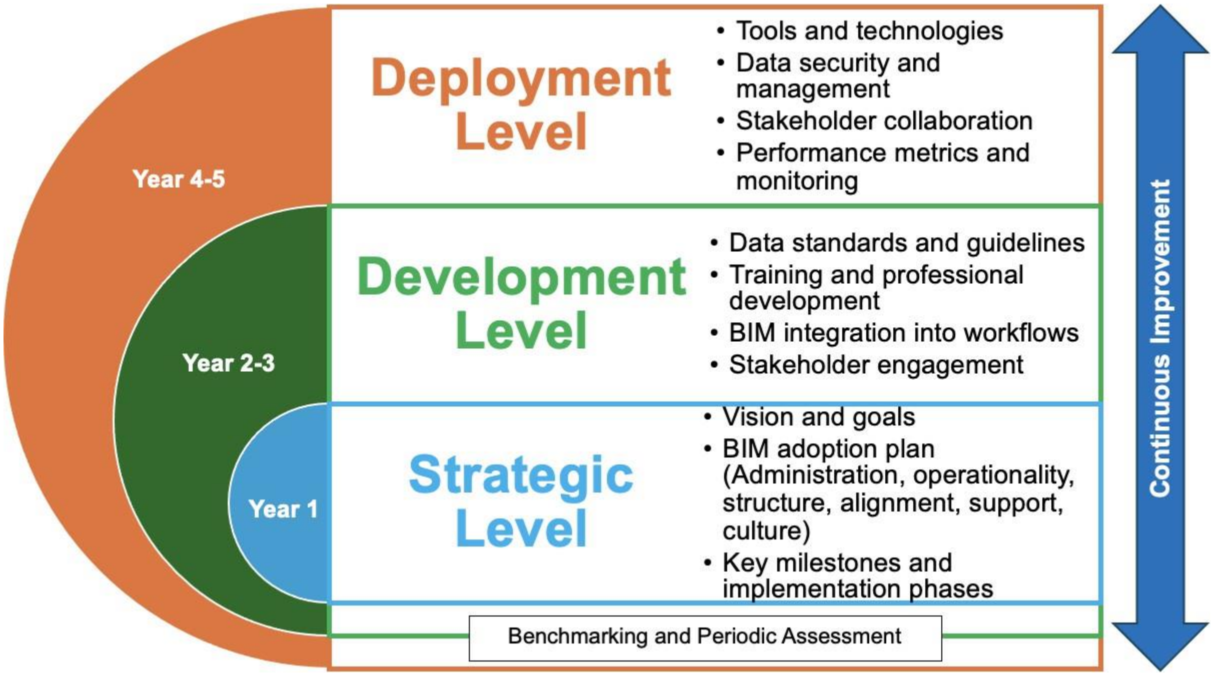


Figure 14 Proposed BIM Implementation Framework

Post-Survey Discussion

Post-survey discussion sessions were scheduled for the participating DOTs to provide an opportunity for deeper engagement and reflection on the results of the study. The discussion aimed to present a comprehensive overview of the research study, results, and proposed framework with a visualization dashboard. Additionally, the conversation highlighted the unique and shared challenges faced by the DOTs in Region 6, as well as the specific action items recommended for each organization to help advance their BIM implementation efforts. A copy of the presentation, including the dashboard, was shared with the DOTs to serve as a resource in their ongoing efforts toward BIM adoption.

Three out of the five DOTs were able to participate in the follow-up discussions, providing important insights and feedback. DOT5 emphasized the significance of the sub-elements displayed on the dashboard, particularly those within the "Tools and Technology" category. DOT5 also expressed concerns about the current technology available for BIM implementation, noting that while some vendors offer promising products, these solutions often lack the comprehensive scope needed to address all aspects of BIM integration across their organization. Furthermore, it also highlighted the varying pace of BIM adoption within the state, with some districts advancing in their use of BIM while others remain reliant on traditional, non-digital methods for data collection and management. This disparity between districts underscores the challenge of achieving uniform BIM integration across the entire organization.

DOT1 raised a question regarding the internal challenges observed at other DOTs, particularly around the difficulty in gaining contractor buy-in for BIM adoption. While consultants are generally more open to using BIM, DOT1 noted that contractors present a greater hurdle in embracing digital tools and processes. This observation suggests that successful BIM implementation may depend on overcoming resistance not only within the DOTs themselves but also among external stakeholders, such as contractors, who are crucial to the successful delivery of BIM-enabled projects.

DOT2 shared positive developments within their administration, noting a significant shift in support for BIM implementation. They expressed optimism that, with growing internal backing, the adoption of BIM could accelerate in the coming years. Louisiana also reported a high level of change readiness among consultants, which could contribute to smoother and more rapid BIM integration. However, DOT also acknowledged the challenge of keeping pace with other DOTs in the study, with the primary objective being to achieve and maintain similar levels of BIM integration across their projects. This highlighted a key concern shared by several DOTs-ensuring that their BIM efforts align with the national and regional benchmarks for BIM maturity.

Overall, the post-survey discussions provided valuable feedback and identified key obstacles and opportunities within each DOT. These insights will inform the ongoing development of strategies to overcome challenges and accelerate BIM adoption across Region 6, while also providing actionable steps for other regions seeking to implement BIM successfully.

BIM Maturity Assessment Dashboard

A comprehensive dashboard was developed to visually represent the survey responses from all states within Region 6 and to provide actionable guidance for DOTs as they navigate the process of BIM implementation. The tool is structured to help agencies better understand their current BIM maturity levels and identify the necessary steps to progress toward higher levels of integration. The dashboard contains six primary tabs, each dedicated to a specific aspect of BIM maturity. These sheets are:

- Summary
- Policies and Processes
- People and Skills
- Data and Standards
- Tools and Technology
- Definitions

Summary Tab
The Summary Tab serves as an overview, summarizing the results of the BIM maturity assessment in both tabular and graphical formats. DOTs can view a radar chart that compares their current BIM maturity level with their target level. This comparison is based on the four main elements outlined in the FHWA Roadmap: Policies and Processes, People and Skills, Data and Standards, and Tools and Technology. The radar chart features two key components:

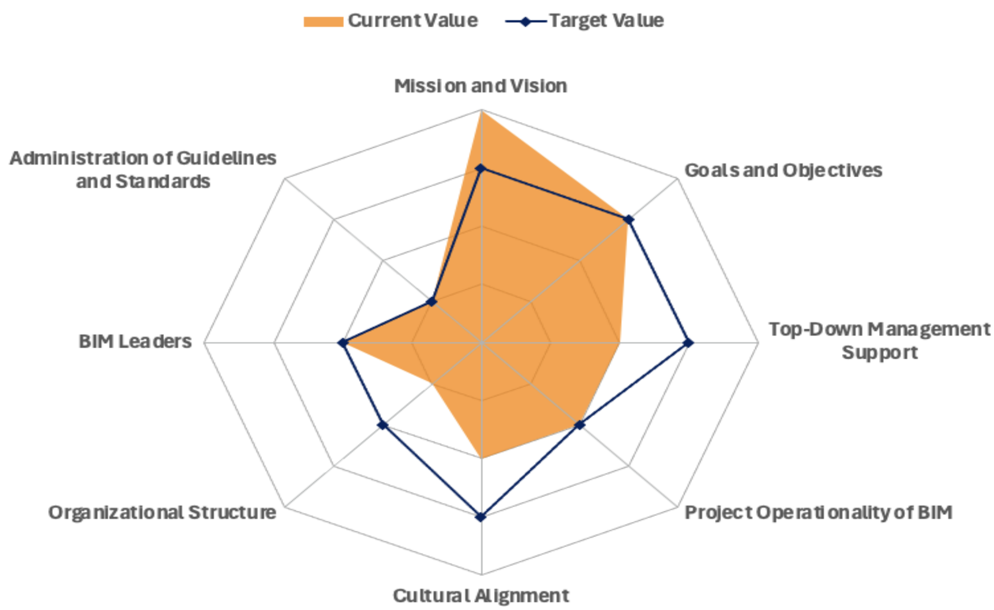
- **Current Level**: This is updated as DOTs input their answers for each sub-element across the four main elements.
- **Target Level**: DOTs manually update their target level, which reflects their desired BIM maturity level based on their timeline for implementation.

The Summary Tab also includes a table displaying the current and target levels of all sub-elements, providing DOTs with a comprehensive view of their BIM maturity status. The table allows for easy comparison across the different sub-elements. The one-on-one interactions between sub-elements were instrumental in creating the action items displayed on the dashboard. These interactions, while primarily confined to their respective main elements, sometimes cross over into other elements, highlighting interdependencies between different aspects of BIM implementation.

Policies and Processes Tab
This tab provides a comprehensive overview of the current and target levels for the sub-elements related to Policies and Processes within the BIM maturity framework. It serves as a guide for DOTs to assess their organizational readiness and progress in key areas that underpin BIM adoption and integration. Each sub-element in this section is assessed to determine its current maturity level, with the goal of helping agencies understand where they stand in relation to best practices outlined in the FHWA Roadmap. The target levels represent the desired BIM maturity that each DOT aims to achieve within a defined timeframe. By setting these target levels, the tab allows DOTs to track their progress and prioritize their efforts as they work toward a fully integrated BIM approach. For each sub-element, action items are provided to guide DOTs on the steps they need to take to improve their BIM maturity in the area of Policies and Processes. These action items are designed to directly address the specific gaps or challenges identified in the maturity assessment. The action items are carefully derived from the FHWA roadmap, ensuring that they align with the national framework and follow a logical progression of activities that help DOTs advance toward higher maturity levels (Figure 15).

POLICIES AND PROCESSES

Sub-Element	Current Value	Target Value
Mission and Vision	3	2
Goals and Objectives	2	2
Top-Down Management Support	1	2
Project Operationality of BIM	1	1
Cultural Alignment	1	2
Organizational Structure	0	1
BIM Leaders	1	1
Administration of Guidelines and Standards	0	0



Action Items

1. Conduct regular training programs for all employees on the administration of BIM guidelines and standards across all phases of a project.
2. Develop a communication strategy that emphasizes how high-quality data contributes to achieving the organization’s mission and vision.
3. Review and update standardized guides to verify that they align with and support the organization’s mission and vision.
4. Outline the responsibilities for each role in the organization that aligns with the established goals.
5. Develop a framework outlining the relationship between goals, objectives, and individual responsibilities for all teams.

Level 0 | Level 1 | Level 2 | Policies and Processes

Figure 15 BIM Maturity Assessment Dashboard

People and Skills Tab

This tab provides similar functionality to the People and Skills sub-components, displaying the current and target levels for relevant sub-elements. Action items related to People and Skills focus on improving organizational capacity for BIM adoption, such as enhancing workforce training, fostering leadership in BIM, and defining roles and responsibilities clearly within the organization. These action items are prioritized based on their importance in building the necessary skills and competencies for successful BIM implementation.

Data and Standards Tab

This tab highlights the current and target levels for sub-elements tied to data management and BIM standards. This section emphasizes the importance of standardizing data formats and ensuring interoperability between systems and stakeholders. Action items here encourage DOTs to streamline their data collection methods, ensure consistency in data usage, and adopt industry standards for BIM.

Tools and Technology Tab

This tab is dedicated to assessing and improving the tools and technology used for BIM implementation within the DOT. This Tab focuses on evaluating the availability and functionality of software, hardware, and infrastructure needed to support BIM workflows. Action items provided in this section are aimed at ensuring that DOTs have the right tools to facilitate effective BIM integration across their projects.

Definitions Tab

This tab provides clear and concise definitions for each element and sub-element used in the survey and dashboard. This ensures that users fully understand the terminology and concepts behind the sub-elements, facilitating accurate self-assessment and meaningful engagement with the dashboard. As the dashboard is designed to be used by multiple DOTs, consistency in how terms are interpreted is crucial. The Definitions Tab ensures that each DOT participating in the BIM maturity survey understands the terminology in the same way, promoting uniformity in the data collected. This consistency is essential for benchmarking the BIM maturity levels across different agencies and ensuring that comparisons between agencies are valid and meaningful.

Action Items for BIM Advancement

The action items displayed on each tab are derived from an extensive list of 49 sub-element interactions, mapped to the FHWA Roadmap. These interactions, which reflect the relationships between different sub-elements, were used to create specific action items tailored to each DOT's needs based on the current state of BIM implementation. The action items are categorized into three priority levels:

- **Low Priority**: These are early-stage actions that will have a minimal impact on BIM maturity but are still necessary as foundational steps at the strategic level.

- **Medium Priority**: These actions are essential for moving the DOT towards higher development levels of BIM maturity, addressing key gaps in the organization's processes.
- **High Priority**: These actions are the most critical for advancing BIM integration and achieving the deployment level, having a significant impact on the organization's ability to implement BIM effectively.

Each action item within the dashboard is designed to increase the BIM maturity level of a given sub-element, with the extent of improvement directly linked to the priority assigned to the action. The priority of each action item, whether high, medium, or low, corresponds to the degree of change it is expected to facilitate within the maturity level of the sub-element. For example:

- High-priority action items are designed to drive substantial improvements and will increase a sub-element's maturity level by 2 points.
- Medium-priority action items are intended for steady progress and will increase the sub-element's maturity level by 1 point.
- Low-priority action items, while important, are expected to contribute more modest improvements, adding 0 points to the sub-element's maturity level.

These differentiated levels of priority help ensure that DOTs focus on the most impactful actions first, addressing the critical gaps in their BIM processes and capabilities. The priority scoring system is designed to streamline the decision-making process for DOTs, guiding them to make the most effective use of their time and resources as they embark on their BIM adoption journey. The dashboard also uses the difference in BIM maturity levels between the sub-elements to identify areas where improvement is most needed. For instance, if a DOT's maturity level for a specific sub-element is significantly lower than for other sub-elements within the same category (such as People and Skills or Policies and Processes), this gap is highlighted to ensure that actions are targeted where the need is most urgent. The action items are mapped directly to these gaps, ensuring that DOTs can prioritize addressing the areas that are lagging. This approach allows DOTs to focus on correcting deficiencies that will have the greatest impact on their overall BIM maturity. This structured approach ensures that DOTs do not get overwhelmed by the complexity of BIM implementation, but instead, can focus on small, manageable steps that lead to meaningful progress over time.

The dashboard is not only a visual representation of the DOT's current BIM maturity levels, but also an actionable guide for advancing through the maturity model. It gives DOTs a personalized path forward, aligned with their specific maturity levels and current gaps identified through the survey. By mapping these gaps to targeted action items, the dashboard makes it easier for DOTs to prioritize their BIM initiatives and direct resources towards the most pressing areas. This level of customization ensures that DOTs receive a tailored, strategic approach to their BIM development that aligns with their unique needs, challenges, and organizational goals.

Chapter 5. Conclusions and Recommendations

The implementation of BIM for infrastructure projects presents both significant challenges and promising benefits. These challenges span multiple areas, including competency development, establishing clear stages and steps for implementation, and refining the overall approach to BIM integration. Case studies from the field have highlighted key advantages of BIM adoption, particularly in terms of time and cost savings. Return on investment (ROI) analyses have also been conducted to quantify the financial benefits of adopting BIM in infrastructure projects, further demonstrating its value. To help guide state transportation agencies in BIM adoption, the FHWA has developed a 10-year roadmap aimed at unifying efforts across the nation. This roadmap focuses on several critical areas: policies, skills development, data management, standards, and tools. It emphasizes a collaborative, phased approach to BIM implementation that will ensure transportation agencies can fully integrate BIM into their operations and deliverables.

The literature review for this study underscores the importance of a standardized matrix model, one that aligns with the FHWA's roadmap, to assess the BIM maturity of state DOTs. Since the FHWA's roadmap is still in its pilot phase, a more comprehensive evaluation is necessary to refine the framework and tailor it to the specific needs and contexts of transportation agencies and their industry partners. Such evaluations will provide valuable insights into how transportation agencies can navigate the challenges of BIM implementation and progressively move toward more sophisticated levels of digital integration.

As part of this effort, a survey was conducted to assess the BIM maturity levels of five state DOTs in the United States. The responses indicated that all of the participating agencies are in the early stages of BIM integration, a finding that is consistent with existing literature on the subject. The survey also highlighted several shared challenges across agencies, most notably the difficulty in aligning organizational culture with the requirements of BIM adoption. For many agencies, BIM integration is not just a matter of adopting new software or technology; it also involves a fundamental shift in how teams collaborate, communicate, and manage information. This cultural shift can be one of the most significant barriers to successful BIM implementation.

Future research is needed to utilize this BIM maturity evaluation metric to guide transportation agencies toward achieving the goals outlined in the FHWA's 10-year plan. One of the roadmap's key milestones is the transition to a Level 2 Federated Object Model and Databases, a standard that emphasizes the integration of multiple systems and stakeholders into a cohesive BIM framework. Achieving this goal will require substantial effort in aligning people, processes, and technology across all levels of the organization, and further studies will be necessary to understand how best to support this transition in the context of state DOTs.

One of the most significant challenges identified through the survey results is the lack of standardization in BIM terminology and practices across transportation agencies. This lack of uniformity in terms, processes, and methodologies has created confusion and fragmentation, hindering the effective adoption of BIM at scale. Overcoming this challenge will require concerted efforts from all involved agencies, including the development of common standards and the sharing of best practices and lessons learned. Collaborative platforms or working groups that bring together agencies, industry partners, and stakeholders could help facilitate this process and promote consistency in BIM implementation nationwide.

While the findings of this study offer valuable insights into the current state of BIM adoption in transportation agencies, several important limitations should be acknowledged, which also highlight areas for future research:

- Limited Sample Size: The study included only five transportation agencies in Region 6, which may not adequately represent the diversity of state DOTs across the country. The experiences and challenges of these agencies may not fully capture the variations in resources, needs, and challenges faced by other state DOTs.

- Self-Reported Data: The survey relied on self-reported data from the participating agencies, which may introduce bias or inaccuracies. Respondents' perceptions, experiences, and interpretations of BIM maturity could influence their responses, potentially over- or under-reporting the actual state of BIM adoption within their agencies.

- Variations in Resources and Capabilities: The resources available to each state DOT, such as funding, personnel, and technical expertise, can significantly impact their ability to implement BIM effectively. Agencies with more resources may be able to adopt BIM technologies more quickly and integrate them more thoroughly, while smaller agencies or those with limited budgets may struggle to achieve the same level of success. Future studies should account for these differences and examine how they affect the pace and scope of BIM implementation across agencies.

- Early-Stage Implementation: Since most of the agencies in this study are still in the early stages of BIM adoption, the survey findings may not provide a complete picture of the long-term challenges and benefits associated with more advanced levels of BIM maturity. Longitudinal studies that track BIM implementation over time within the same agencies could offer valuable insights into the evolving benefits, barriers, and lessons learned as agencies progress toward more sophisticated stages of BIM integration.

To address these limitations and expand on the findings, future research should aim to:

- Conduct longitudinal studies to track the progress of BIM adoption over time within individual agencies. This approach would help identify emerging trends, long-term benefits, and persistent challenges in BIM integration.

- Develop targeted strategies to enhance BIM adoption that cater to the unique needs of different states. For example, larger states may face scalability challenges, while smaller states may benefit from emphasizing the value proposition of BIM in terms of cost savings and efficiency improvements. Tailoring strategies to the specific needs of each state DOT will help ensure that BIM implementation is both practical and effective across the diverse range of transportation agencies.

In conclusion, this study provides important insights into the current state of BIM adoption within Region 6 state DOTs, but it also highlights the need for continued research to refine BIM maturity models, develop targeted strategies for different agency contexts, and track long-term progress. The FHWA's 10-year roadmap for BIM implementation is an ambitious and essential initiative that requires ongoing collaboration, standardization, and support from both federal and state agencies. By addressing the challenges identified in this study, transportation agencies can advance toward achieving a fully integrated, data-driven approach to infrastructure management that will improve project outcomes, enhance collaboration, and deliver long-term value to the public.

Chapter 6. Implementation of Project Outputs

A BIM maturity assessment tool has been developed in alignment with the FHWA National BIM Roadmap, serving as a strategic guide for State DOTs to advance their BIM practices. By following the actionable steps outlined in the dashboard, DOTs can systematically progress toward the goal of achieving BIM Level 2 maturity, as outlined in the FHWA Roadmap. This roadmap functions as the national framework for BIM adoption, aiming to standardize and elevate the use of BIM across infrastructure projects in the United States.

The dashboard tool is designed to support DOTs in Region 6 by providing customized guidance that is in direct alignment with the broader national vision for BIM implementation. Through the tool, DOTs can assess their current BIM maturity, identify areas for improvement, and receive specific action items tailored to their unique needs and challenges. These action items not only provide a clear pathway for improvement but also help DOTs focus their efforts on areas that will yield the greatest impact, thereby ensuring that their BIM adoption process is efficient, strategic, and aligned with national objectives.

In this way, the dashboard functions as both a diagnostic tool and a prescriptive guide. It helps DOTs measure their current BIM maturity levels, identify key gaps in their processes, and prioritize action items to move forward. At the same time, the tool provides a clear roadmap for advancing towards higher levels of BIM integration, fostering a more digitalized, efficient, and collaborative transportation ecosystem. By adhering to the action items recommended in the dashboard, DOTs can align their practices with best industry standards, enhance their capacity for collaboration, and improve the overall management of transportation projects.

To ensure the tool's effectiveness and relevance, the dashboard has been discussed with regional DOTs, and feedback has been actively collected. This collaborative approach has been instrumental in identifying areas where the tool can be enhanced and refined to better meet the specific needs of the DOTs within Region 6. Input from these agencies has provided valuable insights that will guide further improvements to the tool's structure, functionality, and user interface.

Chapter 7. Technology Transfer and Community Engagement and Participation (CEP) Activities

The team designed an enriching full-day immersive program as part of the Transportation Research Immersive Program (TRIP), hosted during the third week of June 2024 at the University of Texas at El Paso. This educational initiative was specifically designed for students from El Paso Community College and high school seniors from the El Paso Independent School District (EPISD). The main objective was to provide a hands-on learning experience that thoroughly engaged students in the complexities and managerial aspects of construction engineering related to transportation projects.

The immersive activity was designed to simulate real-world scenarios where students could directly engage with the challenges of efficiently managing the construction of transportation projects, ensuring they are completed on schedule and within the allocated budget. This experiential learning module allowed students to explore the nuances of project management and the practical application of theoretical knowledge (Appendix D).

Throughout the day, students displayed keen interest and actively participated, asking numerous insightful questions regarding the impact of emerging technologies on the construction and management of transportation projects. Their enthusiasm and curiosity underscored the program's effectiveness in fostering a deeper understanding and appreciation of the field.

Overall, the TRIP proved to be tremendously successful, not only in educating the participants but also in inspiring them to consider future careers in transportation engineering and management. This initiative highlighted the importance of practical, hands-on experiences in academic and professional development, making a significant impact on the students involved.

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Appendix A: National BIM Strategic Roadmap

A1. Definitions of Elements

Element and Sub-elements	Definition
Policies and Processes	**Used to minimize data loss, guarantee information oversight, and encourage attention and elevation of details captured in digital data flow across all stakeholders.**
Mission and Vision	The purpose of implementing BIM and the future state that an organization plans to achieve.
Goals and Objectives	Targets and actionable steps that guide organizations toward successfully adopting and integrating BIM.
Top-Down Management Support	BIM implementation not only has support from management but is being actively pushed by management
Project Operationality of BIM	Roles and uses of BIM are standardized by project stages and are broadly applicable.
Cultural Alignment	The use of BIM through shared platforms that facilitate communication, coordination, and teamwork, aligns with organizational values, beliefs, and behaviors.
Organizational Structure	Organizing project teams, coordinating activities, and optimizing workflows is made possible by the hierarchical structure of roles and responsibilities within an organization.
BIM Leaders	Technically skilled employees who improve processes, facilitate adoption, and manage resistance to change to ensure effective implementation of BIM.
Administration Guidelines and Standards	Managing guidelines, standards, and regulations for the implementation and governance of BIM processes and technologies.
People and Skills	**Employees need to be technically skilled with relevant resources to implement BIM when new and updated technology systems are deployed.**
Goals and Responsibilities	Primary functions that require tasks and obligations to create and guide organizational strategies.
Professional Development Programs / Credentials	Formal instruction and skill development to ensure individuals and teams are fit and proficient in utilizing BIM technology within their roles.
Training Sessions	Organization skill development session without an external instructor.
BIM Acceptance	An organization's willingness and preparedness to integrate BIM, including assessing and. improving proficiency, employee adoption, and attitudes.

Data and Standards	**Used to populate and guide the development of information models. Modeling and information-exchange standards make data and its movement between systems and stakeholders consistent and predictable.**
Standardized Guides	Documentation and resources for understanding and implementing BIM processes and standards within an organization.
Manuals and Templates	Resources to support the understanding of BIM implementation and preset formats to document data.
Plan and Design Phase	Utilizing BIM data and processes facilitates tracking project progress and managing project activities effectively, including the use of software tools to identify and resolve conflicts or clashes in building design and construction virtually.
Construction Phase	Utilizing BIM data and processes to enhance construction
Operations and Maintenance Phase	Utilizing BIM data and processes to optimize the operations and maintenance of built assets.
Document Management	Using standards for efficient organization, storage, and access to project-related information to facilitate data exchange and compatibility with other departments or applications.
Quality of Data	Ensuring BIM processes and outputs meet predefined standards and expectations for accuracy, completeness, and reliability.
Tools and Technology	**Used to build information models and collect, store, share, and analyze the data populated in these models.**
Software	Programs, operating information, specialized tools, platforms, and various applications and technologies utilized for creation, management, analysis, collaboration, and optimization of BIM.
Hardware	Using specialized devices and technology to run software applications to support the creation, visualization, and analysis of BIM.
Tool Recommendations	The organization uses tools recommended to facilitate lifecycle tasks.
General IT/Software Support	Staff in charge of general system management, alongside technical assistance, updates, and resources for software applications.
Cloud Capability	Using a centralized model server or cloud-based platform to store, manage, and distribute BIM data and models.

A2. BIM Maturity Levels

Maturity Levels	Explanation
L0 - Document Oriented	**Shortened version: Reliance on traditional 2D drawings and documents and paper documentation without digital collaboration or integration. Terms, objects, and attributes are inconsistent across the organization.** Information is modeled using electronic or paper documents, and the definitions of data, terms, objects, and attributes are inconsistent across the enterprise. Knowledge about BIM within the organization is limited or nonexistent. Open standards are not used for data management (i.e., modeling, exchange, security, storage). Disparate information and technology systems are used throughout the organization, making data exchanges between these systems difficult. Most of the data integrations that have been carried out are within an asset lifecycle phase (e.g., within the design or O&M phases). Information is often exchanged through informal means such as emails, phone calls, and paper documents.
L1 - Object Oriented	**Shortened Version: Introduction to 3D models for design and documentation. Data exchanges and specific projects are targeted as BIM early pilot projects. Stakeholders are aware of BIM processes, policies, standards, tools, and systems.** Foundation has been built to deploy BIM by adopting open standards for defining data, terms, objects, and attributes. High-value data exchanges across disciplines are being piloted. The industry in general and the agency's internal and external stakeholders are aware of BIM processes, policies, standards, tools, and systems. The agency is bringing together all stakeholders to create implementation action plans, plan data governance policies, and execute early pilot projects. Specific types of projects are being targeted as BIM early pilot projects (e.g., bridge projects using design-bid-build (DBB) contracting).
L2 - Federated Object Models and Databases	**Shortened Version: Standard templates for data exchange within the organization between asset lifecycle phases are developed, which are then used to automate information exchanges. Information requirements and delivery specifications are clearly defined.** The data libraries, terms, and definitions based on open information–exchange standards and adopted in Level 1 have been used to develop standard templates for data exchanges that need to happen within the organization between asset lifecycle phases. These standards have been used to automate information exchanges. Information requirements and delivery specifications are clearly defined.

L3 - Integrated Lifecycles	**Shortened Version: Full integration and collaboration among all project participants during the entirety of the project lifecycle. Data are available to both internal and external stakeholders through automated systems.** Relationships have been built with external stakeholders, such as contractors, who are involved in design-build (DB) projects or public–private partnerships. There is an understanding between internal and external stakeholders about the standards, processes, and protocols used to exchange information. Data are available to both internal and external stakeholders through automated systems.

Appendix B: Existing BIM Maturity Tools for Organizations

No	Country	Year	Tool	Owner	Type	Application	Source
1	Australia	–	BIM Excellence Online Platform (BEOP)	ChangeAgents AEC	Maturity Tool	Organization	301in BIM Maturity Matrix | BIMe Initiative (bimexcellence.org)
2	UK	–	BIM Online Maturity Assessment	National Federation of Builders (NFB)/CITB	Maturity Tool	Organization	Could not find the maturity tool / requires associate membership
3	Netherlands	2019	BIM Supporters' BIM Compass (Compass)	BIM Supporters	Maturity Tool	Organization	BIM Compass – Get insight in your BIM maturity and potential! (bimsupporters.com)
4	UK	2011	CPIx BIM Assessment Form (CPIx)	Construction Project Information Committee	Maturity Tool	Organization	CPIx BIM Assessment Form (bimuk.co.uk)
5	UK	2021	Maturity Matrix: Self-Assessment Questionnaire (MMSAQ)	Project 13 – Institute of Civil Engineers	Maturity Tool	Organization	Project 13 Home - Project 13
6	USA	2012	NBIMS Capability Maturity Model (NBIMS)	National Institute of Building Sciences	Maturity Tool	Organization	Interactive_BIM_Capability_Maturity_Model_v_2_0_NBIMS.xls (live.com)
7	USA	2013	Organizational BIM Assessment (OBA)	Pennsylvania State University	Maturity Tool	Organization	https://lp.constantcontact.com/su/77NsQ0E/BIMforOwners
8	UK	–	SFT's BIM Compass	Scottish Futures Trust	Maturity Tool	Organization	BIM Grading Tool - BIM Level 2 Guidance (scottishfuturestrust.org.uk)
9	UK	–	Supply Chain BIM Capability Assessment (SCBCA)	Wates	Maturity Tool	Organization	Supply Chain BIM Capability Assessment (P02) (wufoo.com)

10	USA	2011	VICO BIM Scorecard	Vico Software	Maturity Tool	Organization	Survey no longer available
11	USA	2014	Owner's BIMCAT (Competency Assessment Tool)	Giel & Issa	Maturity method	Organization	Framework for Evaluating the BIM Competencies of Building Owners (scix.net)
12	UK	–	BIM Maturity Assessment Tool	Department for Transportation	Maturity method	Organization	Subscription to download the article
13	USA	2014	Building Information Modeling Cloud Score (BIMCS)	Du et al.	Maturity method	Organization	(PDF) BIM Cloud Score: Benchmarking BIM Performance (researchgate.net)
14	USA	2013	Organizational BIM Assessment Profile	Pennsylvania State University	Maturity method	Organization	(PDF) BIM Planning Guide for Facility Owners-Version 2 0 | Julian Lopez - Academia.edu
15	Netherlands	2014	Netherlands BIM Maturity Model	Buow Informatie Raad	Maturity Method	Organization	dutch-bim-leaflet.pdf (wordpress.com)

Appendix C: Survey

THE UNIVERSITY OF TEXAS AT EL PASO

Assessing Building Information Modeling (BIM) Maturity and Identifying Barriers to Implementation among Transportation Agencies in Region 6

Hello

You are invited to participate in our survey assessing the maturity level of Building Information Modeling (BIM) among transportation agencies in Region 6. It will take approximately twenty (20) minutes to complete the questionnaire.The Federal Highway Administration (FHWA) has proposed a roadmap for BIM implementation activities to carry out in the next ten years to guide FHWA, transportation agencies, and their partners to increase the maturity and growth of BIM for Infrastructure nationwide. This survey aims to assess the current level of BIM implementation among transportation agencies, identify barriers to implementation, and provide guidance to the transportation agencies involved in this study.

The survey contains five sections. The first four sections are organized around the four elements of BIM for Infrastructure: Policies and Processes, People and Skills, Data and Standards, and Tools and Technology. The elements are described in their respective sections. The last section contains a series of open-ended questions that we will greatly appreciate your response to the best extent.Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. It is very important for us to learn your opinions.

If you have questions at any time about the survey or the procedures, you may contact Dr. Adeeba Raheem at aaraheem@utep.edu or Dr. Jeffrey Weidner at jweidner@utep.eduFunding for this research project is kindly provided by the U.S. Department of Transportation under the University Transportation Center (UTC) grant #DTRT13-G-UTC36.

Thank you very much for your time and support. Please start the survey now by clicking on the Continue button below.

Building Information Modeling (BIM) Maturity Assessment

QuestionPro

Categories and Elements

This survey aims to measure the level of BIM integration at an organizational level. Four (4) main elements contain respective sub elements for evaluation. The element and sub element definitions are listed below:

Policies and Processes: Used to minimize data loss, ensure information oversight, and encourage attention to and elevation of details captured in digital data through an automated and seamless information flow across all stakeholders.

People and Skills: Operate BIM-related tools and technologies, administer BIM policies and processes, and carry out BIM tasks.

Data and Standards: Populate and guide the development of information models. Modeling and information-exchange standards make data and their movement between systems and stakeholders consistent and predictable.

Tools and Technology: Build information models and collect, store, share, provision, and analyze the data held in those models. Tools and technologies enable the deployment of BIM policies and processes.

Does your organization have a Mission and Vision, Goals and Objectives for BIM Integration?

- ◯ No organizational Mission and Vision, Goals and Objectives.
- ◯ Employees know about the Mission and Vision, Goals and Objectives, but it is not formally written.
- ◯ Mission and VIsion, Goals and Objectives are established but there is no team discussion.
- ◯ Mission and Vision, Goals and Objectives are regularly revised for organizational improvement.

The following questions are related to Policies and Processes used to minimize data loss, guarantee information oversight, and encourage attention and elevation of details captured in digital data flow across all stakeholders.

Please answer the following statements ranging from "No BIM use" to "High-Level BIM Integration".

My organization has:

	No BIM Use / Not related to BIM	Little Integration - Digitalization started	Medium Integration - Not fully integrated	High-Level Optimization and Integration
Mission and Vision for BIM	◯	◯	◯	◯
BIM-related Goals and Objectives	◯	◯	◯	◯
Management support for BIM integration	◯	◯	◯	◯
A specific method of implementing BIM	◯	◯	◯	◯
Project operations managed with BIM	◯	◯	◯	◯
A strong BIM culture/environment	◯	◯	◯	◯
A BIM hierarchy/structure (top-down)	◯	◯	◯	◯
BIM leaders who guide others to adopt, manage , and ensure BIM implementation	◯	◯	◯	◯
Administration of policies and procedures	◯	◯	◯	◯

Does your organization have a Mission and Vision, Goals and Objectives for BIM Integration?

◯ No organizational Mission and Vision, Goals and Objectives.

◯ Employees know about the Mission and Vision, Goals and Objectives, but it is not formally written.

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◯ Mission and Vision, Goals and Objectives are regularly revised for organizational improvement.

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Does management support BIM integration for the organization?

- No management support.
- Some support of BIM implementation but limited resources to implement.
- Full support of BIM implementation and resources allocated for this purpose.
- Management actively seeks for more ways to implement BIM implementation in the organization.

Is there a specific method of implementing BIM in the organization?

- Information is managed without the use of BIM.
- Information is recorded in BIM but not maintained.
- BIM data is manually maintained for operational uses.
- Highly organized information exchange and processes using BIM information exchange

How is project operation managed using BIM?

- ◯ Data generated from each project is unstructured, leading to inefficiencies and limited collaboration.
- ◯ Basic categorization of data in each project phase with low level of standardization.
- ◯ There is integration of data across project phases that allow collaboration between stakeholders.
- ◯ Project data is interconnected and accessible throughout the project's lifecycle.

What is the culture of the organization regarding BIM?

- ◯ Collaboration is done verbally and is not documented.
- ◯ Collaboration is documented in a digital platform but are not accessible to everyone.
- ◯ Digital information exchange is more structured to improve coordination among users.
- ◯ Seamless digital information-exchange, decision-making, and integration among users.

Is there a form of structure for BIM within the organization?

- ◯ BIM implementation is not structured within the organization.
- ◯ Small BIM implementation team outside of the organization's structure.
- ◯ There is a large interdisciplinary BIM group within the organization.
- ◯ There is a BIM Implementation Team who manages all operating groups within the organization.

Are there any BIM leaders within the organization who guide others in adopting, manage change in processes, and ensure BIM implementation?

- ◯ No BIM leaders within the organization.
- ◯ There is one BIM leader within the organization with adequate time commitment to this role.
- ◯ Multiple BIM leaders for each group within the organization.

- One main BIM leaders who works closely with other BIM leaders to promote interoperability.

How are policies and procedures administered within the organization?

- No established guidelines and protocols for policies and procedures.
- Basic guidelines are being developed.
- Policies and procedures are established that ensure consistency and accountability.
- Very detailed policies and procedures are adhered for BIM implementation.

Are roles and responsibilities for BIM Implementation established?

- No roles and responsibilities established.
- Roles and responsibilities defined by an Interdisciplinary group but not adhered.
- BIM responsibility lies within each operating group.
- Roles and responsibilities are clearly defined and revised to maintain to ensure they are properly distributed among the organization.

Are there any educational programs or training offered for BIM?

- No educational programs or training offered.
- There are some educational programs offered but not required.
- Educational programs are conducted on a regular basis and mandatory training for some employees.
- Educational programs and training regularly conducted with up-to-date information on new BIM processes.

Is the implementation of BIM accepted among the organization?

- BIM implementation is not accepted among stakeholders and employees.

- ◯ Upper management is accepting the need to implement BIM.
- ◯ BIM implementation is accepted by stakeholders and some employees.
- ◯ Willingness to accept BIM is the culture in the organization.

Are there any standardized guides, manuals and templates used?

- ◯ No guides, manuals and templates used within the organization.
- ◯ Guides, manuals, and templates are available but not required.
- ◯ Guides, manuals, and templates are used by some units to enable interoperability.
- ◯ All guides, manuals, and templates are used by the entire organization to promote seamless interoperability.

Is BIM used during the Planning and Designing phase?

- ◯ No planning and designing used in BIM.
- ◯ Basic planning and designing using BIM tools for simple projects.
- ◯ Collaborative workflows and multidisciplinary integration in the planning and designing phase.
- ◯ BIM is used for complex projects, integrating decision-making processes and simulations.

How does the organization store, organize, and access documents using a BIM environment?

- ◯ No document management for BIM.
- ◯ Basic document management using BIM tools for storing and accessing documents.
- ◯ Document management with structured organization, version control, and collaboration features.
- ◯ Project documentation, automated workflows, and seamless information exchange across project stakeholders.

What is the current quality in BIM processes?

- ○ No data quality management for BIM.
- ○ Quality is focused on individual models components and have basic checks for consistency.
- ○ Data is validated, clash detection is introduced, and quality is adhered to industry standards.
- ○ Quality of data in BIM is managed autonomously, improved, and real-time quality monitoring.

What is the software environment of BIM within the organization?

- ○ No BIM software available.
- ○ Basic BIM Software systems available and used for simple projects.
- ○ Advanced BIM software systems used across multiple projects.
- ○ Advanced BIM software used on all projects, and program established for continuous updating of BIM software systems.

What is the hardware environment of BIM within the organization?

- ○ No hardware capable of running BIM software.
- ○ All hardware is capable of running basic BIM software.
- ○ Some systems have updated hardware to run advanced BIM software.
- ○ All systems have hardware for advanced BIM software, and a program is established to update the hardware.

Is there General IT/Software support available within the organization?

- ○ No IT/Software support for BIM.
- ○ Basic IT infrastructure, technical assistance and occasional updates.
- ○ IT setup with enhanced network capability, storage solutions, and cybersecurity measures. Regular updates and technical assistance.

○ Cloud computing, advanced network integration, dedicated account management, customizations, and access to advanced training and resources.

What is the current cloud capability of BIM?

○ No centralized model server. BIM data is stored and managed on individual devices.

○ Basic model server for storing and sharing BIM models but limited in scale and functionality.

○ Model server is integrated with BIM authoring software and collaboration tools for efficient data exchange and version control.

○ Advanced cloud-based model server that provides enhanced collaboration features, scalability, and accessibility across multiple projects and stakeholders in real-time.

The University of Texas at El Paso

Appendix D: TRIP Summer Camp Activity

UTEP Transportation Research Immersive Program (TRIP)

Activity Facilitator Guide
Construction Engineering and Management for Transportation Projects

Learning Objective:

The participant will:

- Have fun
- Gain a high-level understanding of construction engineering and management
- Learn about transportation related student opportunities and experiences at UTEP

Summary:

Each year, hundreds of Universities across North America participate in the ASCE/AISC Student Steel Bridge Competition. This competition challenges students to design and fabricate a steel bridge that meets a set of criteria, and build that bridge in a timed competition. They are judged on weight, build time, construction costs, aesthetics, and the ability of the bridge to carry load. This is a fun competition which students always enjoy. The Steel Bridge competition teaches students many things, not the least of which is optimizing the design to minimize build time and cost.

- Activity Introduction and Discussion (15 min)
  - Introduce the activity, deliverables and specific guidelines.
- Challenge Planning (2 hours)
- K'nex Bridge Challenge: Build, Connect, Conquer! (whole afternoon)
  - Unleash your creativity and engineering prowess in the ultimate K'nex Bridge Competition. Design and build your masterpiece – the challenge is on!
- Score Showdown and Wrap-up (15-20min)
  - Celebrate the winners and wrap up.

Materials:

- K'nex connectors
- Drawing Papers, Pencils and/or Computers (Excel Sheet and software like Inventor, SolidWorks, or Tinkercad)

Prepare ahead of time:

The following will be set up by 8.00am for the construction day:

- Computer set up with required software
- K'nex material

Instructions:

- In this exercise, teams will design and construct a bridge from k'nex. The bridge will have to meet the criteria provided.
- Each piece will cost a certain amount to include in your design.
- In the morning, team may optimize its design to minimize cost and maximize load-carrying capacity or strength. In the afternoon, team will build your bridge as fast as possible in a timed competition.

- The bridge will then be loaded to the prescribed level. The total score will be a function of strength, cost, and build time.

- Preliminary Parameters:
  - Bridge Must Span 24”
  - Bridge must support four AISC Steel Manuals at midspan
- **Deliverables:** You will have access to a custom Microsoft Excel sheet for estimating costs. You should create some design drawings (either in software like Inventor, SolidWorks, even Tinkercad) or by hand so that you can recreate your design in the timed build. These two will be submitted for evaluation.
- **Prize**: The winning team will receive a gift card to the UTEP Bookstore (or similar)

Clean up in-between participants:
- None

Notes to Facilitator:
- Dr. Raheem and Dr. Weidner will be present during the whole day.

Conversational Prompts:
- None

Difficult Concepts:

Bridges built with K’nex are most similar to truss bridges. A truss has three primary characteristics:
- Truss bridges are built up with smaller structural members that form a network of triangular shapes
- The smaller structural members that form the triangles of the truss are connected to one another with “pins” meaning that they are free to rotate relative to one another
- The smaller structural members carry only compression forces (causing shortening) or tension forces (causing elongating).

Reflection Prompts:

- Two big parts of being an engineer are iteration and optimization. How did you use iteration to optimize your design?
- How might emerging technologies (i.e., VR/AR, AI, Robotics) change how you approach this challenge? How about real construction?
- What are some of the failure mechanisms that the teams have observed?
- How the bridge could have been built stronger?

UTEP TRIP Construction Day Led by Drs. Raheem and Weidner

Students Planning for K’nex Bridge Construction

Southern Plains
Transportation Center

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