SJSU SAN JOSÉ STATE UNIVERSITY

MTI MINETA TRANSPORTATION INSTITUTE

Survey of Building Information Modeling for Infrastructure (BIM4I)

Maria Calahorra-Jimenez, PhD
Nigel Blampied, PhD
Elhami Nasr, PhD
Tariq Shehab, PhD

MINETA TRANSPORTATION INSTITUTE

Founded in 1991, the Mineta Transportation Institute (MTI), an organized research and training unit in partnership with the Lucas College and Graduate School of Business at San José State University (SJSU), increases mobility for all by improving the safety, efficiency, accessibility, and convenience of our nation's transportation system. Through research, education, workforce development, and technology transfer, we help create a connected world. MTI leads the Mineta Consortium for Equitable, Efficient, and Sustainable Transportation (MCEEST) funded by the U.S. Department of Transportation, the California State University Transportation Consortium (CSUTC) funded by the State of California through Senate Bill 1 and the Climate Change and Extreme Events Training and Research (CCEETR) Program funded by the Federal Railroad Administration. MTI focuses on three primary responsibilities:

Research

MTI conducts multi-disciplinary research focused on surface transportation that contributes to effective decision making. Research areas include: active transportation; planning and policy; security and counterterrorism; sustainable transportation and land use; transit and passenger rail; transportation engineering; transportation finance; transportation technology; and workforce and labor. MTI research publications undergo expert peer review to ensure the quality of the research.

Education and Workforce Development

To ensure the efficient movement of people and products, we must prepare a new cohort of transportation professionals who are ready to lead a more diverse, inclusive, and equitable transportation industry. To help achieve this, MTI sponsors a suite of workforce development and education opportunities. The Institute supports educational programs offered by the Lucas Graduate School of Business: a Master of Science in Transportation Management, plus graduate certificates that include High-Speed and Intercity Rail Management and Transportation Security Management. These flexible programs offer live online classes so that working transportation professionals can pursue an advanced degree regardless of their location.

Information and Technology Transfer

MTI utilizes a diverse array of dissemination methods and media to ensure research results reach those responsible for managing change. These methods include publication, seminars, workshops, websites, social media, webinars, and other technology transfer mechanisms. Additionally, MTI promotes the availability of completed research to professional organizations and works to integrate the research findings into the graduate education program. MTI's extensive collection of transportation-related publications is integrated into San José State University's world-class Martin Luther King, Jr. Library.

Report 24-50

Survey of Building Information Modeling for Infrastructure (BIM4I)

Maria Calahorra-Jimenez, PhD

Nigel Blampied, PhD

Elhami Nasr, PhD

Tariq Shehab, PhD

January 2025

A publication of the
Mineta Transportation Institute
Created by Congress in 1991

College of Business
San José State University
San José, CA 95192-0219

TECHNICAL REPORT

DOCUMENTATION PAGE

1. Report No. 24-50	**2. Government Accession No.**	**3. Recipient's Catalog No.**	
4. Title and Subtitle Survey of Building Information Modeling for Infrastructure (BIM4I)		**5. Report Date** January 2025	
		6. Performing Organization Code	
7. Authors Maria Calahorra-Jimenez, PhD https://orcid.org/0000-0002-1981-8828 Nigel Blampied, PhD https://orcid.org/0000-0001-8597-6691 Elhami Nasr, PhD Tariq Shehab, PhD		**8. Performing Organization Report** CA-MTI-2453	
9. Performing Organization Name and Address Mineta Transportation Institute College of Business San José State University San José, CA 95192-0219		**10. Work Unit No.**	
		11. Contract or Grant No. ZSB12017-SJAUX	
12. Sponsoring Agency Name and Address State of California SB1 2017/2018 Trustees of the California State University Sponsored Programs Administration 401 Golden Shore, 5th Floor Long Beach, CA 90802		**13. Type of Report and Period Covered**	
		14. Sponsoring Agency Code	
15. Supplemental Notes 10.31979/mti.2024.2453			

16. Abstract

The rapid development of information technologies is transforming how data and information are produced, shared, exchanged, and managed. This transformation is accelerating in state departments of transportation (DOTs) across the country due to the pressing need for efficient means of delivering transportation projects and an enhanced need for internal and external collaboration. A key driver for this transformation is the implementation of Building Information Modeling for Infrastructures (BIM4I). The primary objective of this research was to develop actionable recommendations for DOTs to facilitate the effective adoption of BIM4I, based on national and international lessons learned and best practices. A four-step methodology was employed including: (1) a literature review identified key stakeholders and best practices; (2) data collection targeting transportation agencies included a survey of 94 participants and 18 follow-up interviews; (3) data analysis utilized statistical and content analysis to extract themes and insights; and (4) tailored recommendations were formulated based on findings. Main recommendations include:

- Strategic Planning: Establish a clear definition of Building Information Modeling (BIM), create an implementation plan including a roadmap with defined objectives, and assess organizational readiness for BIM adoption.
- Standardization and Training: Develop clear standards and guidelines for BIM usage, prioritize data quality, and invest in training.
- Technology Integration: Ensure that BIM tools and software are compatible with existing systems and establish a user-friendly Common Data Environment (CDE) for effective data sharing.
- Collaboration and Communication: Foster interdepartmental and cross-stages collaboration and engage stakeholders early in the design process to enhance understanding of project impacts.

Recommendations from this research will help DOTs transitioning to digital delivery to enhance efficiency, collaboration, and project outcomes, providing a framework for effective BIM integration.

17. Key Words Building information models, Project management, Project delivery, Contracting, Information, data, and knowledge.	**18. Distribution Statement** No restrictions. This document is available to the public through The National Technical Information Service, Springfield, VA 22161.		
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 157	**22. Price**

Form DOT F 1700.7 (8-72)

DOI: 10.31979/mti.2024.2453

Mineta Transportation Institute
College of Business
San José State University
San José, CA 95192-0219
Tel: (408) 924-7560
Fax: (408) 924-7565
Email: mineta-institute@sjsu.edu

transweb.sjsu.edu/research/2453

ACKNOWLEDGMENTS

The authors want to acknowledge all of the Caltrans personnel involved in the development of this research for their guidance and support: Mina Pezeshpour, Jesus Mora, Stefan Sutton, Aaron Ott, Stephen Capuno, Scott Blair, Devin Porr, Tyler Monson, Lakeda Huckaby, Balwinder Tarlok, Amy Fong, Devin Porr, and Akber Ali.

The authors also want to thank all state departments of transportation, local transportation agencies, international transportation agencies, university professors, and private firms that provided input for this study.

CONTENTS

List of Figures

LIST OF TABLES

Executive Summary

The purpose of this research is to provide Caltrans with recommendations for implementing Building Information Modeling for Infrastructure (BIM4I) by surveying the lessons learned and best practices from international, national, and local infrastructure agencies and stakeholders that have implemented BIM in one or several stages of infrastructure project delivery. This research is driven by the California Department of Transportation's (Caltrans) strategic goal to enhance project delivery through digital construction management technologies, as mandated by recent legislative requirements.

The research employed a four-step methodology, including: (1) Literature Review and Contact Gathering: A systematic review of existing literature on BIM implementation was conducted, identifying key agencies and stakeholders for outreach; (2) Data Collection: A questionnaire was distributed to targeted agencies, followed by follow-up interviews to gather qualitative insights. The survey aimed to assess the status of BIM implementation, challenges faced, and best practices; (3) Data Analysis: Both statistical and content analysis methods were utilized to interpret the survey results and interview responses, identifying common themes and insights; and (4) Recommendations: Tailored recommendations for BIM4I implementation were formulated based on the analysis.

The research employed a four-step methodology, including: (1) Literature Review and Contact Gathering, considering a systematic review of existing literature on BIM implementation and identifying key agencies and stakeholders for outreach; (2) Data Collection using a questionnaire that was distributed to targeted agencies, followed by follow-up interviews to gather qualitative insights. The survey aimed to assess the status of BIM implementation, challenges faced, and best practices; (3) Data Analysis using both statistical and content analysis methods were utilized to interpret the survey results and interview responses, identifying common themes and insights; and (4) Recommendations for BIM4I implementation were formulated based on the analysis.

The survey gathered 94 responses, with representation from international, national, and local transportation agencies, and key findings include:

- BIM Usage: Many agencies reported using BIM in various project types, predominantly in bridge and highway projects. Most organizations utilize BIM during the design and construction phases.

- Implementation Levels: Agencies reported varying levels of BIM implementation, with many still transitioning from 2D to 3D modeling. Most respondents indicated that BIM was applied selectively rather than universally across all projects.

- Data Standards and Workflows: The ISO 19650 series and Industry Foundation Classes (IFC) were the most commonly referenced standards. However, many agencies expressed a need for clearer guidelines and training on data management and interoperability.

- Training and Support: A significant portion of respondents indicated a lack of formal training programs for staff, highlighting the need for comprehensive training initiatives to facilitate BIM adoption.

The analysis of survey responses and follow-up interviews led to 102 recommendations revolving around the following topics:

- Strategic Planning: Establish a clear definition of BIM, create a roadmap with defined objectives, and assess organizational readiness for BIM adoption.

- Standardization and Training: Develop clear standards and guidelines for BIM usage, prioritize data quality, and invest in training for all staff involved in BIM processes.

- Collaboration and Communication: Foster interdepartmental collaboration and engage stakeholders early in the design process to enhance understanding and communication of project impacts.

- Technology Integration: Ensure that BIM tools and software are compatible with existing systems and establish a user-friendly Common Data Environment (CDE) for effective data sharing.

- Continuous Improvement: Regularly review and update BIM implementation strategies based on feedback and lessons learned from ongoing projects.

The findings of this survey underscore the potential of BIM4I in enhancing project delivery within transportation agencies. By considering the recommendations outlined in this report, agencies can navigate the complexities of BIM integration, ultimately leading to improved efficiency, collaboration, and project outcomes. The insights gained from this research not only serve Caltrans but also provide a valuable framework for other transportation agencies seeking to implement BIM technologies effectively

1. Introduction

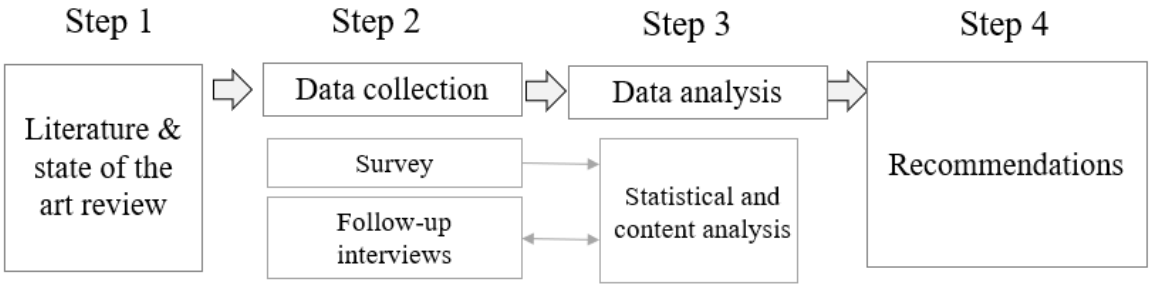
The purpose of this research is to provide Caltrans with recommendations for the implementation of Building Information Modeling for Infrastructure (BIM4I) by surveying lessons learned and best practices from international, national, and local infrastructure agencies and stakeholders that have implemented BIM in one or several stages of infrastructure project delivery. This research responds to the rapid development of information technologies that is transforming how information is produced, shared, exchanged, and managed. This transformation is accelerating in state Departments of Transportation (DOTs) across the country due to the pressing need for efficient ways of delivering transportation projects and an enhanced need for collaboration internally and externally. The California Department of Transportation (Caltrans) rolled out a new Strategic Plan in 2021, and one of its strategic goals focuses on stewardship and efficiency (Caltrans, 2021). On March 14, 2022, the Caltrans Project Delivery Program adopted a charter to implement BIM4I, also known as Virtual Design and Construction and Advanced Digital Construction Management systems (ADMS), to improve project delivery. Furthermore, California legislative requirements were set forth in 2022 by Assembly Bill 1037 to implement Digital Construction Management Technologies (DCMT). These requirements include, but are not limited to, the following: (1) develop and post guidance, policies, and procedures for the use of digital construction management technologies on the department's internet website by January 1, 2025; (2) begin using digital construction management technologies during the predevelopment stage of project development by July 1, 2026; (3) begin using digital construction management technologies through the final design of project development by January 1, 2028; and (4) begin using digital construction management technologies through construction by July 1, 2029. To achieve the Caltrans goal in a timely manner and meet the aggressive legislatively required schedule, research on the use of BIM at international, national, and local levels is needed.

In the US, current practice shows that no DOT has completely implemented BIM4I, and some state DOTs have implemented portions of BIM4I technologies. Further, there are many literature articles and ongoing pool fund studies at the national level. However, additional research is needed to gather lessons learned and determine how consultants are utilized. Internationally, there are countries that have fully implemented BIM4I in portions of their project delivery process. As a result, the research should focus heavily on what and how other countries have implemented BIM4I technologies. Finally, there may be some local agencies that have implemented BIM4I technologies, and research is needed to investigate what and how they have done this.

2. Methodology

This research aims to identify current BIM4I implementation practices in transportation agencies at international, national, and local levels. To this end, a four-step approach was followed (Figure 1).

Figure 1. Research Methodology



In Step 1, the literature and state-of-the-art review set the foundation for designing a survey questionnaire and identifying contact information related to the agencies that will be targeted. Throughout Step 2, the research team collects the information for the research using a survey questionnaire and follow-up interviews. The survey design considers the main BIM4I implementation themes provided by Caltrans and the fact that the survey will be sent to different transportation agencies, including international, national, and local ones. After the survey is sent and the data collected, descriptive statistical analysis and qualitative content analysis are conducted (Step 3). The results of the analysis led to the selection of a group of target agencies to interview to obtain more in-depth knowledge. Finally, based on the analysis of survey responses and follow-up interviews, recommendations for BIM4I implementation are provided in Step 4.

2.1 Step 1. Literature Review and Gathering Contacts

The research team followed a systematic literature review approach to collect relevant published articles on BIM implementation in infrastructure. Two databases were used: Engineering Village and Web of Science. Two independent researchers searched each database using the following keywords: "BIM Implementation, Infrastructures," "BIM Implementation Transportation," "BIM Implementation Bridges," "BIM Implementation Highways," "BIM Implementation Interchanges," "BIM Implementation Pavements," and "BIM Implementation Roads."

Articles found were analyzed based on the title and abstract to decide whether they applied to this research. Further, articles found in both databases were compared, and duplicates were removed. A total of 240 articles were considered for further examination, including the country where the research was done. Countries with the most publications were selected to extract the authors and

contact them. Additionally, articles directly related to BIM implementation were summarized in Appendix A.

2.2 Step 2. Data Collection: Survey and Follow-up Interviews

This section includes the process followed in the survey design, Human Subjects Protocol approval, the collection of survey responses, and follow-up interviews.

2.2.1 Survey Design

The BIM4I survey aimed to gather data on the status of BIM infrastructure implementation across the United States and internationally. The key objective was to understand how different departments of transportation, government agencies, and academic institutions are utilizing BIM. The approach for developing the survey was a structured and collaborative process involving multiple steps and extensive stakeholder engagement. By selecting Qualtrics as the tool of choice and working closely with Caltrans, the research team ensured that the final survey was robust, comprehensive, and aligned with industry standards. This will not only help to understand the status of BIM implementation but also set a precedent for future collaborative research efforts.

The following describes each of the steps of the process taken by the research team:

Step I: Initiation

The initiation step began by ensuring the survey's objectives would be comprehensive yet specific to infrastructure. This involved initial discussions and meetings to conduct a thorough needs assessment and define the survey's objectives. Engaging key stakeholders was crucial in this step, and the research team met several times, both as a team and with Caltrans stakeholders, to gather input, collect feedback, and document the requirements and expectations. This stakeholder engagement ensured alignment and buy-in from all relevant parties, setting a solid foundation for the project's success.

Step II: Development and Refinement of Survey Questions

The development of the survey questions was an iterative process aimed at both ensuring comprehensive coverage of the research questions and meeting Caltrans's expectations. The research team began by identifying potential questions based on the initial objectives, focusing on the status of BIM implementation, challenges, and best practices across various departments of transportation, government agencies, and academic institutions.

Once the initial questions were drafted, the research team embarked on a rigorous review and refinement process. This involved multiple iterations where questions were revised to ensure clarity, relevance, and alignment with the research goals. The research team conducted review

sessions with Caltrans representatives, gathering feedback and making necessary adjustments. The diversity of the target audience prompted the research team to continually revisit and refine the questions to ensure they were accessible and relevant to all respondents.

Throughout this process, the research team maintained close collaboration with Caltrans staff, leveraging their expertise and insights. Regular check-ins and joint review sessions with Caltrans representatives were integral to the research team's approach. Caltrans feedback helped fine-tune the questions, ensuring they comprehensively addressed all necessary aspects of BIM implementation. By incorporating Caltrans input, the research team enhanced the survey's robustness and relevance, aligning it with both organizational and regulatory standards (Appendix B).

Finally, the research team grouped and categorized the refined questions into logical themes, facilitating a coherent flow and ease of response (Table 1). This organized structure helped ensure that respondents could navigate the survey smoothly, providing accurate and comprehensive data. The final version of the survey questions reflected the collective insights and rigorous efforts of the research team and stakeholders, making it ready for deployment and data collection.

Table 1. Survey Themes and Number of Questions

Themes	Number of Questions
1. Introduction	1
2. General Information	6
3. Levels of Implementation	2
4. BIM Implementation Approach—General	3
5. BIM Implementation—Data Standards and Workflows	4
6. BIM Implementation—3D Model Use	2
7. BIM Implementation—Communications	8
8. BIM Implementation—Use of Technology Partners and Consultants	2
9. BIM Implementation—Training and Processes	3
10. Lessons Learned	8

Step III: Exploring and Evaluating Tools

In this step, the research team focused on researching and evaluating available tools for survey development and data collection. The team identified several potential tools and conducted a comparative analysis of their features, capabilities, and costs based on the project's requirements. After discussing the findings and facilitating discussions, the team selected Qualtrics as the most

suitable tool for the survey due to its robust features, ensuring that the choice of tool would support the project's needs effectively.

Step IV: Drafting and Iteration

The drafting step involved developing initial drafts of the survey questionnaire using Qualtrics. The research team set up the Qualtrics platform and designed the initial survey questions, incorporating feedback from the initial stakeholder meetings. Multiple review cycles were then conducted to refine these drafts. The team organized review sessions with stakeholders and experts, collected their feedback, and integrated it into subsequent drafts. This iterative process ensured that the survey was continually aligned with the project's objectives and stakeholders' requirements, resulting in a comprehensive and well-structured questionnaire (Appendix B).

Step V: Preliminary Survey and Data Collection Preparation

To test the survey and gather initial data, the research team conducted a pilot survey. The team designed the pilot survey using Qualtrics and distributed it to a small group of Caltrans stakeholders. The results were analyzed to identify any issues and opportunities for improvement. Based on the insights gained from the pilot survey and continued stakeholder feedback, the research team finalized the survey questionnaire. This final version underwent additional reviews and obtained the necessary approvals, preparing it for full deployment.

Step VI: Finalization and Deployment

The final step involved securing approval from Caltrans. The research team presented the finalized survey, addressed any remaining concerns or adjustments, and obtained formal sign-off. With the survey approved, the team launched it for full-scale data collection on May 16, 2024.

2.2.2 Human Subjects Research Protocol Approval

US federal law requires that all organizations that receive federal funds must obtain a Human Subjects Research Protocol approved by an Institutional Review Board (IRB) before they conduct research that collects personally identifiable information (Title 49 US Code, Part 11). The universities involved in this study and Caltrans are recipients of federal funds and are, therefore, subject to this requirement. Universities in the US normally have the needed IRB. The current research asks respondents for their name, e-mail, telephone number, and employer, all of which are personally identifiable information. A protocol was therefore prepared and submitted to the San José State University IRB, which gave its approval. The protocol included a consent notice, which the IRB required be displayed to respondents at the start of the questionnaire. The questionnaire also had a link to allow respondents to download a copy of the consent notice that showed the university's seal (Appendix B).

2.2.3 Gathering Information from Surveys

On May 16, 2024, Caltrans approved the publication of the questionnaire. Within 48 hours of the questionnaire's publication, the research team contacted 108 of the target agencies, inviting them to respond to the questionnaire. Eighty-eight of these contacts were by e-mail, and the remainder were made through online forms on agency websites. The e-mail addresses had been collected in advance from Caltrans, from contacts known to the researchers, and from agency websites. In addition to these agency contacts, the researchers contacted 383 authors who had published papers on Building Information Modelling for Infrastructure (BIM4I) in peer-reviewed journals, as identified in the Web of Science database. These academic contacts were made within 72 hours of the questionnaire's publication. The contacts were asked for their contact information at the agencies where they had conducted their research. Some agencies and academic contacts responded immediately to the requests.

The questionnaire was also publicized on several LinkedIn groups, with almost 500,000 members between them, and to the 1,864-member Co-operative Network of Building Researchers (CNBR).

Follow-up and additional emails and contacts were sent in the second week to 101 agencies by e-mail, online forms, telephone, and even LinkedIn messaging.

A further 84 contacts were made in the third and fourth weeks, this time finding and using different contact methods than before for each agency so as not to repeatedly contact the same persons in vain. The effort began to switch toward the telelphone rather than e-mail. Telephoning can be more effective than e-mail but requires considerably more effort. Some physical visits were also made to target agencies to invite their participation.

In the fourth week, the team noticed that there appeared to be a lack of participation from China and Germany. These two countries provided the authors with almost half of the published articles mentioned above, with 104 authors from China and 77 from Germany. The research team had been contacting the central governments of these countries and decided to shift their focus to the next tier of government, namely the province-level administrative divisions of China and the states ("Länder") of the German Federation. During the fifth week, an effort was made to contact each of these provinces and states. Further efforts were also made to contact some agencies that had previously been contacted, and altogether 98 agencies were contacted in the fifth week.

Initially, the research targeted a list of 133 agencies or countries, but this list was expanded during the course of the data-gathering process. In the end, 212 agencies were contacted, most of them more than once, and contacts were also made with the authors, LinkedIn group members, and CNBR. The agencies included all fifty US states along with Puerto Rico, US Federal infrastructure-owning agencies, the states of Australia and Germany, the provinces of Canada and China, several jurisdictions in Spain, the countries of the United Kingdom, several national

governments, the twenty largest cities in the US, the ten largest cities and ten largest counties in California, two Class 1 railroads, and several California utilities and regional transportation planning agencies.

2.2.4 Follow-up Interviews

Upon analysis of the results obtained and in collaboration with Caltrans, the research team selected agencies to interview. The purpose of the follow-up interviews was to gather deeper insight related to the topics that Caltrans was most interested in. According to the research's project schedule, the follow-up interviews were planned to be developed in two months, between mid-July and mid-September. This report includes the results of the follow-up interviews. The follow-up interview process followed a four-step approach. First, the criteria for selecting the interviewees were established. Second, an interview protocol was drafted. Third, the research team contacted the potential interviewees to set dates and times for the interviews. Finally, once each interview was completed, transcripts were reviewed and saved for the analysis stage.

2.2.4.1 Criteria for follow-up interviewee selection

The research team, in coordination with Caltrans, established the following criteria for interviewee selection:

- Agencies that have implemented BIM in more than ten projects
- Agencies with a level of implementation two or above
- Agencies that have implemented BIM in different phases
- Agencies that maintain asset information using BIM principles
- Agencies with BM4I strategic plans or initiatives
- Agencies following Industry Foundational Classes (IFC), Smart BIM, or five-part International Organization for Standardization ISO 19650 series standards
- Agencies using cloud-based servers for hosting
- Organizations that are using models as legal documents
- Organizations using 3D models for interaction with permitting agencies
- Organizations that have implemented or are implementing training programs
- International respondents

Not all the survey respondents met all of the criteria. Thus, for the US respondents, the research team filtered the information in the survey and selected those agencies that met more than seven criteria. Eight DOTs were considered for an interview, and twelve international respondents were selected from all the countries that responded to the survey. The follow-up interview process considered the following steps:

2.2.4.2 Creating an interview protocol

An interview protocol was created in collaboration with Caltrans. The interview protocol aimed to ensure consistency across interviewers an0d that all main aspects relevant to Caltrans were discussed. A copy of the interview protocol can be found in Appendix C.

2.2.4.3 Setting and conducting the interviews

Each research team member was assigned several interviews to conduct, all of which were finalized by September 23, 2024.

2.2.4.4 Generating interview transcripts

Depending on the interviewee's preference, the research team conducted the interviews via Zoom or Microsoft Teams. The interviews were recorded, and a transcript was generated. After analysis, the recordings and transcripts were destroyed in compliance with the Human Subjects Protocol.

2.3 Step 3. Data Analysis: Statistical and Content Analysis

The survey questions aimed to collect nominal and textual data. Graphical, descriptive statistical analysis (with Microsoft Excel) was used to evaluate nominal data, while content analysis (with MAXQDA) was used to obtain insights from textual data. Interviews provided textual data that were analyzed using content analysis. The purpose of the content analysis was identifying common themes and topics leading to recommendations for BIM implementation.

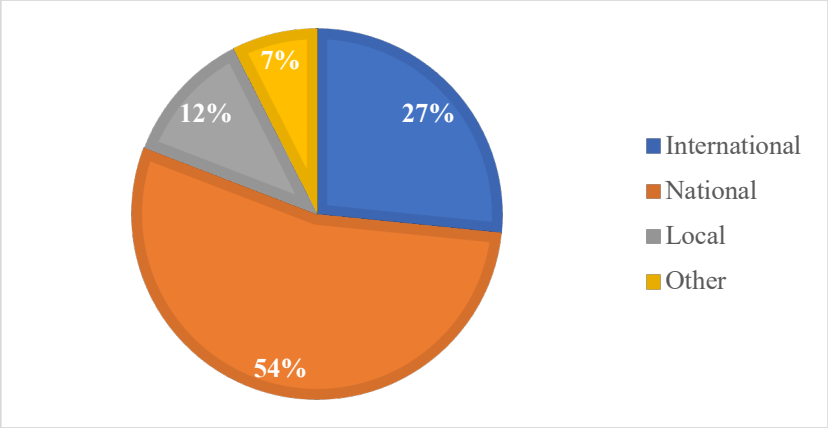
2.4 Step 4. Recommendations

Analyses of the survey answers and the follow-up interviews are included in this report, along with recommendations for implementing Building Information Modeling (BIM4I).

3. Results

Data collection was conducted from May 15, 2024 to September 23, 2024. During this time, the survey collected 94 responses, with 27% of these coming from international agencies, 54% from national agencies (defined in the next paragraph), and 12% from local agencies in the US. An additional 7% came from university professors and software vendor representatives (Figure 2).

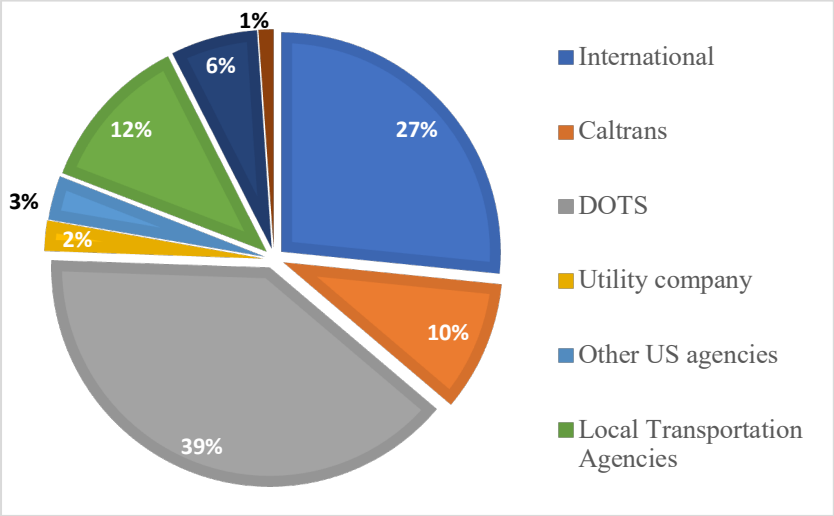
Figure 2. Total Responses Received



**Percentages calculated based on a total of 94 responses*

In Figure 3, the "national" category includes Caltrans, other DOTs, utility companies, Class 1 Railroads, and other US agencies. The category "others" is also broken down in Figure 3, including university professors and software vendor representatives.

Figure 3. Break Down of International, National, and Local Agencies



**Percentages calculated based on a total of 94 responses*

This number of responses represents a 41% response rate from the 133 targeted agencies/countries. A country or agency might have provided several responses. For example, Spain, a targeted country, provided five responses from different agencies. Similarly, some US DOTs provided more than one response. The response rate is calculated considering only one response per targeted agency/country (Table 2).

Table 2. Response Rate per Target Agency Categories

Agency Categories	Targeted	Responded	Response rate
International	**25**	**11***	**44%**
Canadian Provinces	10	5	50%
Other Countries	15	6	40%
National	**70**	**36**	**51%**
DOTs & FHWA	53	31	58%
Utility Companies	5	2	40%
Class 1 Railroad	2	1	50%
Other US Agencies	10	2	20%
Local	**39**	**7**	**18%**
TOTAL	**134**	**54**	**40%**

**This number considers one response per country or Canadian Province.*

The specific agencies and countries that completed the survey are shown in Table 3.

Table 3. Survey Respondents by Target Agency Category

Target Agency	Respondents
International	Australia, Canada (different provinces), Ireland, Spain (different administrations including roads, rail, and ports), Sweden, and UK.
National.	
DOTs & FHWA	Alabama, Caltrans, Connecticut, District of Columbia, FHWA, Florida, Idaho, Illinois, Indiana, Iowa, Kentucky, Michigan, Montana, Nevada, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Utah, and Washington State
Utilities and Rail	LA County Department of Water and Power and Union Pacific
Other US Agencies	California Department of Water Resources, US Navy
Local	
Transportation Agencies	County of San Diego, Fresno County, the City of Phoenix, the City of Sacramento, Riverside County, Philadelphia Department of Streets, Nashville Department of Transportation, and Orange County.

Following the survey data collection, eighteen follow-up interviews were conducted, eight with state DOTs and ten with international organizations (Table 4).

Table 4. Organizations Participating in Follow-Up Interviews

	Interviewees
International	
Australia	Queensland Department of Transport and Main Roads
Canada	Quebec Ministry of Transport and Sustainable Mobility
Ireland	Transport Infrastructure
Norway	Trimble Norway
Spain	ADIF and INGECID
UK	Network Rail
National	
State DOTs	Montana, Pennsylvania, Utah, Texas, Michigan, Iowa, Oklahoma, and Arizona

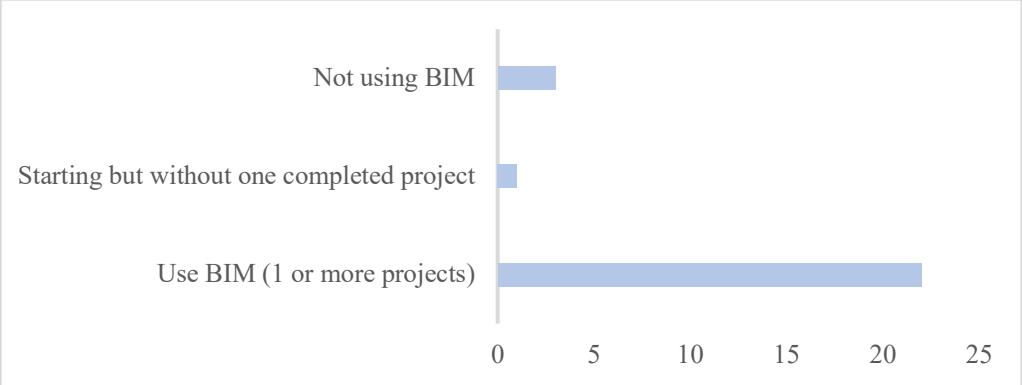
The following sections include the results obtained at the international, national, and local levels. Each section is organized based on the following topics: general information about the use of BIM, levels of implementation, data standards and workflows, use of 3D models, communications, use of technology partners and consultants, training and implementation processes, and lessons learned.

3.1 International Survey Analysis

The international survey targeted ten Canadian provinces and fifteen countries, including Australia, China, Denmark, Finland, Germany, India, Italy, Norway, Poland, Portugal, South Korea, Spain, Sweden, the Netherlands, and the United Kingdom.

Out of 26 responses received from different countries and Canadian provinces, 22, reported they have used BIM in one or more projects. One respondent indicated that they are starting but have not completed one project at this time. Three respondents shared that they do not use BIM (Figure 4).

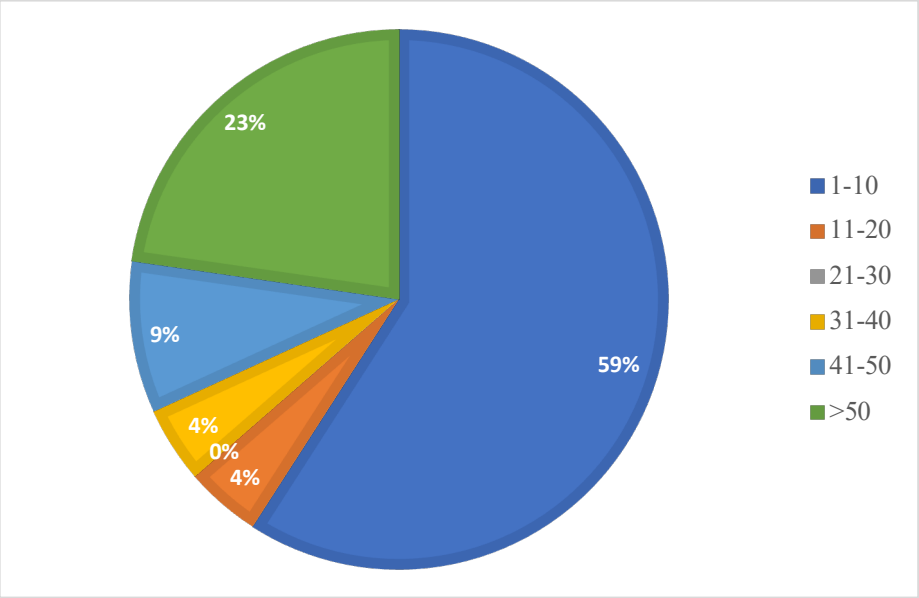
Figure 4. Number of Projects Developed Using BIM. International



**Data shown based on a total of 26 responses*

The survey asked about the approximate number of infrastructure projects the respondents' organizations have developed using BIM4I. Among the 22 organizations that have already used it, 13 (59%) organizations have used it to develop up to 10 projects, one (4%) organization has used it to develop up to 20 projects, one (4%) organization has used it to develop up to 40 projects, two (9%) organizations have used it to develop up to 50 projects, and five (23%) have used it to develop more than 50 projects (Figure 5).

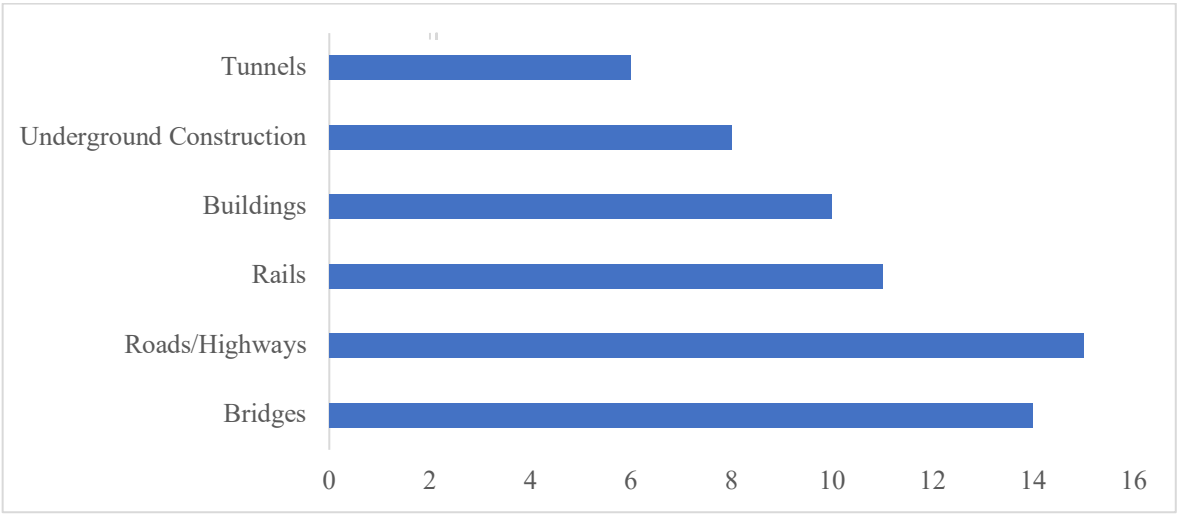
Figure 5. Number of Projects Developed Using BIM. International



**Percentages calculated based on a total of 22 responses*

These organizations have used BIM4I in different types of projects most of which are bridge and highway projects (Figure 6). As shown on Figure 6, 10 (38%) organizations have used it in bridge projects, and 15 (57%) organizations have used it in highway projects. Eleven (42%) of the organizations have used it railway projects, 10 (38%) of the organizations have used it in building projects, eight (30%) of the organizations have used it in underground utility projects, and six (23%) of the organizations have used it in tunneling projects (Figure 6).

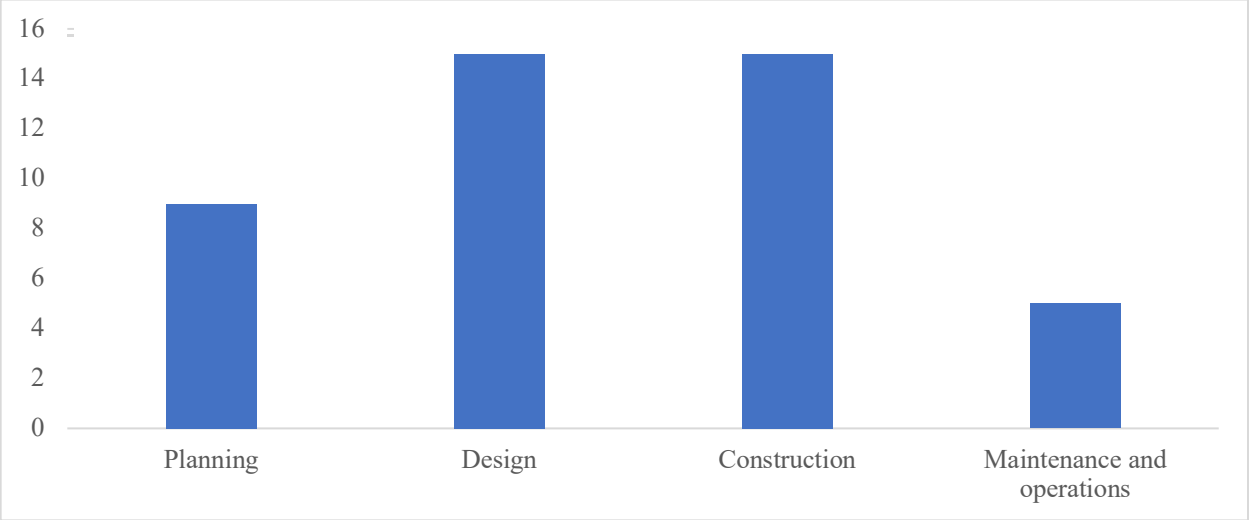
Figure 6. Type of Projects Developed Using BIM. International



**Data shown based on a total of 26 responses*

Most organizations have used BIM4I in the design and construction phases of these projects. As depicted in Figure 7, 15 organizations (65%) have used it during their design and construction phases, nine organizations (39%) have used it during their planning phase, and five organizations (21%) have used it during their operation phase.

Figure 7. Project Phases When BIM is Used. International



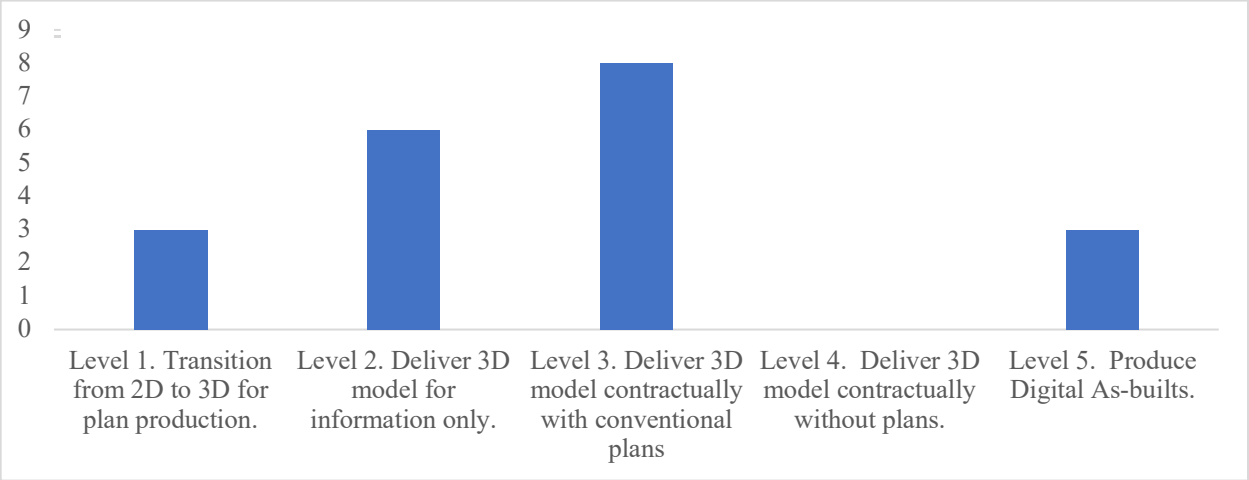
**Data shown based on a total of 23 responses*

Levels of implementation and implementation approach

The survey solicited specific information about projects in which BIM4I was used. These questions inquired about the level of implementation and if it was implemented in all projects or select ones only. The level of implementation was rated from 1–5: level 1: transition from 2D to 3D for plan production; level 2: deliver 3D model for information only; level 3: deliver 3D model contractually with conventional plans; level 4: deliver 3D model contractually without plans; and level 5: produce digital as-built drawings.

The responses received for the level of implementation are shown in Figure 8. Three (15%) have used it as a transitional tool from 2D to 3D for plan production (i.e., level 1), six (30%) organizations have used BIM4I to deliver 3D models for information only (i.e., level 2), eight (40%) have used it to deliver 3D models contractually with conventional plans (i.e., level 3), and three (15%) organizations used it as a tool to produce digital as-built drawings. As presented in Figure 5, no one has used it to deliver 3D models contractually without conventional plans (i.e., level 4).

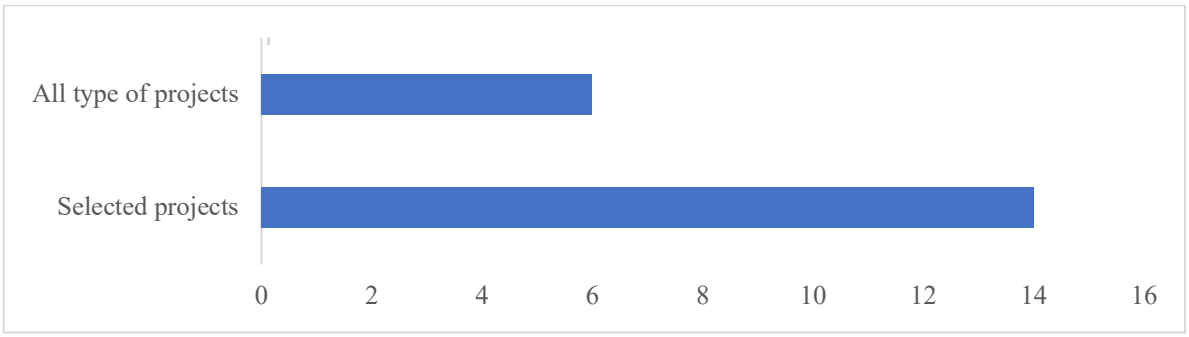
Figure 8. Levels of BIM Implementation. International.



**Data shown based on a total of 20 responses*

Regarding the selection process, six (30%) organizations have implemented BIM4I in all their projects, and fourteen (70%) have implemented it in select projects only, which included buildings, railroads, communication/signaling projects, tunnels, bridges, roads, roundabouts, and projects with a capital value >$50M (Figure 9).

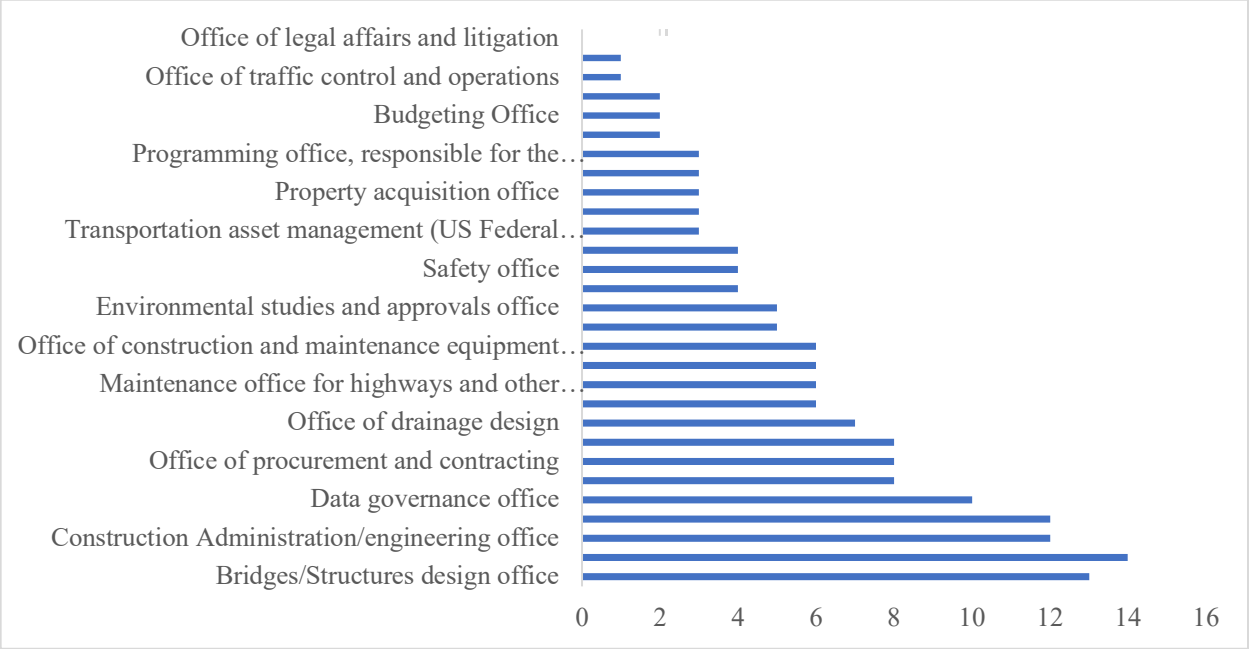
Figure 9. BIM4I Implementation Approach. International.



**Data shown based on a total of 20 responses*

The survey requested information about the office(s) within organizations that were involved in the implementation process of BIM4I, the office(s) that took the lead during the implementation process, and the office(s) that owned the data. The offices of Bridge/Structures Design, Design of Highways/other Transportation Facilities, and Construction Administration/Engineering were involved in the implementation process in most organizations (Figure 10). The design office of highway/other transportation facilities and the office of Construction Administration were involved in fourteen organizations (73%), and the office of Bridge/Structure Design was involved in thirteen organizations (68%).

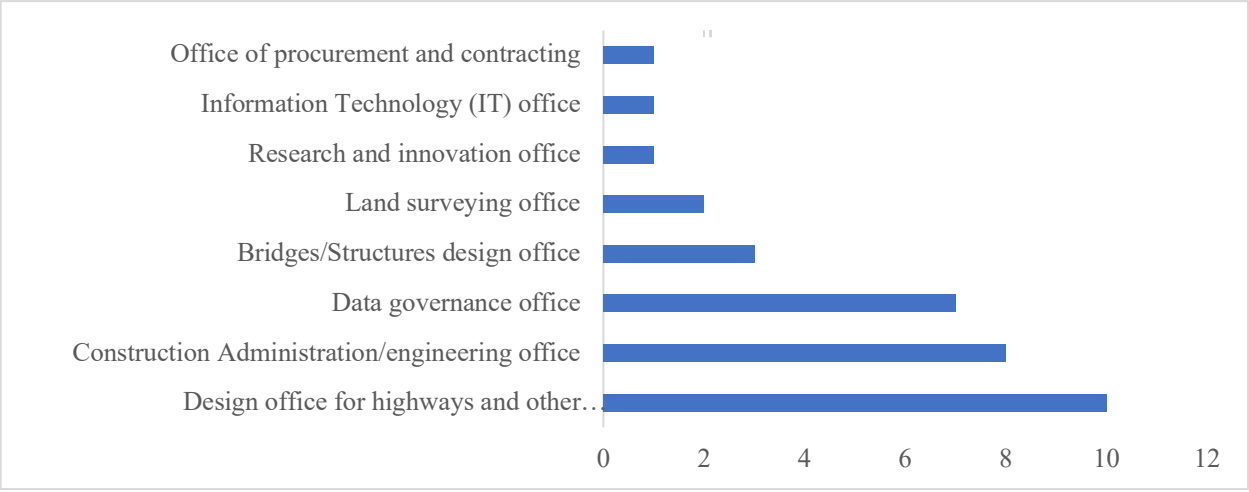
Figure 10. Groups/Division from within the Organization Involved in the BIM Implementation Process. International.



**Data shown based on a total of 19 responses*

The design office of Highways/other Transportation Facilities and the office of Construction Administration/Engineering took the lead during the implementation process in as many as ten (55%) organizations each. The offices of Construction Administration/Engineering, Data Governance, and the design office of Highways/other Transportation Facilities owned the data in many organizations (Figure 11).

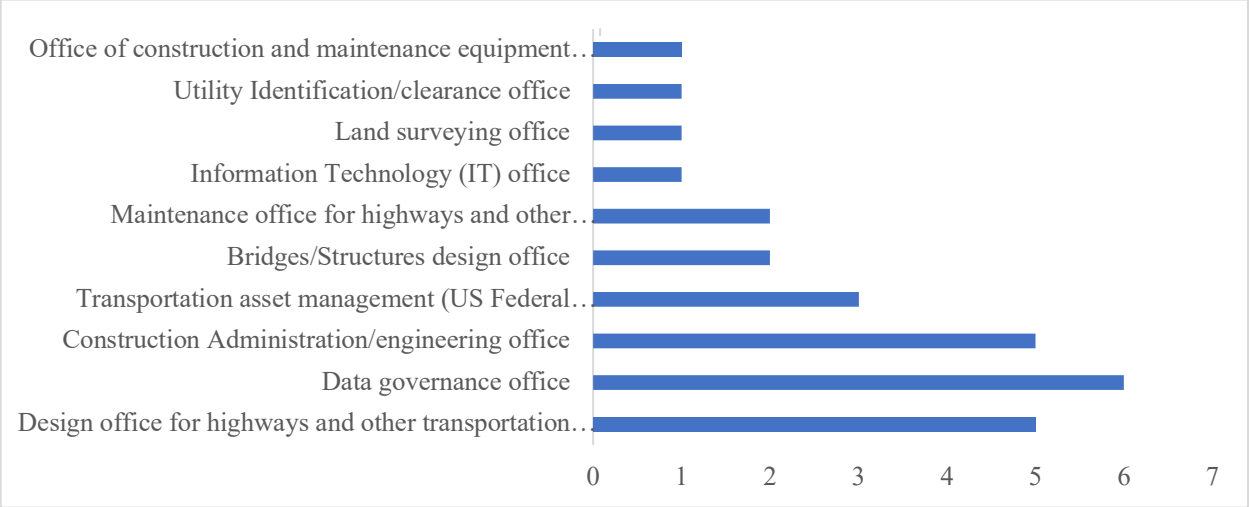
Figure 11. Groups/Division Leading the BIM Implementation Process. International.



**Data shown based on a total of 18 responses*

As shown in Figure 12, the data governance office, construction administration/engineering office, and the design office for highways were reported as the owners of the data, in six (35%), five (29%), and five (29%) agencies, respectively. Other offices have also contributed to the implementation process, taking the lead and owning the data, but at a lesser percentage.

Figure 12. Groups/Divisions Identified as the Owner of the Data. International.



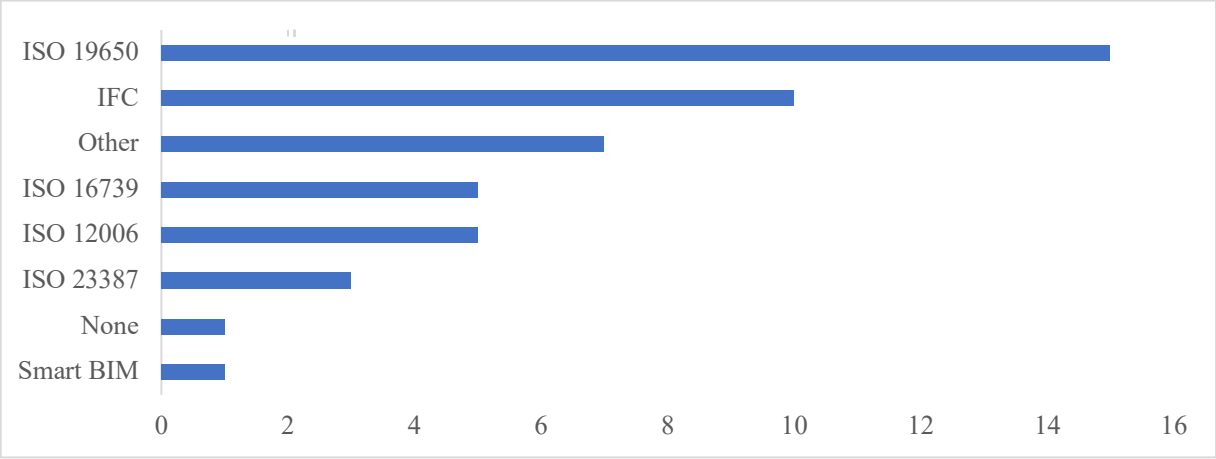
**Data shown based on a total of 17 responses*

Data standards and workflows

During the implementation process of BIM4I, the international community has used different data standards, software packages (when sharing information with other agencies), data storage destinations, and workflow approaches.

The ISO 19650 series and IFC (ISO 16739-1) were the most-used data standards. These standards were both used by 15 (79%) organizations, respectively. They have been followed by "others" (37%). In the category "other," respondents reported the use of: ISO/IEC 27001, ISO 9001, ISO 14001, UNE 166002, UNI 73401, ISO 45001, ISO 37301, IDS, ISO 55000, and ISO 81346. ISO 23387 was used by three (15%) organizations, and ISO 12006 was used by five (26%) organizations. Smart BIM was used by one (5%) organization (Figure 13).

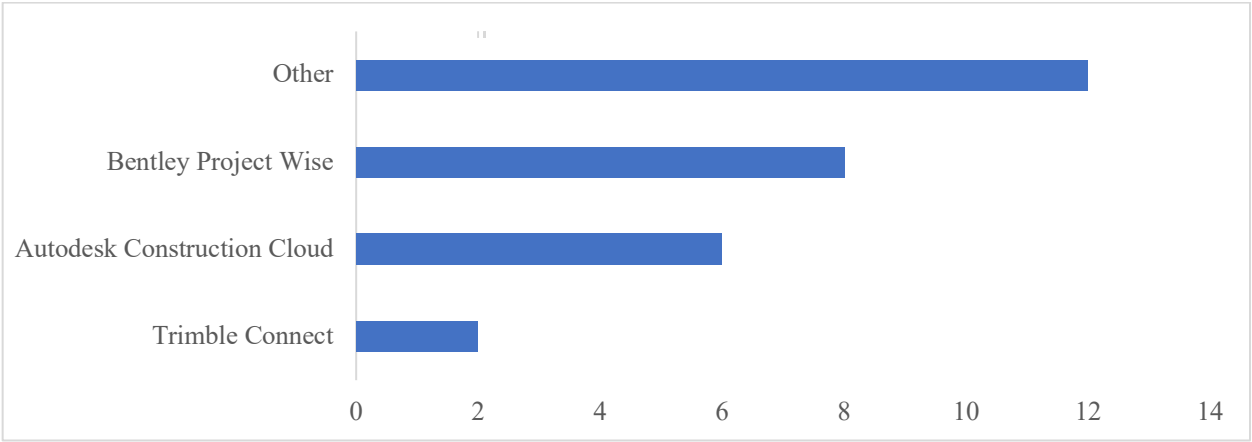
Figure 13. Data Standards Used in BIM Implementation. International.



**Data shown based on a total of 19 responses*

In eight documents, Nextcloud, SharePoint, and in-house systems were reported as some of the software used in a CDE by organizations when sharing information with others. Respondents provided this information in the category "others," which account for 75% of the organizations. From the options offered in the survey, Autodesk Construction Cloud, Bentley Project Wise, and Trimble Connect have been used by six (33%), eight (44%), and two (11%) organizations, respectively (Figure 14).

Figure 14. Software Used in CDE to Share Information. International.

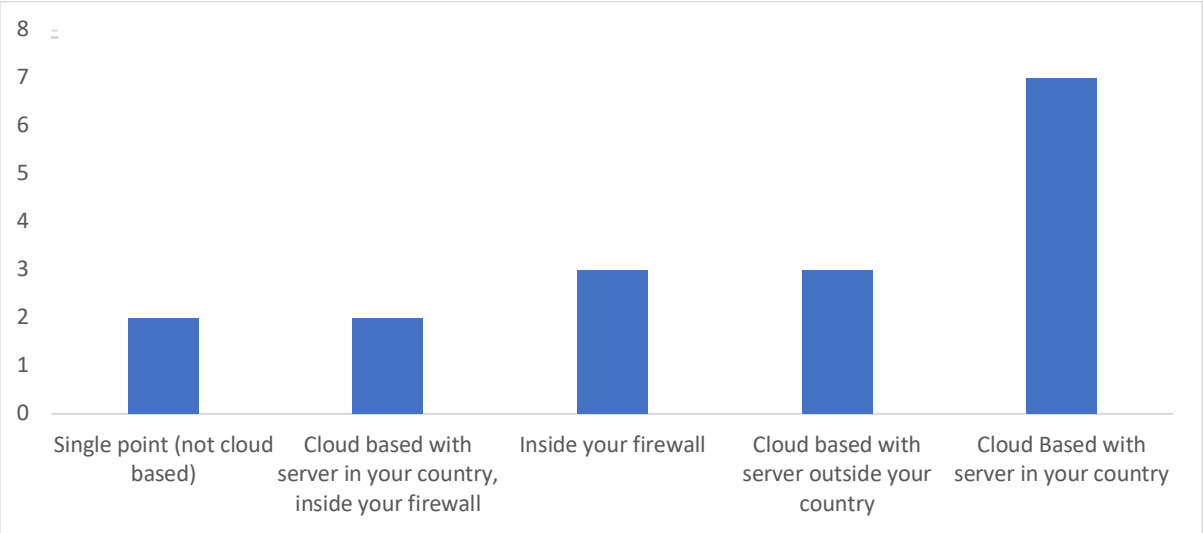


**Data shown based on a total of 18 responses*

Regarding storage of data, all given options were almost equally used by all organizations. Inside firewalls were reported by three organizations (15%). Other means to store data, such as single point (not cloud-based), were used by two (10%) organizations; cloud-based with server in their own country was used by seven (36%) organizations; inside their own firewall was used by

two (10%) organizations; and cloud-based with server outside their country was used by three (15%) organization (Figure 15).

Figure 15. Types of Data Storage. International.

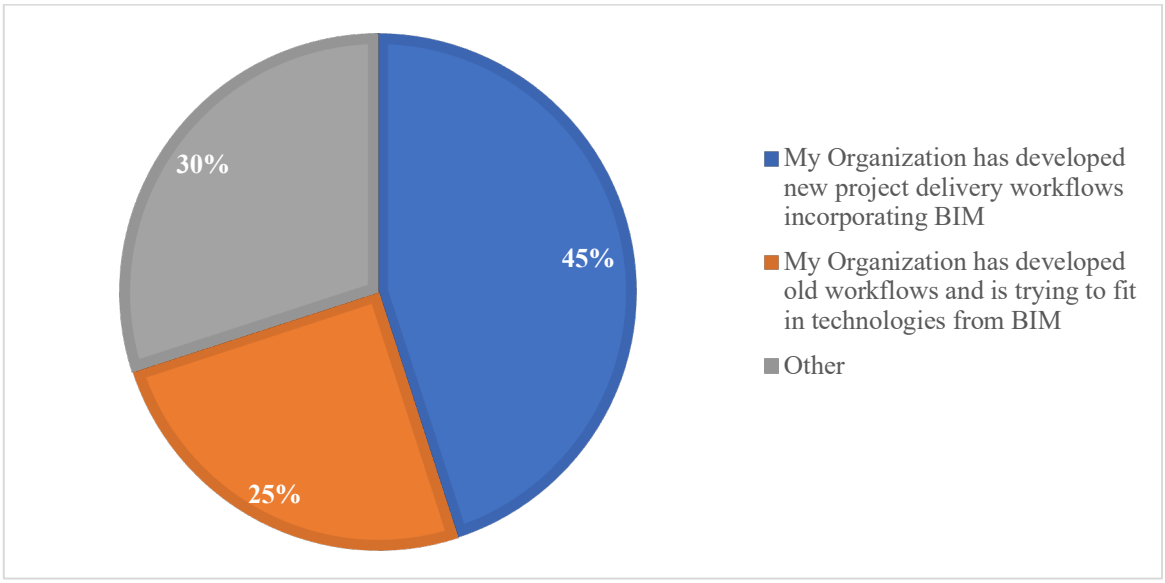


**Data shown based on a total of 19 responses*

Five out of nineteen answers (26%) indicated other options such as "with Vircore," "Cloud-based with servers in EU," "Cloud-based, hosted by consultant," "Single point secured shared network drive," or "Externally until project is completed, then likely cloud-based in country."

Agencies were asked about their approach to project delivery workflows when implementing BIM. To this question, nine (45%) respondents reported that their organizations have developed new project delivery workflows incorporating BIM4I technology, while five (25%) have tried to fit the technology within existing workflows. Of the six (30%) that responded "other" (Figure 16), replies included: "Piloting BIM with the expectation that the workflows will need to be changed," "Both of the above depending on the project/technical environment," and "No BIM-specific delivery workflow; working to incorporate BIM into old project delivery workflow."

Figure 16. Type of Workflows used in BIM Implementation. International.



**Data shown based on a total of 20 responses*

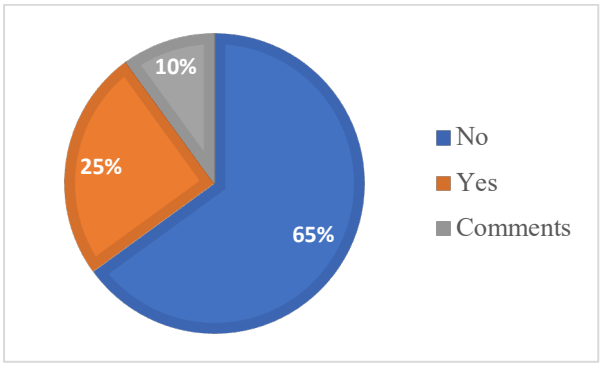
Use of 3D models

Agencies were asked whether they have used 3D models as legal documents and/or for asset management/maintenance. Five organizations (25%) indicated that they have used 3D models as legal documents, and five organizations (55%) used them for asset management and maintenance purposes (Figure 17).

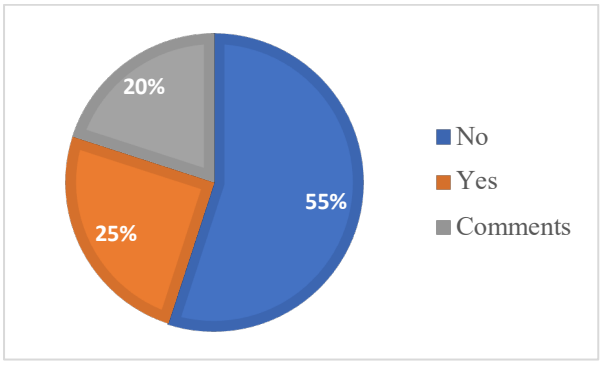
Figure 17. 3D Models Use. International.

Has your organization used 3D models…

As a legal construction document?



For asset management/maintenance?



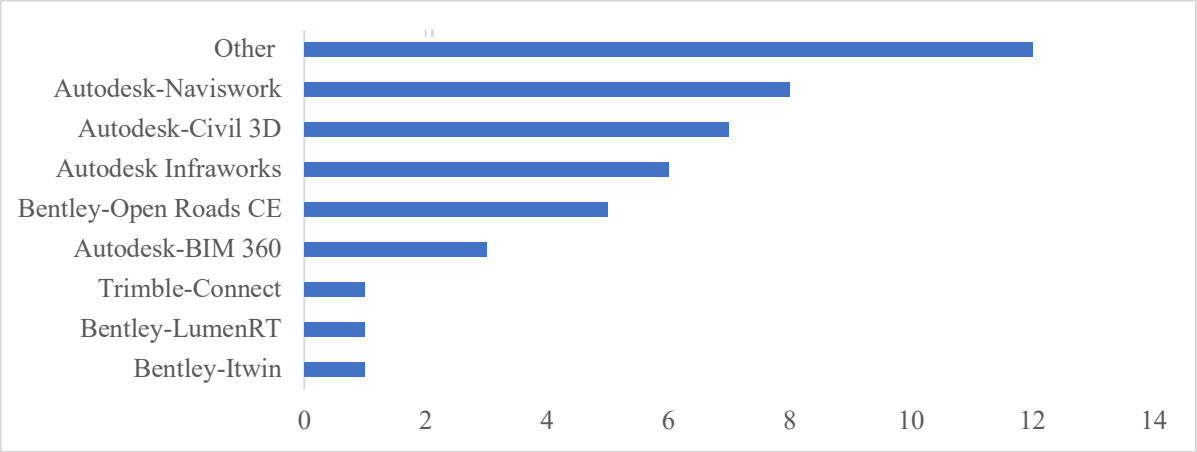
**Percentages calculated based on a total of 20 responses*

Communications

This section of the survey focused on communication with environmental agencies, utilities, or other regulatory/permitting agencies. It included questions about the software used to communicate information, the need for training, the involvement of private engineering firms in delivering information to external agencies, the use of Industry Foundation Classes (IFC) when sharing this information, and the review process using 3D models.

When asked about the software products used to communicate information with environmental agencies, utilities, or other regulatory/permitting agencies, respondents reported the software they use in the design stage and the construction, operation, and maintenance stages. Seventy-one percent (71%) of the respondents reported "other," followed by forty-seven percent (47%) using Autodesk-Navisworks. Civil 3D was identified by forty-one present (41%), followed by Bentley-Open Roads CE (35%) to communicate information in the design stage (Figure 18). Other tools reported are Bentley – 12D Model, BIM Visions, GIS, Istram, Nextcloud, pdf, ProjectWise, Revit, and Solibri.

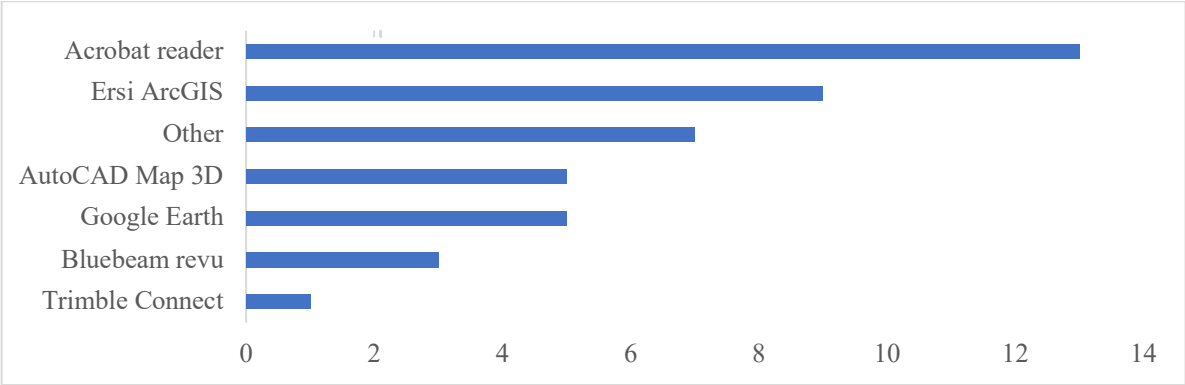
Figure 18. Software Products Used to Communicate Information in the Design Stage. International.



**Data shown based on a total of 17 responses*

Agencies were also asked about the software used to communicate information during the construction, operation, and maintenance stages. In this case, seventy-six percent (76%) of the respondents reported the use of Acrobat Reader, followed by Esri ArcGIS (53%) and AutoCAD Map 3D (Figure 19). Other tools reported were Autodesk Infraworks, Bentley Synchro, Bentley View, and pdf.

Figure 19. Software Products Use to Communicate Information in the Construction, Operation, and Maintenance Stages. International.



**Data shown based on a total of 17 responses*

To the question "Do environmental agencies, utilities, or other regulatory/permitting agencies need training?," 64% of respondents agreed that "yes, these external agencies need training" (11 out of 17 international respondents).

To the question "Do design firms participate in the development of digital delivery to environmental agencies?," 82% of respondents agreed that "yes, design firms participate in the development of digital delivery" (14 out of 17 international respondents).

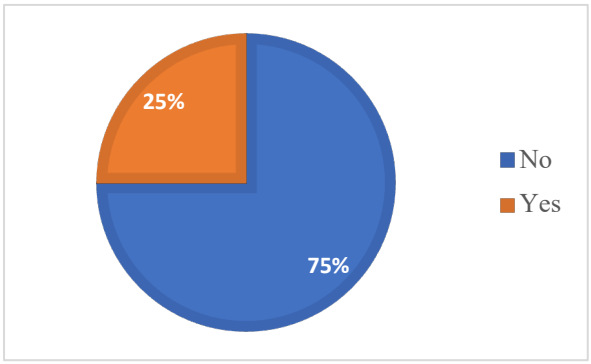
To the question, "Has your agency submitted any Industry Foundation Classes (IFC) files or shared any model via CDE with a regulatory agency that will issue a permit?," 82% of the respondents did not share IFC files or shared models with regulatory agencies (14 out of 17 DOT respondents).

To finalize this section about communications, agencies were asked about the review process with external agencies, shown in Figure 20. Twelve respondents (75%) reported that in the review process with permitting agencies they were not asked for additional information to include in the model. Further, ten respondents (71%) indicated that the review process using 3D models does not require more iterations if compared with the traditional 2D process.

Figure 20. Review Process with External Agencies. International.

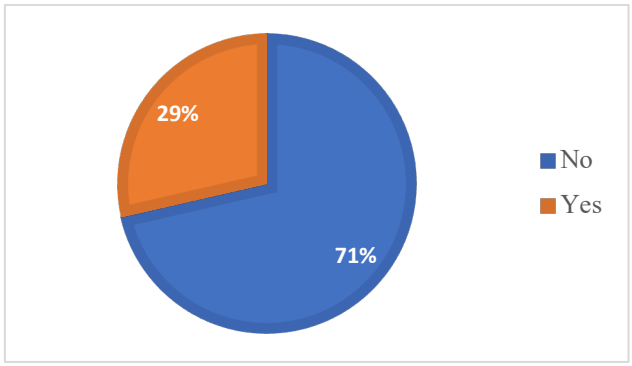
In the review process with permitting agencies using a 3D model

Have these agencies requested additional information to be included in the model?



*Percentages calculated based on a total of 16 responses

Does the review process require additional iterations as compared to the traditional 2D process?



*Percentages calculated based on a total of 17 responses

Use of technology partners and consultants

Target agencies were asked about the technology partners and products they have used in their BIM implementation process. Ten international agencies out of 26 provided responses. In total, they reported the use of Autodesk Civil 3D, Bentley ORD, BIM Vision, Infraworks, OBM, PosStructures, Revit, and Tekla Structures. About the scope of work assigned to the technology partners, the respondents mentioned: "design and construction supervision," "modeled bridges," and "CDE implementations."

Another survey question asked about the use of consultants during the BIM implementation process. Ten international agencies out of 26 provided responses to these questions. They reported a total of 17 different consultants. The scope of work assigned to these consultants was reported to be "design development," "development of digital engineering requirements," "BIM implementation," "BIM training," BIM manual elaboration," "BIM strategy design," "3D model evaluation," "BIM construction audit," and "standards updates."

International agencies were asked to rate (between 1 (poor) and 5 (excellent)) the effectiveness of the consultants they used in achieving their BIM4I implementation objectives. Seven international agencies provided answers to this question. Eighty-five percent (85%) of the answers gave a rating of 4 or 5.

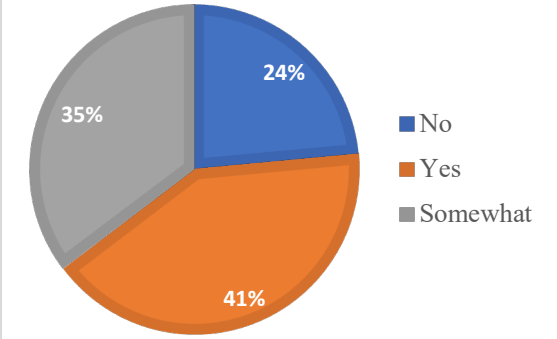
Training and implementation processes

Agencies were asked to report about training aspects, such as having a training program and/or staff development plan, for BIM implementation and whether they had a BIM implementation plan.

As shown in Figure 21, four respondents (24%) indicated that they did not have a training program or staff development plan for BIM implementation. Thirteen respondents (76%) reported "yes" or "somewhat." Of the thirteen agencies that reported having training or something similar, four of them indicated that they were conducting these trainings internally, while three agencies reported that they conducted the training in a hybrid format, combining internal resources and consultants. Three agencies stated that they develop the training through external consultants.

Figure 21. Training Program and/or Staff Development Plan. International.

Have you implemented a training program and/or staff development plan for BIM implementation?



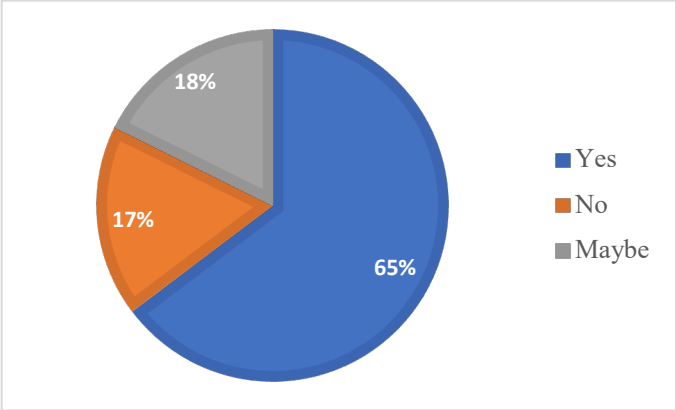
*Percentages calculated based on a total of 17 responses

If "yes" or "somewhat," how is the training?

*Data shown based on a total of 13 responses

Figure 22 shows the responses to the question "does your organization have a BIM implementation plan?" Eleven respondents (65%) indicated that they had a BIM implementation plan, while three (17%) stated that they did not have one.

Figure 22. BIM Implementation Plan. International.



**Percentages calculated based on a total of 17 responses*

Lessons learned

This section provides a summary of the lessons learned as provided by different international agencies regarding (1) organizational and/or IT structure, (2) how to manage communications with environmental agencies and other stakeholders, (3) integration of software technology partners, (4) improvements agencies would like to see in their partnerships with technology vendors, (5) integration of BIM advice consultants, (6) specific outcomes or successes that have resulted from the partnership with BIM advice consultants, (7) obstacles faced and resolution of those obstacles in the process of BIM implementation, and (8) additional comments and remarks that might help in the process of implementation.

Organization and/or IT structure

The key lessons learned regarding the organizational and IT structure for BIM users in a diverse and siloed transport agency include the importance of collaboration across different departments, such as design, construction, and IT. Establishing shared standards and procedures that are applied transversally can contribute to greater organizational efficiency. However, some organizations are still in the early stages of BIM implementation, focusing on a project-by-project approach rather than a comprehensive organizational strategy. Additionally, the human and cultural aspects, such as aligning business processes before implementing IT systems, are crucial considerations for successful BIM adoption.

How to manage communications with environmental agencies and other stakeholders

Effective communication is crucial in BIM projects. Utilizing a CDE can help ensure reliable, secure, and durable information sharing among project stakeholders, including external parties. Lessons learned suggest the importance of establishing clear communication protocols and

leveraging the benefits of a shared data environment to facilitate efficient and transparent information exchange.

Integration of software technology partners

The key lessons learned regarding the integration of software technology for international BIM users include the importance of BIM-GIS integration, particularly the interoperability between Autodesk and Esri products. While some software vendors may prioritize selling their products over addressing user implementation issues, consultants have found value in these integrations. Additionally, the use of data and information, as well as the commitment to IFC standards for interchangeability and the testing of various viewers to assess compatibility, are important considerations. Collaboration with similar agencies is also recommended.

Improvements you would like to see in your partnership with technology vendors

Lessons learned provided by international agencies include the need for quicker uptake of IFC 4.3 within software for improved IFC import/export functionality, continuous learning and adaptation, and improvements with integrating BIM software with other enterprise systems such as SAP, IBM Maximo, and Opentext Documentum. Users would like to see native BIM software capable of allowing the completion of property set parameters directly on site, using mobile devices, and by personnel not specialized in the software, at a low cost. There is a desire for better support for technological advances and a growing awareness that users do not want to be reliant on a single technology or software vendor.

Integration of BIM advice consultants

Lessons learned provided by international agencies suggest that consultants can be of enormous value. There need to be rigorous criteria guiding the selection of consultants. Consultants can provide the necessary support needed to advance and learn what is needed for a correct implementation. They have also helped in defining requirements and producing documentation, thereby helping the agencies to develop a macroscopic vision of BIM4I.

Specific outcomes or successes that have resulted from the partnership with BIM advice consultants

Some of the successes shared are that "the organization selected had a proven track record and visible results, which was key in developing the BIM implementation strategy." Further, "defining the current and future states was crucial in mapping out the BIM implementation journey." In another case, "the BIM implementation has been beneficial for everyone, especially for the human recognition of companies." Another success shared was that "the organization has developed 50 BIM projects, with over 150 companies and 2000 users working in the CDE."

Obstacles faced and resolution of those obstacles in the process of BIM implementation

Obstacles faced in BIM implementation include organizational resistance to change, a lack of functionalities in the CDE, and low BIM maturity among private partners. Contractual challenges, such as changes in practices, have also hindered progress. Delays in tendering and adjusting expectations around 2D plans derived from 3D models have also posed challenges. Misaligned departmental BIM maturity and the lack of open standards have further complicated the implementation process.

Additional comments and remarks that might help in the process of implementation

The respondents emphasized the importance of aligning BIM strategies with international standards and principles, such as Open BIM, BuildingSMART, and ISO standards. Several policies, guides, and websites were also found during the course of the research that could be adapted and used as models by agencies that are starting on the path of BIM adoption. These are tabulated in Appendix E. Agencies highlighted the need to focus on practical implementation and staff training when organizations are in the exploratory stages of BIM and currently using it only for 3D modeling. The respondents caution against rushing the implementation process and emphasize that people are the greatest asset, but they need support to keep up with the technological changes. Overall, international agencies suggest a gradual and thoughtful approach to BIM implementation, prioritizing alignment with standards, practical application, and supporting the workforce.

Follow-up interviews' main insights

The interview insights are organized into three subsections: (1) Technology, Data Standards, and Common Data Environment (CDE); (2) Organizational Structure, Processes, and Workflows; and (3) People, Training, and Change Management Strategies.

Technology, Data Standards, and Common Data Environment (CDE)

Interviewees from international organizations emphasize the necessity of adhering to established data standards, particularly ISO 19650 and Industry Foundation Classes (IFC). These standards are foundational guidelines for managing information effectively and ensuring interoperability across various software platforms. The adoption of a Common Data Environment (CDE) is crucial for securely managing project data, although challenges such as software compatibility and document naming conventions persist. Organizations are encouraged to focus on a common data exchange rather than solely relying on a CDE, as this approach enhances data flow and integration. Information about the ISO standards related to BIM implementation is included in Appendix F.

Furthermore, integrating geospatial data and using standardized formats are essential for effective asset management. Security concerns regarding data management, especially when information is stored externally, must be addressed to ensure compliance and protect sensitive data. The development of robust document management systems and the establishment of clear requirements for data exchange are vital for successful BIM implementation.

Organizational Structure, Processes, and Workflows

A structured approach to processes and workflows is critical for successfully integrating BIM. Organizations should establish clear workflows that align with project requirements and ensure that all stakeholders understand their roles and responsibilities. The creation of Task Information Delivery Plans (TIDPs) can help ensure that the right information is delivered at the right time, enhancing project efficiency.

Pilot projects are often utilized to test new workflows and software tools, allowing organizations to refine their processes incrementally. The integration of existing workflows with new BIM practices is essential to minimize disruption and facilitate a smoother transition. Continuous improvement processes should be in place to adapt workflows based on lessons learned from pilot projects and ongoing experiences.

Moreover, organizations must prioritize collaboration across different disciplines and departments to ensure that all aspects of BIM implementation are aligned. Clear contractual documentation is necessary to manage BIM processes effectively and set expectations for all parties involved.

People, Training, and Change Management Strategies

The human element is critical to the successful implementation of BIM. Organizations must address cultural resistance to change by fostering a collaborative environment encouraging trust and open communication. Engaging staff at all levels and involving them in the change process can help mitigate fears associated with new workflows and technologies.

Training and capacity building are essential components of a successful BIM strategy. Organizations should develop tailored training programs that cater to the specific needs of their staff, ensuring that all team members are equipped with the necessary skills and knowledge to work effectively with BIM tools and processes. Ongoing training should be emphasized to keep staff updated on new developments and best practices.

Leadership plays a vital role in guiding the organization through the transition to BIM. Strong executive support is necessary to drive the implementation process and ensure that the vision for BIM integration is clearly communicated. Establishing a community of practice or BIM champions within the organization can facilitate knowledge sharing and promote a culture of continuous improvement.

In summary, successfully implementing BIM4I requires a multifaceted approach encompassing technology, organizational processes, and people. Transportation agencies can navigate the complexities of BIM integration and enhance their project delivery capabilities by focusing on data standards, structured workflows, and effective training and change management strategies.

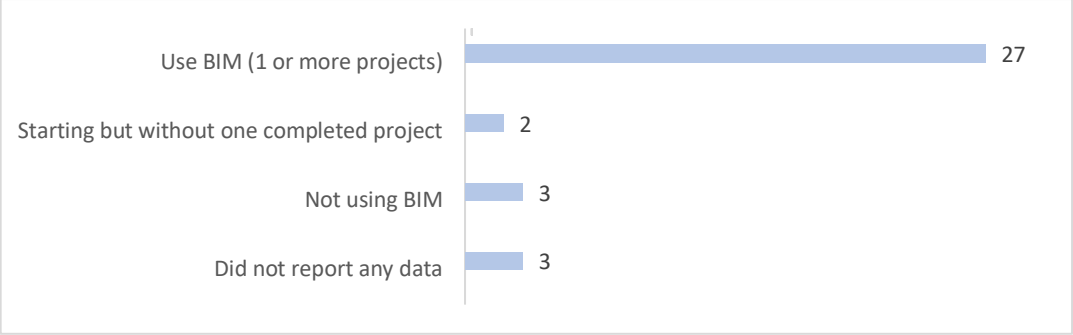
3.2 National Survey Analysis

The national category of targeted agencies includes (1) DOTs and FHWA, (2) Federal Agencies, and (3) utilities and railroad companies. For that reason, the results are structured in these three groups.

3.2.1 DOTs and FHWA

Out of 35 responses received from DOTs and FHWA, 27 reported they have used BIM in one or more projects. Two DOTs indicated that they are starting and have not completed one project at this time. Three DOTs shared that they do not use BIM. Finally, three DOTs did not report any data in the survey (Figure 23).

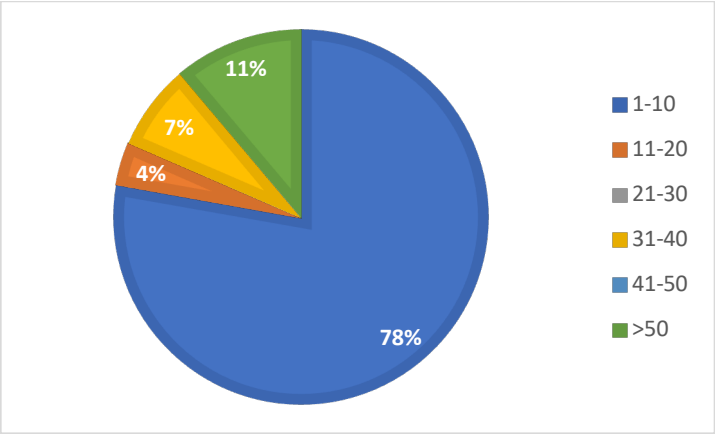
Figure 23. BIM4I Use in DOTs.



**Data shown based on a total of 35 responses*

Among the DOTs that have completed more than one project, 78% of the respondents indicated that they have used BIM in 1–10 projects in their organization. Four percent (4%) reported the use of BIM in 11–20 projects in their organization, while 7% and 11% indicated they use BIM in 31–40 projects and >50 projects, respectively (Figure 24).

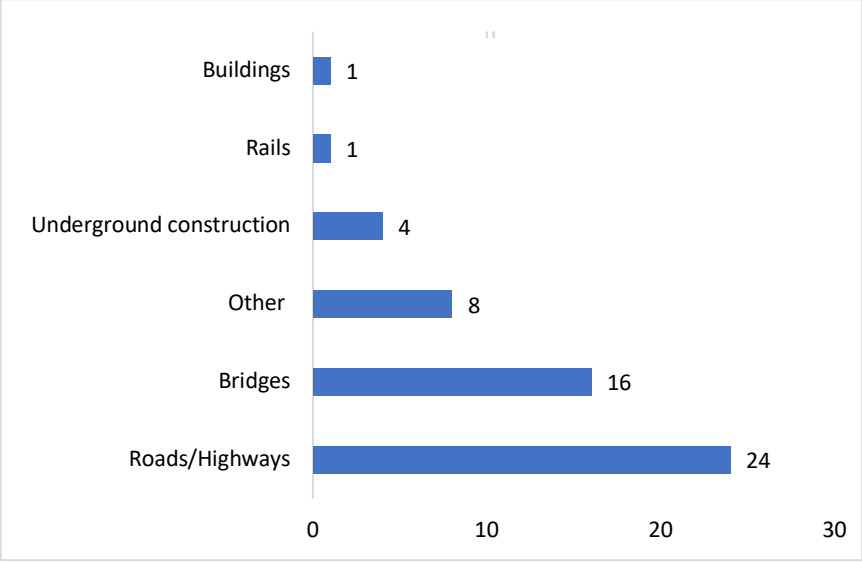
Figure 24. Number of Projects Developed Using BIM. National.



**Percentages calculated based on a total of 27 responses*

DOTs reported the use of BIM in roads/highways, bridges, underground construction, rail, tunnels, and buildings. Roads/highways projects were developed using BIM by 24 DOTs, followed by bridge projects that were reported by 16 DOTs out of 27 (Figure 25).

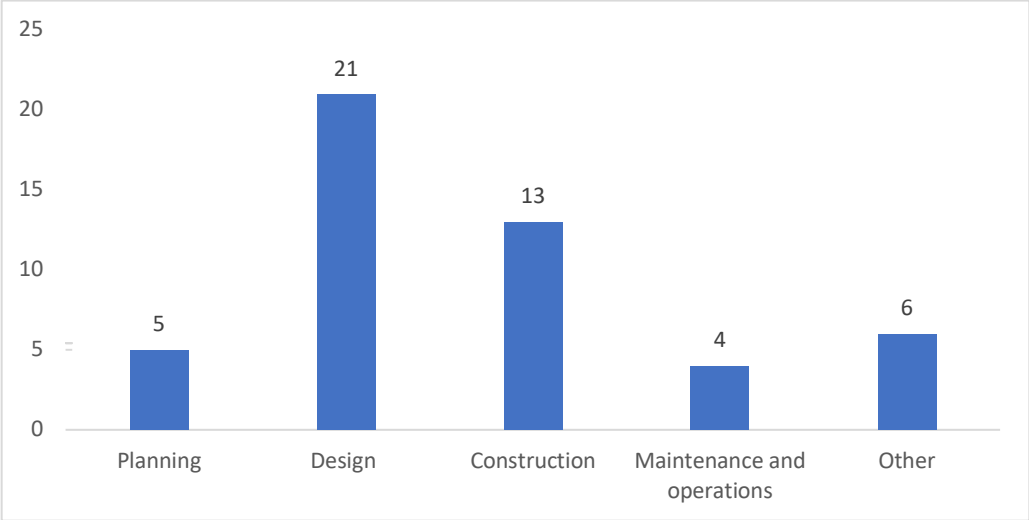
Figure 25. Type of Projects Developed using BIM. National.



**Data shown based on a total of 24 responses*

Respondents also reported on the phases of the project lifecycle where they use BIM. Twenty-one out of 27 respondents indicated the use of BIM in the design stage, followed by 13 respondents that reported the use in the construction state (Figure 26).

Figure 26. Project Phases when BIM is Used. National.

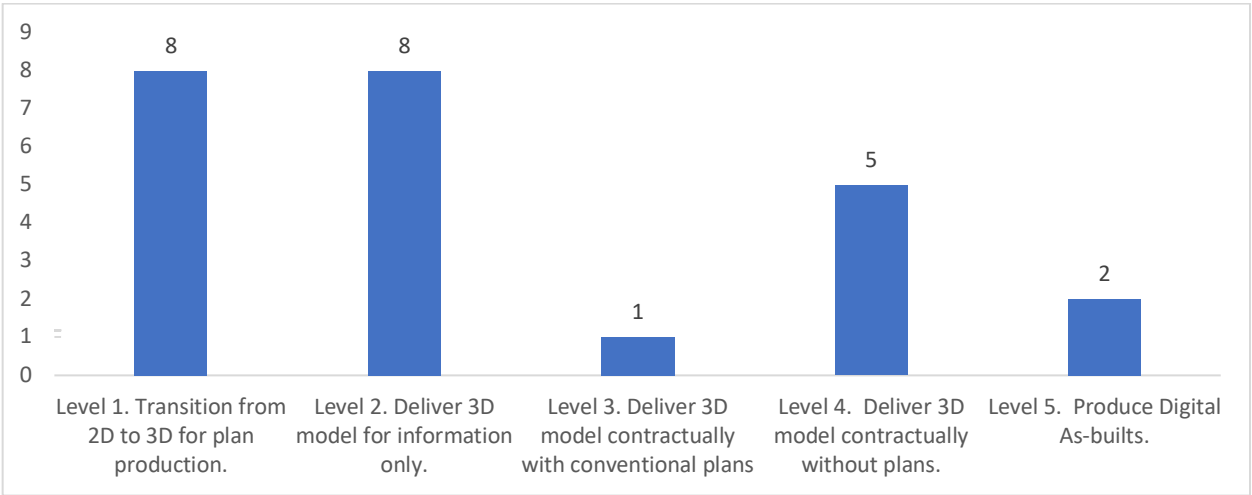


**Data shown based on a total of 27 responses*

Levels of implementation & implementation approach

Target agencies were asked to self-report the level of implementation they think their organization could be categorized in. The levels included: level 1: transition from 2D to 3D for plan production; level 2: deliver 3D model for information only; level 3:deliver 3D model contractually with conventional plans; level 4: deliver 3D model contractually without plans; and level 5: produce digital as-builts. Eight out of 24 DOTs reported to be in level 1, eight in level 2, one in level 3, five in level 4, and two in level 5 (Figure 27).

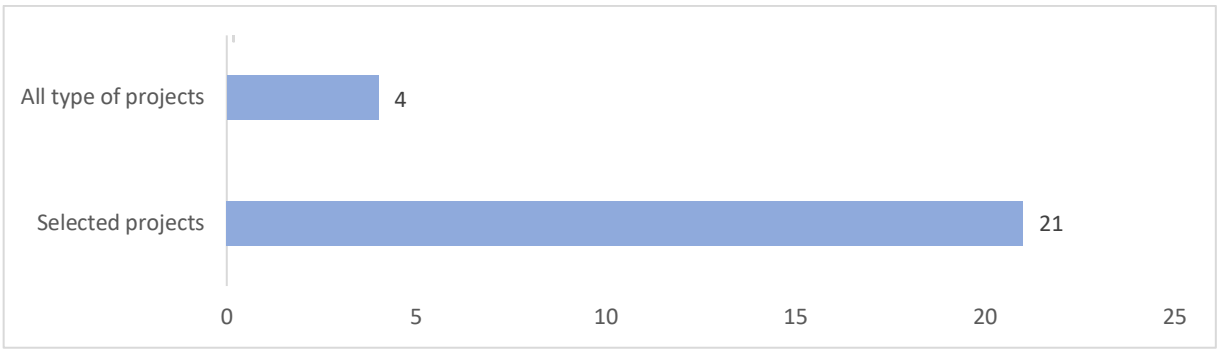
Figure 27. Levels of BIM Implementation. National.



**Data shown based on a total of 24 responses*

The survey asked the agencies to report whether they implement BIM in all types of projects or only in selected projects. Twenty-one DOTs indicated that they use BIM in selected projects, while four reported the use of BIM in all types of projects (Figure 28).

Figure 28. BIM4 Implementation Approach. National.



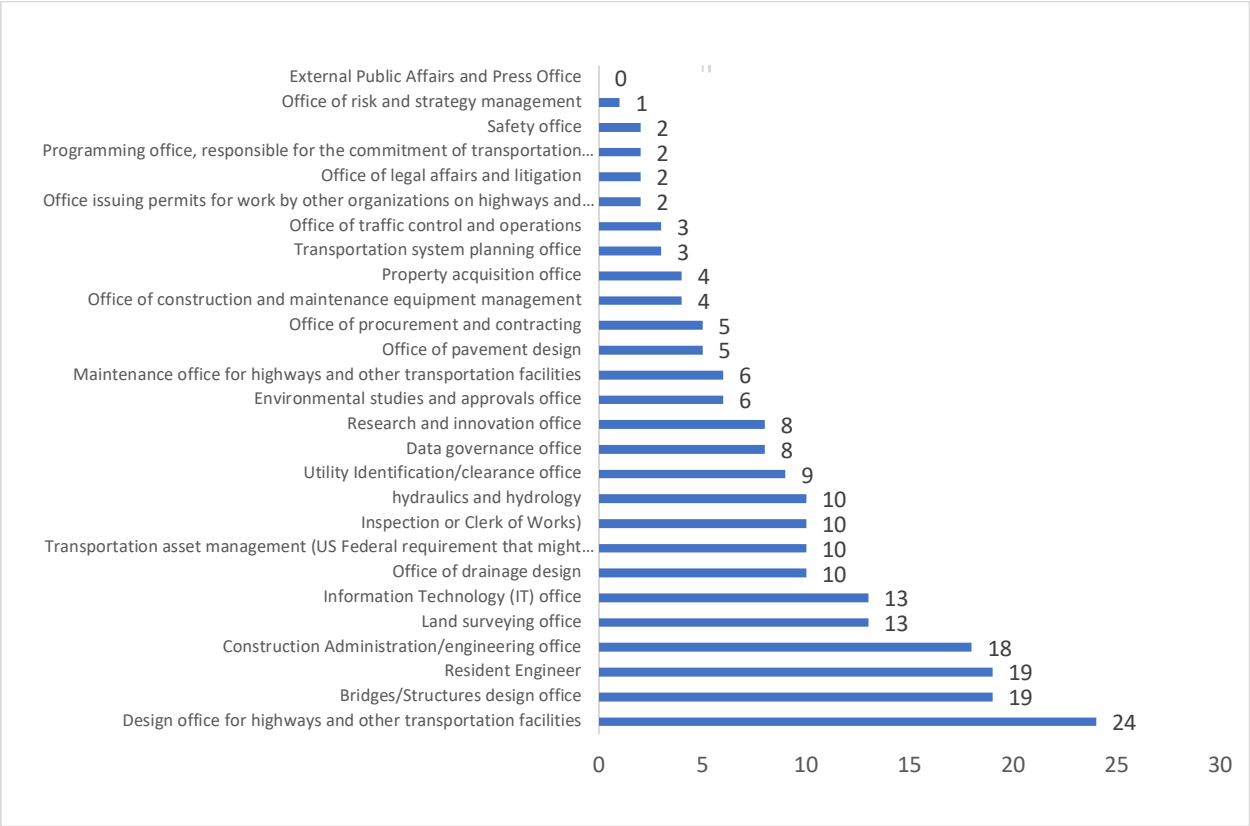
**Data shown based on a total of 23 responses*

DOTs had the opportunity to report more details about their implementation approach in an open-ended question associated with the previous one. In this instance, DOTs reported the use of BIM in earthwork, hot mix asphalt (HMA), concrete overlays, highways, bridges, new routes, major widening, minor reconstruction, bridge rehabilitation, safety improvements, and roundabouts. One DOT also reported that BIM is implemented in those projects with the most opportunity for return on investment (ROI).

Some DOTs also reported on their process approach. One indicated that it used "a full model-based digital delivery in three selected projects, and hybrid digital delivery in most of the projects." Another DOT reported the use of "3D models for road rehabilitation and reconstruction since 2016," and now they are "just starting piloting 3D models without traditional plans." They indicated that they have "also piloted BIM models for maintenance/operation of select location for utilities as well as tunnels."

Given that several departments in the organization are involved in the BIM4I implementation process, target agencies were asked three questions regarding what groups/division are involved in that BIM implementation process. From those groups/divisions, they were then asked to identify which ones were the leaders in the implementation. Finally, agencies were asked to indicate who the owner of the data (data steward) was. Responses to these questions are shown in Figures 29, 30, and 31. As shown in Figure 29, the three divisions most frequently mentioned by DOTs are the "Bridge/Structures office," "Design office for Highways and other transportation facilities," and "Construction Administration/Engineering Office."

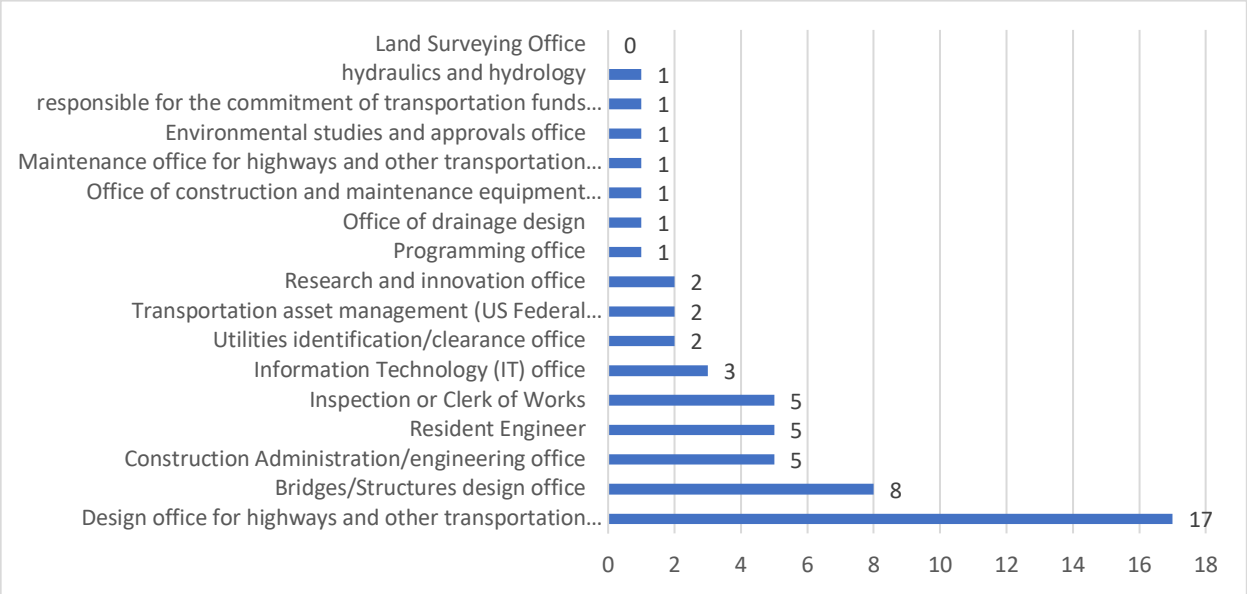
Figure 29. Groups/Division from within the Organization Involved in the BIM Implementation Process. National.



**Data shown based on a total of 24 responses*

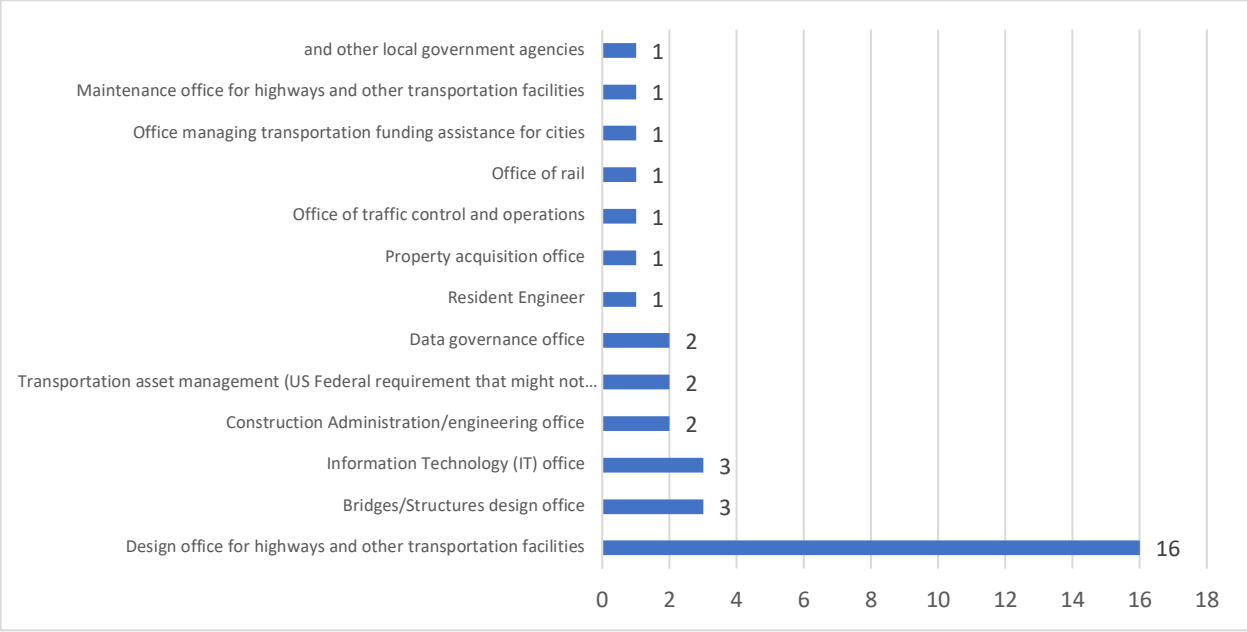
The "Design Office for Highways and other transportation facilities" was reported by 17 DOTs out of 24 as the office that leads the BIM implementation process (Figure 30). This office was also identified as the owner of the data by 17DOTs (Figure 31).

Figure 30. Groups/Divisions Leading the BIM Implementation Process. National.



**Data shown based on a total of 24 responses*

Figure 31. Groups/Divisions Identified as the Owners of the Data. National.

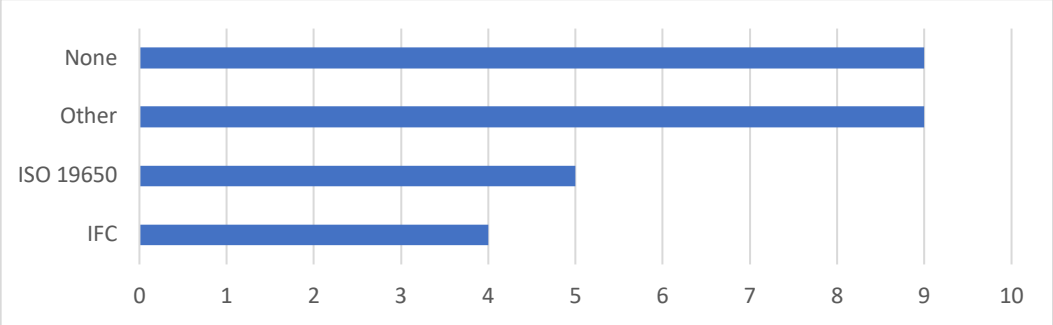


**Data shown based on a total of 24 responses*

Data standards and workflows

DOTs were asked to indicate the data standards they are using in their BIM implementation process. Options provided included ISO 12006, ISO 16739, ISO 19650, ISO 23387, Smart BIM, DIGGS, IFC, None, or Other. "Other," an open-ended question, allowed respondents to explain in greater detail. Nine out of 24 respondents indicated that they did not use any standard, and another nine reported using "Other," while five used ISO 19650 and four IFC (Figure 32).

Figure 32. Data Standards Used in BIM Implementation. National.

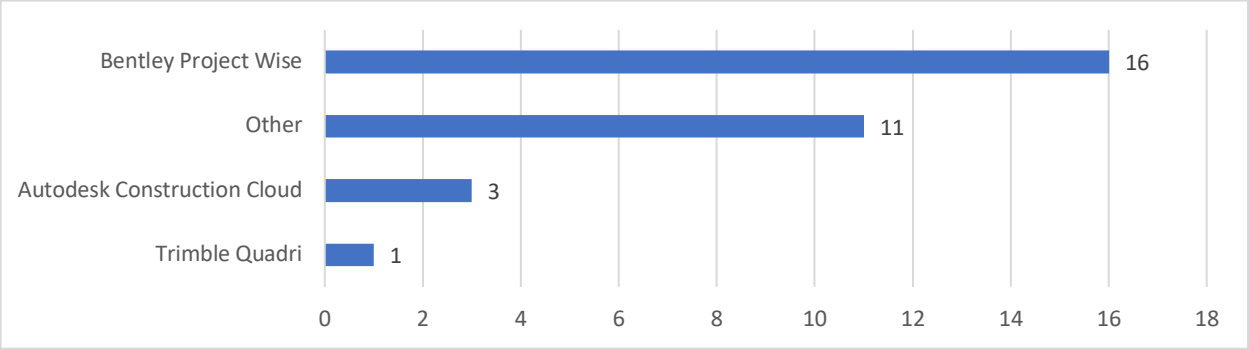


**Data shown based on a total of 24 responses*

With the answer "Other," one DOT indicated that they are "kicking off a contract that will help explore IFC," and another DOT stated that they use "State DOT CADD Standards." Further, "Other" responses included "Pilot phase, currently coordinating" and using "internal data dictionaries."

DOTs were also asked what software their organizations use as a CDE when sharing information with others. Sixteen out of 24 respondents reported the use of Bentley ProjectWise. Eleven out of 24 respondents reported the use of "Other" software (Figure 33). Respondents provided the following software in the "Other" category: ArcGIS Online Portal, Bentley Syncro, ESRI ArcGIS, Itwin, MFT site, OneDrive, SharePoint, and Trimble Business Center.

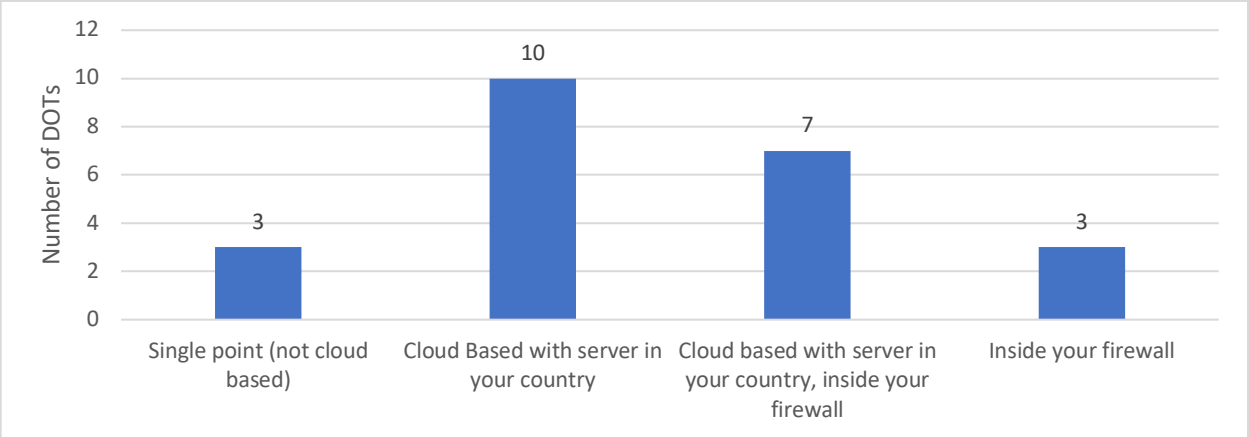
Figure 33. Software use in CDE to Share Information.



**Data shown based on a total of 24 responses*

DOTs were asked about how the data are stored and were provided the options of "single point (not cloud-based)," "cloud-based with the server in your country," "cloud-based with a server outside your country," and "inside your firewall." Ten out of 25 respondents indicated that their data storage is "cloud-based with a server in your country." Three DOTs, reported "single point, not cloud-based," and seven DOTs indicated that they use "cloud-based with a server in your country" and "inside your firewall." Only three DOTs selected only the option "inside your firewall" (Figure 34). Finally, two respondents selected the option "other" and reported that they use "cloud-based with department servers" and "none yet."

Figure 34. Types of Data Storage. National.

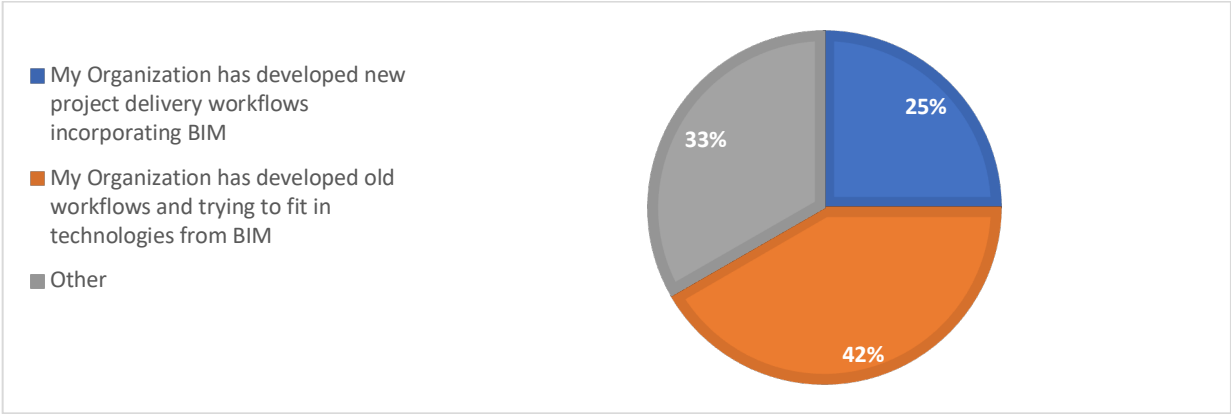


**Data shown based on a total of 25 responses*

With respect to workflows, DOTs were asked to report whether their organization was "developing new project delivery workflows incorporating BIM" or "developing old workflows and trying to fit in technologies from BIM." As shown in Figure 35, 25% of the respondents indicated that they are developing new workflows, while 42% of them reported the use of old workflows. Interestingly, 33% of respondents selected the option "Other." Other approaches included a mix

of both new and old workflows, workflows in development, "finding that old workflows do not work for BIM and try to find new workflows," and "working through current project delivery workflows to see if the data can be incorporated or if the workflows need to change to incorporate them."

Figure 35. Type of Workflows Used in BIM Implementation. National.



**Percentages calculated based on a total of 24 responses*

Use of 3D models

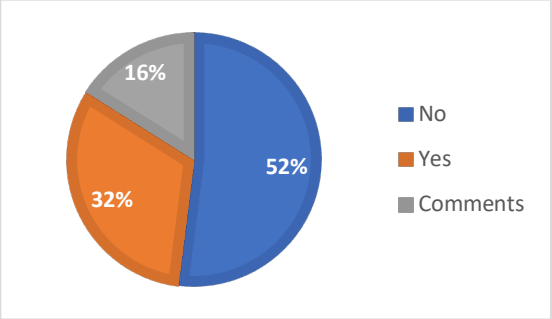
The survey asked participants to report on the use of 3D models as legal construction documents and for asset management/maintenance. Fifty-two (52%) of respondents indicated that they had not used BIM as a legal document, while 72% reported not having used BIM for asset management/maintenance (Figure 36). Some comments provided on the use of 3D models as a legal document include "we legally cannot until there is a mechanism to seal/lock the model," "first will let in Oct 2024," and "we have only bid one project with BIM but also provide a 2D set of plans as well as the model."

Six DOTs did not select "yes" or "no" in the question about the use of 3D models for asset management/maintenance. Instead, they provided the following comments: "Piloting/Proof Concept," "in the process of development," "one selected case—underground utilities," "in the process of piloting," and "2D is used, not 3D for most assets."

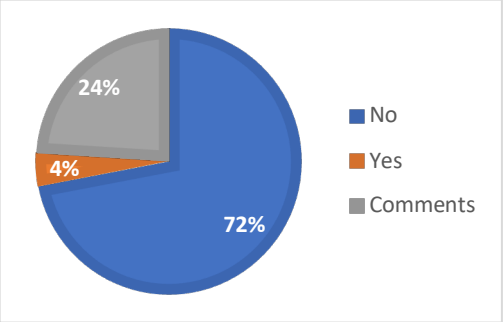
Figure 36. 3D Models Use. National.

Has your organization used 3D models…

As a legal construction document?



For asset management/maintenance?



**Percentages calculated based on a total of 25 responses*

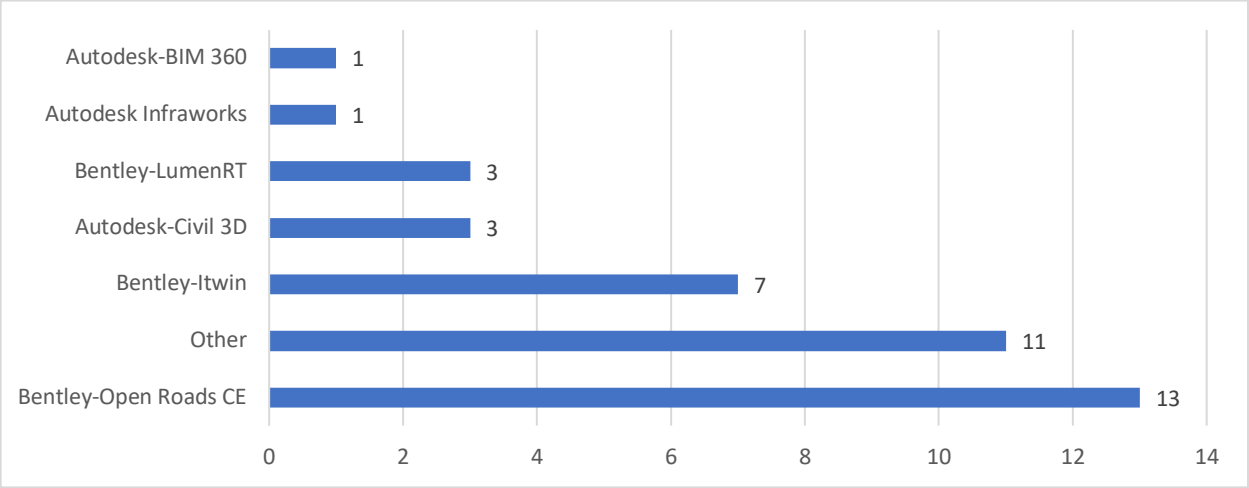
Communications

This section of the survey focuses on communication with environmentally responsible agencies, utilities, or other regulatory agencies. It included questions about the software used to communicate information, the need for training, the involvement of private engineering firms in delivering information to external agencies, the use of Industry Foundation Classes (IFC) when sharing this information, and the review process using 3D models.

With respect to the software products used to communicate information with environmental agencies, utilities, or other regulatory/permitting agencies, DOTs were asked to report the software they use in the design stage and the construction, operation, and maintenance stages. Thirteen out of 24 respondents reported using Bentley-Open Roads CE followed eleven who responded "Others" to communicate information in the design stage (Figure 37). Other tools reported are Bentley-InRoads, GIS/Autodesk, pdf, and Trimble Business Center.

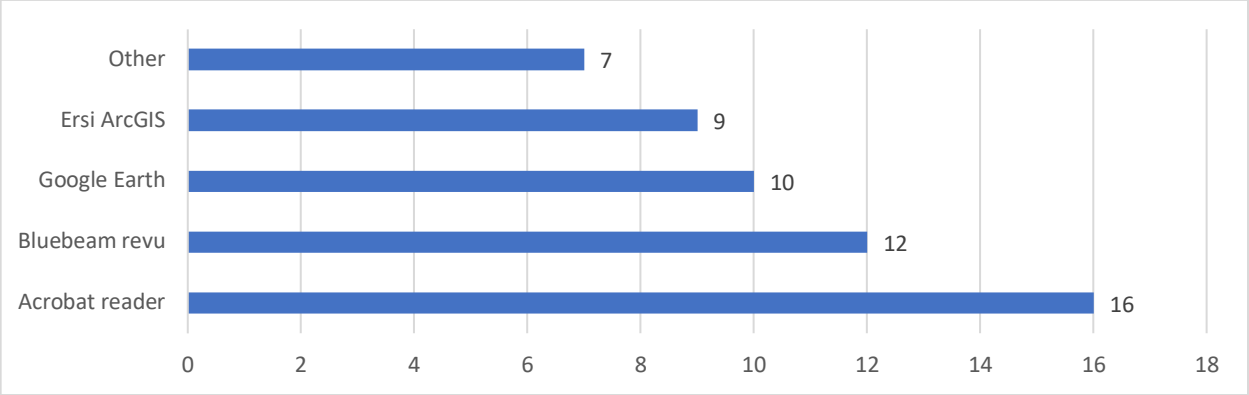
Sixteen out of 24 respondents reported the use of Acrobat reader as the software tool to communicate information in the construction, operation, and maintenance stages, followed by Bluebeam Revu (12 respondents) and Google Earth (10 respondents) (Figure 38). Other tools reported were Autodesk Infraworks, Bentley Synchro, and pdf.

Figure 37. Software Products Used to Communicate Information in the Design Stage.



**Data shown based on a total of 24 responses*

Figure 38. Software Products Used to Communicate Information in the Construction, Operation and Maintenance Stages.



**Data shown based on a total of 24 responses*

To the question, "Do environmentally responsible agencies, utilities, or other regulatory/permitting agencies need training?," 96% of respondents agreed that yes, these external agencies need training (24 out of 25 DOT respondents).

To the question "Do design firms participate in the development of digital delivery to environmentally responsible agencies?," (72% of respondents agreed that yes, design firms participate in the development of digital delivery (18 out of 25 DOT respondents).

To the question, "Has your agency submitted any Industry Foundation Classes (IFC) files or shared any model via Common Data Environment (CDE) with a regulatory agency that will issue

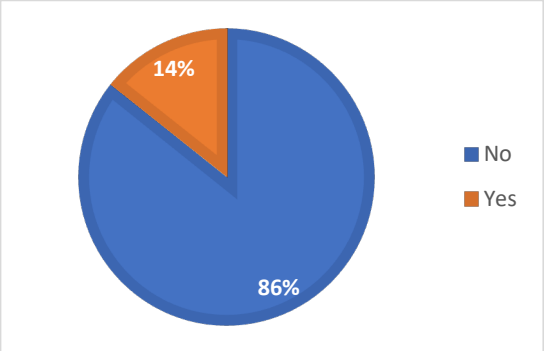
a permit?," 96% of the respondents did not share IFC files or any models with regulatory agencies (24 out of 25 DOT respondents).

To conclude this section about communications, agencies were asked about the review process with external agencies, as shown in Figure 39. Eighty-six percent (86%) of respondents reported that in the review process with permitting agencies they were not asked for additional information to include in the model. Further, 65% of respondents indicated that the review process using 3D models did not require more iterations as compared to the traditional 2D process.

Figure 39. Review Process with External Agencies.

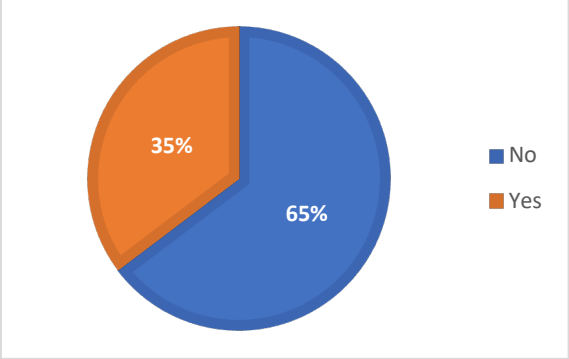
In the review process with permitting agencies using a 3D model

Have these agencies requested additional information to be included in the model?



*Percentages calculated based on a total of 21 responses

Does the review process require additional iterations as compared to the traditional 2D process?



*Percentages calculated based on a total of 17 responses

Use of technology partners and consultants

Target agencies were asked about the technology partners and products they have used in their BIM implementation processes, and six DOTs out of 25 provided responses. Between them, they reported the use of Autodesk, Bentley, Esri, Haul Hub, Info Tech, Propeller Aero, and Trimble. Products used from these technology partners include Bentley ProjectWise, BIM 360, Civil 3D, GIS tools, Infrastructure Cloud, OBM, Openground, ORD, and Syncro. As to the scope of work assigned to the technology partners, the respondents mentioned "Pilot Assistance—3D model as contract pilot," "Providing digital modeling data to supplement agency field inspection," "design/construction," and "GIS/design/construction."

To a question related to the use of consultants in the process of BIM implementation, eight DOTs out of 25 provided responses. In total, they reported a total of 21 different consultants. The scope of work assigned to these consultants was reported as follows: "design-digital delivery pilot project," "construction-digital delivery pilot projects," "assist digital delivery team," "develop training materials, work with a pilot project, meet with all the divisions to discuss needed materials and teach those materials, draft all documents associated with transition," "review all survey files submitted in ORD, work with pilot projects," "pilot project design project manager," "digital delivery resource," and "design/GIS/construction." DOTs were asked to rate (between 1 (poor) and 5 (excellent)) the effectiveness of the consultants they used in achieving their BIM4I implementation objectives. Seven DOTs provided answers to this question. Eighty-five percent (85%) of the answers gave a rating of 4 or 5.

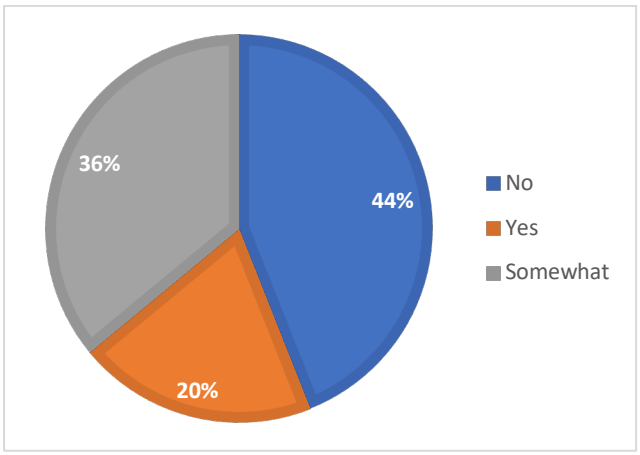
Training and implementation processes

Agencies were asked to report on training aspects such as having a training program and/or staff development plan for BIM implementation and whether they had a BIM implementation plan.

As shown in Figure 40, 44% of the respondents indicated that they did not have a training program and/or staff development plan for BIM implementation. Fifty-six percent (56%) of respondents reported "yes" or "somewhat." Of the agencies that reported having training or something similar, five of them indicated that they are conducting this training internally, while another four agencies reported conducting the training in a hybrid format that combined internal resources with consultants. One agency stated that they develop the training through external consultants. Finally, six agencies answered "Other," indicating that "they have an internal core team developing a plan," "through grant funds to hire resources," and "we are starting training on Open Roads and MicroStation Connect."

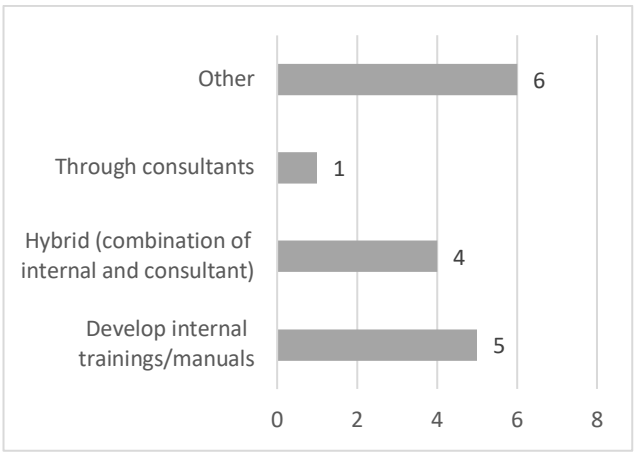
Figure 40. Training Program and/or Staff Development Plan. National.

Have you implemented a training program and/or staff development plan for BIM implementation?



*Percentages calculated based on a total of 25 responses

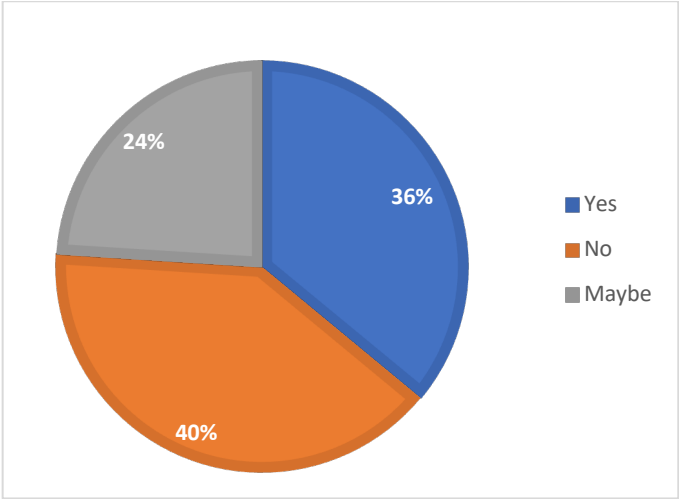
If "yes" or "somewhat," how is the training?



*Data shown based on a total of 16 responses

Figure 41 shows the responses to the question "does your organization have a BIM implementation plan?" Forty percent (40%) of respondents indicated that they do not have a BIM implementation plan, 36% stated that they have one, and 24% of respondents selected the option "maybe."

Figure 41. BIM Implementation Plan.



Percentages calculated based on a total of 25 responses

Lessons learned

This section provides a summary of the lessons learned provided by different DOTs regarding (1) organizational and/or IT structure, (2) how to manage communications with environmental agencies and other stakeholders, (3) integration of software technology partners, (4) improvements you would like to see in your partnership with technology vendors, (5) integration of BIM advice consultants, (6) specific outcomes or successes that have resulted from the partnership with BIM advice consultants, (7) obstacles faced and resolution of those obstacles in the process of BIM implementation, and (8) additional comments and remarks that might help in the process of implementation.

Organization and/or IT structure

The key topics emerging from the DOTs' responses are the importance of cross-functional collaboration, executive-level support, a phased and flexible approach, addressing data and technology integration challenges, and managing organizational change. A comprehensive, strategic, and user-centric approach seems to be crucial for successful BIM implementation.

How to manage communications with environmental agencies and other stakeholders

This topic was identified as challenging. Some agencies propose forming a committee with the organization to manage communications to stakeholders or digital delivery stakeholder groups (DDSG). Meeting often and using a communication/change management plan was suggested.

Integration of software technology partners

Key advice for integrating technology partners in BIM implementation based on DOTs responses included (1) staying focused on your agency's specific needs and requirements, (2) establishing clearly defined expectations and collaborative working relationships, (3) ensuring interoperability and open standards among technology partners, (4) maintaining close engagement and responsiveness from software developers, and (5) facilitating workshops and collaborative sessions for knowledge sharing and alignment.

Improvements you would like to see in your partnership with technology vendors

Respondents would like to see software vendors improve their commitment to interoperability, particularly by incorporating the Industry Foundation Classes (IFC). They emphasize the need for vendors to better understand the diverse needs and processes of different state agencies and to coordinate with them to develop solutions that meet their collective requirements. Respondents express a desire for more vendors to provide tools that can read and work with BIM models, as well as better integration between different software products from the same vendor. They also

request more transparency from vendors regarding their product roadmaps and a willingness to seek collective input from state transportation departments to avoid the need for multiple, potentially conflicting, solutions.

Integration of BIM advice consultants

According to the respondents, engaging a diverse range of BIM consultants is crucial to drive industry progress. While national consulting firms with local experience can provide valuable expertise, it is important to maintain agency ownership and not let consultants steer the process. Partnering with advisory consultants to develop BIM implementation plans can be beneficial, as they can share insights from other states' BIM initiatives. However, agencies should also leverage their own in-house knowledge and not rely solely on external consultants. Clear communication and collaboration between the agency and consultants are key to ensuring successful BIM integration.

Specific outcomes or successes that have resulted from the partnership with BIM advice consultants

Based on respondents' answers, partnering with BIM consultants has allowed the departments to know more about the national experience and obtain lessons learned from others, helping them develop a best-fit deliverable. In one case, they reported success in getting close to the goal of developing a program that started from ground zero to being able to deliver a complete digital project in five years. Other outcomes reported were having clear directions and goals and getting a greater understanding of what is happening internationally.

Obstacles faced and resolution of those obstacles in the process of BIM implementation

Based on the open-ended responses received, the main obstacles respondents have faced in BIM implementation include:

Resistance to change and adoption of new workflows: One DOT mentioned, "Change is hard for humans; developing new workflows and understanding the old ones don't work," indicating that transitioning to new digital tools and processes can be challenging for staff.

Lack of training and support for non-design staff: One respondent noted that "Staff outside of design did not have experience reviewing and consuming information in 3D models. Project-specific training was developed and provided to allow staff to consume the model information." This suggests a need for comprehensive training to enable all stakeholders to utilize BIM data effectively.

Interdepartmental issues and ownership conflicts: One respondent highlighted that "every discipline thinks they should own the process since they all have a piece of it" and the lack of resources to establish an oversight office, leading to collaboration challenges. Another agency also

mentions that "[e]veryone wants to control 'their' data," indicating territorial issues around data ownership.

Technological limitations and interoperability challenges: One respondent refers to "[p]latform differences, lack of data exchange standards," suggesting issues with software compatibility and data sharing across different systems and platforms.

Slow performance and technical glitches: One respondent noted "[m]odel viewer slow to load, saved views. Drone imagery didn't create shape file for comparison on Synchro," highlighting technical obstacles with BIM software and data integration.

Additional comments and remarks that might help in the process of implementation

The advice from the respondents' answers can be synthesized in the following points:

Engage stakeholders and foster communication: Coordinate with both the design and construction industry during the development of BIM pilot projects. This communication helps refine the deliverables and ensure they are consumable during construction.

Ensure that your department is capturing lessons learned for future improvements: Develop a digital vision for the department along with a roadmap for implementation to align different divisions and offices on an overall goal for digital processes and digital delivery.

Address change management and buy-in challenges: Recognize that staff may be experiencing "change fatigue" without a clear path to implementation, making it difficult to get buy-in.

Understand that the high buy-in cost and resource requirements can make it challenging for leadership to see the potential ROI (Return on Investment) and embrace future needs when their daily focus is on emergencies and current resource limitations.

Start with a phased approach and pilot projects: Many agencies are still working to develop processes and workflows to determine how to best implement BIM. Pilot projects can help understand the issues and potential resolutions as the agency works to develop its BIM implementation plan. For one agency, a 3D pilot project was helpful in refining the deliverables and ensuring they were consumable during construction.

Align with industry standards and best practices: BIM implementation should start with road standards that are accessible on any smartphone device, then evolve to corridor projects. The end goal of a Digital Twin can make organizations significantly more efficient.

Seek external expertise and guidance: One DOT's partnership with a BIM advisory consultant to develop a Digital Vision and implementation roadmap has been beneficial.

Acknowledge the varying levels of BIM adoption: Recognize that while some DOTs are still using older software like MicroStation v8i, there are very few full BIM adopters. Tailor the approach and expectations accordingly.

In addition to the responses obtained from different DOTs, nine Caltrans employees filled out the survey. The specific analysis of Caltrans responses is included in Appendix D.

Follow-up interviews' main insights

The interview insights are organized into three subsections: (1) Technology, Data Standards, and Common Data Environment (CDE); (2) Organizational Structure, Processes, and Workflows; and (3) People, Including Training and Change Management Strategies.

Technology, Data Standards, and Common Data Environment (CDE)

Interviewees from state DOTs emphasize the importance of adopting standardized data management practices, particularly ISO 19650. While some organizations are striving to align with these standards, they acknowledge their current immaturity in this area. Challenges related to data interoperability persist, necessitating collaboration with technology partners to create effective data exchanges. Information about the ISO standards related to BIM implementation is included in Appendix F: ISO Summary.

The integration of various software systems is crucial for effective data management. Organizations are working towards ensuring that different software can communicate effectively. The use of pilot projects serves as a testing ground for new technologies and workflows, allowing organizations to learn what works best before broader implementation. Additionally, the need for a data dictionary and effective data-sharing mechanisms is recognized as essential for improving data integration and usability.

Organizational Structure, Processes, and Workflows

A structured approach to BIM implementation is vital for success. Many organizations have established digital delivery teams and technical committees to facilitate collaboration and communication among stakeholders. Pilot projects allow for incremental testing of new processes, ensuring that lessons learned from previous projects inform future implementations.

Organizations also focus on integrating new technologies into existing workflows rather than overhauling them completely. This approach helps maintain continuity while adapting to new practices. Continuous improvement is emphasized, with organizations conducting gap analyses to identify areas for enhancement. The establishment of executive oversight and collaboration subcommittees ensures alignment with organizational goals and facilitates the sharing of best practices across functional areas.

People, Including Training and Change Management Strategies

The successful implementation of BIM requires a strong focus on workforce development and change management. Organizations face challenges transitioning from 2D to 3D workflows, necessitating significant workforce planning and development efforts. Engaging staff at all levels in the change management process is crucial for fostering a culture of collaboration and innovation.

Training and development programs are being created to equip staff with the necessary skills for BIM implementation. This includes providing just-in-time training and involving early adopters to help integrate new practices into current projects. Organizations recognize the importance of addressing change fatigue among staff and ensuring that communication is clear and consistent throughout the transition.

Moreover, collaboration with external partners, such as contractors and consultants, is essential for successful implementation. Engaging local stakeholders and educational institutions can further enhance the effectiveness of training initiatives and ensure that future professionals are prepared for the evolving landscape of digital delivery.

3.2.2 Utilities and Rail

The research team only received answers from the Los Angeles County Department of Water and Power (Utilities) and Union Pacific (Rail). Both reported that they do not use BIM.

3.2.3 Other US Agencies

Two other US agencies responded to the survey. One indicated that they have used BIM in one to ten projects and that they only use BIM in Buildings and the planning stage. They reported a level of implementation 1: transition from 2D to 3D for plan production and indicated that they use BIM in selected projects. Finally, they highlighted that they have not broadly adopted BIM as a process. The other agency did not report any information regarding the use of BIM.

3.3 Local Survey Analysis

Nine answers were received from local agencies. Of those, six reported that they do not use BIM. The three that used BIM indicated that they had used it in one to ten projects, including roads/highways, bridges, and underground construction. They reported using BIM in the design and construction stages, and each of these three agencies reported a different level of implementation, varying between 1 and 3.

4. Recommendations

Based on the survey and follow-up interview responses, the following recommendations are provided to organizations engaged in the process of implementing BIM for infrastructure projects:

4.1 Recommendations on the General Implementation Approach

Strategic Planning and Governance

#	Recommendations	Description
1	Start with a clear definition of BIM.	Ensure that all stakeholders understand BIM as a process, not just a tool. This clarity will help align expectations and objectives.
2	Create a roadmap with a clear mission, vision milestones, and objectives.	This helps track progress and ensure accountability throughout the implementation process.
3	Assess the complexity and scale of the project.	Determine if BIM is necessary based on the project's size, requirements, complexity, risk factors, and potential benefits.
4	Develop a phased approach to BIM implementation.	Start with pilot projects to test and refine processes before full-scale implementation. Pilot projects allow organizations to test workflows and identify challenges before full-scale implementation.
5	Evaluate the readiness of the organization and its stakeholders for BIM.	Ensure that all parties involved are prepared to adopt BIM practices.
6	Start with a clear understanding of the organization's current workflows and processes.	This helps identify how BIM can be integrated without causing major disruptions.
7	Focus on the benefits of BIM for different stakeholders.	Ensure all parties understand how BIM will improve their roles and responsibilities.
8	Utilize existing knowledge and experience from other sectors.	Leverage lessons from previous projects in different sectors to inform BIM implementation strategies.
9	Consider the long-term maintenance and operational needs of the project/Integrate BIM into Asset management.	Ensure that BIM is used not just for design and construction but also for future asset management.

Standardization, Training, and Implementation

#	Recommendations	Description
10	Establish clear standards and guidelines for BIM usage early on.	This can prevent confusion and misalignment later in the implementation process. Guidelines should outline processes, standards, and expectations for all stakeholders involved in the project.
11	Focus on data quality.	Prioritize the accuracy and integrity of data before moving to advanced modeling techniques.
12	Invest/engage in training and education for all staff involved.	Ensuring everyone is on the same page regarding BIM practices can facilitate smoother implementation.
13	Synchronize training with real tasks.	Align training sessions with actual project tasks to enhance learning and retention.
14	Establish clear requirements for BIM usage in contracts.	Establish clear requirements for BIM usage in contracts to ensure it is utilized as a communication tool throughout the project lifecycle.
15	Regularly update the BIM implementation strategy.	Regularly review and update the BIM implementation strategy based on feedback and lessons learned from ongoing projects.
16	Document lessons learned. Generate a feedback loop to improve continuously.	After each project, conduct debriefs to capture what worked and what didn't, which will inform future projects.

Collaboration and Communication within Caltrans

#	Recommendations	Description
17	Adopt the term "Digital Transformation," or a similar term, rather than BIM.	Respondents have found that the term BIM is inadequate for describing the effects and uses of this technology, especially when it is applied to transportation facilities and other horizontal infrastructure.
18	Recognize that BIM is part of a universe of digital transformation technologies that deserve to be coordinated across the Department.	BIM has overlapping features with Geographic Information Systems (GIS), and can build upon many prior Caltrans efforts including the Pavement Management System, Maintenance Management System, and Transportation System Network. These prior efforts were undertaken before the advent of BIM technology, but they developed location-based databases that seem to be adaptable for use within the rapidly developing BIM environment. This recommendation is consistent with the recommendation for using "Digital Transformation" as a catch-all term rather than isolating the various technologies.
19	Recognize that BIM/Digital Transformation is not confined to project development and construction, but that some of the greatest benefits from this technology, as it develops, seem likely to be found in areas such as maintenance and operations.	Transportation, by definition, is the movement of people and goods from one location to another. This means that almost all activities in transportation organizations are associated with specific locations or vectors. BIM and GIS build on location-based data and it seems that they have potential for use in almost all location and vector-related activities.
20	Encourage Collaboration/Communication Across Departments.	Foster interdepartmental collaboration/communication to ensure that all stakeholders understand and utilize BIM effectively.
21	Foster a culture of collaboration, communication, and openness to change.	Encourage open dialogue, trust, and collaboration among all stakeholders to address concerns and share insights.
22	Engage stakeholders early in the design process.	Engage stakeholders early in the design process using BIM models to facilitate better understanding and communication of project impacts.
23	Collaboration between transportation agencies and software vendors.	Establish a close collaboration between transportation agencies and software vendors from the outset to ensure that the software meets the agency's specific needs.
24	Engage with experienced consultants or firms.	Partnering with organizations that have a proven track record in BIM can provide valuable insights and support.
25	Importance of Key Personnel.	Recognize the critical role of key personnel in the success of BIM implementation and ensure their retention.
26	Create a glossary of terms.	Ensure all stakeholders are using the same language to avoid confusion and miscommunication.

Broader Collaboration and Communication

#	Recommendations	Description
27	Participate in national and international efforts to advance BIM technology.	Some agencies abroad participate in their countries' committees that review the BIM standards being developed by ISO. Caltrans could consider participating in the US TAG for ISO TC 59/SC 13 (see Appendix F: ISO Summary). If not Caltrans, then it would be advisable for AASHTO to participate because US transportation agencies have interests that differ from those of other US participants. It might also be advisable for Caltrans to become a member of BuildingSmart USA, the US association for BIM development. BuildingSmart USA has a Roads and Bridges Committee, which works closely with AASHTO.

4.2 Recommendations on BIM Implementation Plans

On Policies for Implementing BIM Processes

#	Recommendations	Description
28	Ensure top-down support.	Secure commitment and support from top management to drive the BIM initiative throughout the organization.
29	Establish clear policies and procedures for BIM usage, including resource allocation.	This includes defining roles, responsibilities, and workflows for all stakeholders involved. Resources include personnel, technology, and training.
30	Ensure that policies are flexible enough. Create living documents.	To adapt to the evolving nature of BIM technology and practices.
31	Incorporate feedback mechanisms to continuously improve BIM processes.	Regularly review and update policies based on lessons learned from ongoing projects.

On Ownership of BIM Implementation Plans

#	Recommendations	Description
32	Designate a dedicated BIM management team/person (or Central BIM team).	Establish a central team responsible for overseeing the implementation and ensuring adherence to standards (Governance structure).
33	Involve cross-functional teams in the planning process.	This ensures that all perspectives are considered, and that the implementation plan is comprehensive.
34	Ensure that the owning department has the necessary resources and authority.	To drive the BIM implementation process.

On Key Information to include in BIM Implementation Plans

#	Recommendations	Description
35	Define roles, responsibilities, and expectations for all stakeholders.	This ensures accountability and clarity in the implementation process.
36	Establish metrics for success and evaluation associated with maturity levels and goals.	This helps assess the effectiveness of BIM implementation and make necessary adjustments.
37	Include detailed information on data management.	Ensure that the BIM execution plans include detailed information on data management, including data standards and interoperability requirements.
38	Regularly review and update Bim implementation/execution plans. Establish feedback mechanisms.	Regularly review and update the BIM execution plan to reflect changes in project scope or stakeholder needs.
39	Include detailed workflows and processes for BIM usage.	Clearly outline how BIM will be integrated into existing workflows.
40	Outline training and support resources.	Provide information on available training and support for staff involved in BIM processes.
41	Include practical examples in plain language.	Include practical examples and plain language requirements in the BIM execution plan to ensure clarity and understanding among all stakeholders.

On Supporting Structures to Implement BIM

#	Recommendations	Description
42	Incorporate BIM in the organization's strategic planning.	Ensure that BIM implementation is included in the organization's strategic plan to highlight its importance.
43	Establish a BIM Support Group/Digital delivery team/BIM committee.	Create a dedicated group comprising BIM leads (From different departments) and IT support to oversee implementation practices and address challenges.
44	Designate BIM champions in each department.	Designate BIM champions within each department to facilitate communication and support the adoption of BIM practices.
45	Encourage collaboration between departments and create cross-functional teams.	This fosters a culture of teamwork and shared responsibility for BIM implementation.
46	Invest in ongoing professional development, training, and resources for staff (new and existing).	Allocate sufficient resources for training and technology to support the transition to BIM. This helps to keep skills current and relevant in a rapidly evolving field.
47	Facilitate regular training sessions.	Organize ongoing training and workshops to keep staff updated on BIM practices and tools.
48	Promote existing staff who demonstrate proficiency in BIM/Leverage existing staff expertise.	To leadership roles within the implementation team.
49	Hire personnel with expertise in BIM and related technologies.	This ensures that the organization has the necessary knowledge and skills for successful implementation.
50	Consider hiring consultants for specialized knowledge.	This can provide additional support and expertise during the implementation process.
51	Create a BIM-related materials repository.	Create a centralized resource hub for BIM-related materials, including manuals, training videos, and best practices.
52	Collaborate with educational institutions.	to develop training programs that prepare new graduates for BIM roles in the organization.
53	Regularly assess staffing needs and adjust hiring strategies.	Based on the evolving requirements of the BIM implementation process.
54	Assess the effectiveness of BIM support structures.	Regularly assess the effectiveness of BIM support structures and make adjustments as needed to enhance user experience.

4.3 Recommendations on Technology

On Data Standards

#	Standard Implementation recommendations	Description
55	Evaluate and adopt relevant ISO standards for BIM implementation as a guiding framework.	This ensures consistency and quality across projects.
56	Develop internal standards that align with industry best practices.	This helps to ensure that the organization is following the most effective processes. Standards tailored to the organization's needs while aligned with broader industry standards.
57	Regularly review and update standards based on feedback and lessons learned (using a structured approach).	This ensures that the organization remains agile and responsive to changes in the industry.
58	Create a central repository for standards.	Establish a central repository where all BIM standards and guidelines can be easily accessed by staff.
59	Communicate standards clearly.	Ensure that all staff are aware of and understand the standards being implemented for BIM.
60	Develop a data dictionary.	Create a comprehensive data dictionary that outlines naming conventions and data standards to ensure consistency across departments.
61	Provide comprehensive training on standards to all relevant staff.	This ensures that everyone understands the importance of adhering to standards. It also ensures consistency and understanding across the organization.
62	Encourage collaboration between departments to ensure alignment with standards.	This fosters a culture of teamwork and shared responsibility for compliance.
63	Establish a monitoring system to ensure compliance with standards.	This helps to identify areas for improvement and ensure accountability.
64	Encourage feedback on standards.	Solicit feedback from staff on the effectiveness of standards to identify areas for improvement.
65	Implement standards initially on pilot projects.	To test their effectiveness before wider application.

#	Standard Implementation recommendations	Description
66	Create a transition plan.	To guide departments in adopting new standards and processes.
67	Designate a specific team or individual responsible for maintaining and updating data standards.	This ensures accountability and clarity when maintaining standards. It also ensures to keep pace with technological advancements and industry best practices.
68	Encourage cross-departmental collaboration in maintaining standards (IT, design team).	This ensures that all perspectives are considered and that standards remain relevant.
69	Regularly review and update standards based on industry developments.	This ensures that the organization remains current and competitive.
70	Communicate updates to all staff promptly.	To ensure everyone is aware of changes and their implications.

On Common Data Environment

	Recommendation	Description
71	Ensure that the CDE is user-friendly and accessible to all relevant staff.	This encourages adoption and effective use of the system.
72	Ensure CDE integration/compatibility.	Ensure that the CDE is integrated with existing software tools to streamline data sharing and collaboration.
73	Establish clear protocols for data entry and management.	Establish clear protocols for data management and document control within the CDE to maintain organization and accessibility.
74	Provide training on the chosen CDE software to all relevant staff.	This ensures that everyone is equipped to use the software effectively. All users need to know how to utilize the CDE for their specific roles effectively.
75	Regularly review and update software to ensure it meets the organization's needs, functionality, and user experience.	This helps to maintain efficiency and effectiveness in data management.
76	Provide training on using different design tools and their integration with the CDE.	This ensures that staff are knowledgeable about the entire process.
77	Standardize Design Tools.	Encourage the use of standardized design tools that are compatible with the CDE to facilitate smoother data transfer.

4.4 Recommendations on Processes

Workflows

#	Recommendations	Description
78	Assess existing workflows to identify areas for improvement and potential technology integration.	This helps to ensure that the implementation process is efficient and effective.
79	Involve staff in the workflow design process to ensure buy-in and acceptance.	This fosters a sense of ownership and accountability among team members.
80	Develop new workflows that integrate BIM processes and tools.	To enhance efficiency and collaboration.
81	Regularly review and update workflows based on feedback and lessons learned.	This ensures that the organization remains agile and responsive to changes.
82	Provide training in new workflows.	Provide training on new workflows to ensure that all team members are equipped to implement them effectively.

2D-3D Use

#	Recommendations	Description
83	Use 2D drawings for regulatory approvals/regulatory compliance.	Use 2D drawings for regulatory approvals and permits while transitioning to a fully 3D BIM approach for project execution.
84	Provide 2D drawings as contractual documents while transitioning.	Ensure that 2D drawings are available as contractual documents for clarity and compliance.
85	Educate Stakeholders on 3D benefits.	Educate stakeholders on the benefits of 3D models to encourage their use in project discussions and approvals.

#	Recommendations	Description
86	Integrate asset management processes with 3D project information models.	This ensures that all information is current and relevant for future maintenance and operations. Including data standardization.
87	Develop a strategy for 3D information use.	Create a clear strategy for how 3D information will be utilized post-project (maintenance and operations) to maximize its value.
88	Encourage collaboration between design, construction, and maintenance teams.	This fosters a culture of teamwork and shared responsibility for asset management.
89	Engage asset management teams early in the BIM process.	To ensure that 3D information is integrated into asset management systems.

4.5 Recommendations on People and Change Management

On Training

#	Recommendations	Description
90	Develop a comprehensive training program for all staff.	This ensures that everyone is knowledgeable about BIM practices and tools.
91	Utilize/Encourage the use of external training resources and workshop.	To supplement internal training efforts.
92	Encourage staff to share knowledge and best practices with one another.	This fosters a culture of continuous learning and improvement.
93	Utilize a mix of training formats.	Offer a combination of online training, workshops, and face-to-face sessions to accommodate different learning preferences.
94	Utilize Experienced trainers.	Engage experienced trainers to deliver training sessions and workshops on BIM tools and processes.
95	Utilize hands-on training methods.	Provide practical training sessions that allow staff to work with real projects and tools.

On Change from Silos-mindset to Common Data Environment Mindset

#	Recommendations	Description
96	Foster a culture of collaboration & Knowledge sharing and communication among departments.	This encourages teamwork and shared responsibility for BIM implementation.
97	Provide training on the benefits of a common data environment.	This helps to ensure that all staff understand the importance of collaboration and data sharing.
98	Develop a mentorship program/Encourage peer support network.	Develop a mentorship program to support less experienced staff in their BIM training and development. Foster a culture of peer learning where staff can share knowledge and experiences related to BIM implementation.

On Managing Organizational Change

#	Recommendations	Description
99	Engage leadership in the change process.	Involve senior management in promoting the benefits of BIM implementation to encourage buy-in from all staff.
100	Develop a change management plan to guide the implementation process.	This helps to ensure that all stakeholders are informed and engaged in the transition. Focus the change management on the cultural shift required within the organization.
101	Involve staff and key stakeholders in the transition process.	Involve staff in the transition process to gather input and address concerns related to the shift in mindset. Staff involved in the decision-making process might increase buy-in and ownership.
102	Provide training and support to help staff navigate the changes.	This ensures that everyone is equipped to handle potential challenges.

Appendix A: Literature Review. Main Articles

Article title	Authors
Understanding barriers to BIM implementation: Their impact across organizational levels in relation to BIM maturity	(Siebelink et al., 2021)
The role of the industry's cultural-cognitive elements on actors' intention to adopt BIM: an empirical study in Peru	(Murguia et al., 2023)
The implementation of geotechnical data into the BIM Process	(Tawelian & Mickovski, 2016)
The implementation of Building Information Modelling in the United Kingdom by the transport industry	(Blanco & Chen, 2014)
Leveraging micro-level Building Information Modeling for managing sustainable design: United Kingdom experience	(Liu et al., 2020)
Information modeling in the context of highways property complex management	(Kostesha et al., 2021)
Exploring the impact of information and communication technology on team social capital and construction project performance	(Huang et al., 2020)
Exploiting digitalization for the coordination of required changes to improve engineer-to-order materials flow management	(Q. Chen et al., 2022)
Digital twin enhanced BIM to shape full life cycle digital transformation for bridge engineering	(Honghong et al., 2023)
Digital twin and its implementations in the civil engineering sector	(Jiang et al., 2021)
Development and application of a specification-compliant highway tunnel facility management system based on BIM	(L. Chen et al., 2020)
Design and implementation of bridge information management system based on BIM	(D. Chen et al., 2022)
Defining a digital strategy in a BIM environment to manage existing reinforced concrete bridges in the context of Italian regulation	(Ciccone et al., 2022)
Building Information Modeling (BIM) practices in highway infrastructure	(Mallela, Jan et al., 2021)
Bridging the gap: bringing BIM to construction workers	(Bråthen & Moum, 2016)
Analytical review and evaluation of civil information modeling	(Cheng et al., 2016)
ADOT digital delivery program guidance document	(HDR, 2023)
Utilization of building information modeling in infrastructure's design and construction	(Zak & Macadam, 2017)
Stakeholder competency in evaluating the environmental impacts of infrastructure projects using BIM	(Murphy & Nahod, 2017)
Road map to BIM use for infrastructure domains: Identifying and contextualizing variables of infrastructure projects	(Ghasemzadeh et al., 2022)
Contract obligations and award criteria in public tenders for the case study of ANAS BIM implementation	(Semeraro et al., 2018)
Case study of building information modeling implementation in infrastructure projects	(Guo et al., n.d.)

Article title	Authors
Building Information Modeling in Quebec's procurement for public infrastructure: A case for integrated project delivery	(Jobidon et al., 2021)
Bridging the life cycle: a case study on facility management infrastructures and uses of BIM	(Miettinen et al., 2018)
BIM in the construction process – selected problems at the stage of implementation in Polish road engineering	(Juszczyk, 2022)
BIM implementation throughout the UK construction project lifecycle: An analysis	(Eadie et al., 2013)
BIM for infrastructure: An overall review and constructor perspective	(Bradley et al., 2016)
BIM compatibility and its differentiation with interoperability challenges as an innovation factor	(Shirowzhan et al., 2020)
An institutional approach to digitalization in sustainability-oriented infrastructure projects: The limits of the Building Information Model	(Hetemi et al., 2020)
Aligning building information model tools and construction management methods	(Hartmann et al., 2012)

A.1 Questionnaire questions for Caltrans Review 1—03222024

<Caltrans logo> <MIT/CSU San Jose, Long Beach Fresno Logo>

BIM FOR INFRASTRUCTURE (BIM4I)
BIM4I Implementation Questionnaire
Sharing Best Practices and Lessons Learned

Survey Questions

1. GENERAL INFORMATION

1. Full name:
   Title or role in your organization: [List of Targeted Potential Roles + Other]
   Email:
   Telephone:
   In what country and region are you currently employed:
   - Country [Pick List of Countries + Other Option]
   - State, Province, or Region

2. Name of your organization:
   What type of organization is this:
   - Government Agency,
   - Private Firm,
   - Academia
   - Other [Indicate]

3. Years of experience in BIM implementation in infrastructure projects:
   - 0-2
   - 2-5
   - 5-10
   - >10

4. Approximate number or infrastructure projects project that, to your knowledge, your organization has developed or is developing using BIM:
   - 1-10
   - 11-20
   - 21-30
   - 31-40
   - 41-50
   - ≥ 50

5. Types of infrastructure projects on which your organization has applied BIM *[multiple answers]*
   - Roads/Highways
   - Structures
   - Tunnels
   - Underground construction
   - Other: [indicate]

6. Phases of the project where you have been involved in BIM *[multiple answers]*
   - Conception (Planning)
   - Design
   - Construction
   - Operation

<Caltrans logo> <MIT/CSU San Jose, Long Beach Fresno Logo>

2. BIM IMPLEMENTATION

Organizational, Information Technology (IT) infrastructure and data standards

In your organization:

7. Is the design of infrastructure done in-house, by your own employees? *[yes/no/no apply]*
8. Is the IT infrastructure in-house, managed by your own employees rather than by an external contractor? *[yes/ no/partially/no apply]*
9. If in the previous question the answer is "partially", please indicate what components are contracted out. *[text question]*
10. How the IT infrastructure is organized and supported. *[multiple choice +other OR text question]*
11. How IT needs are prioritized. *[text question]*
12. What data standards are you using? *[add choices]*
    - ISO
    - SmartBIM
    - XXX
    - Other
13. How the data are storage? *[add choices]*
    - Single point
    - Cloud based with server in the US
    - Cloud based with server outside the US
    - XXX
    - Other

Communications

If your organization does not own the transportation facility (road, rail, etc.) please skip this section]. ***Will Have SKIP function in the Qualtrics survey.***

As the owner of a transportation facility on which BIM is used in project design, construction or operations:

14. What tools do you use to communicate project information with **environmental review agencies**? *[text question]*
15. In your case, do the **environmental review agencies** need training? *[Yes/No]*
16. Do contractors participate in the development of digital delivery to environmental review agencies? *[text question]*

Use of technology partners

In your organization

17. What technology partners have you worked with in BIM4I implementation?
    [provide option to add several technology partners, each one with all these fields]
    - Company Name:
    - Contact Name
    - Contact email/telephone

<Caltrans logo> <MIT/CSU San Jose, Long Beach Fresno Logo>

- Scope of work required/assigned:
- Tools used/what department used them

18. Are the partnerships working today? *[Text question]*

Use of consultants

In your organization, for the process of BIM4I implementation

19. Did you use consultants to advise you in BIM implementation? *[Yes/No]*
20. If yes, please, indicate which consultants you worked with:
[provide option to add consultants, each one with all these fields]
- Company Name:
- Contact Name
- Contact email/telephone.
- Scope of work required/assigned:
- Tools used/what department used them

3. LESSONS LEARNED

As an owner using BIM4I in design, construction of infrastructure projects, please *[Skip if not owner]*

21. Provide lessons learned on organizational and/or IT structure. *[text question]*
22. Provide lessons learned about how to manage communications with environmental agencies and other stakeholders. *[text question]*
23. Provide lessons learned on the use of technology partners *[text question]*
24. Provide lessons learned on the use of consultants *[text question]*

As a professional involved in BIM4I in design, construction of infrastructure projects, please.

25. Provide lessons learned about obstacles you faced and the resolution of those obstacles in the process of BIM4I implementation *[text question]*

4. GENERAL COMMENTS AND REMARKS

26. Please, provide any additional comments and remarks on the topics addressed in the survey that might help in the process of BIM for infrastructures implementation.

Essay Text

Thank you for taking the survey.

A.2 Draft Questionnaire for Caltrans Review 2—040524

BIM FOR INFRASTRUCTURE (BIM4I)
BIM4I Implementation Questionnaire
Sharing Best Practices and Lessons Learned
Survey Questions

1. GENERAL INFORMATION

1. Full name:
   Title or role in your organization: *[List of Targeted Potential Roles + Other]*
   Email:
   Telephone:
   In what country and region are you currently employed:
   - Country *[Pick List of Countries + Other Option]*
   - State, Province, or Region

2. Name of your organization:
   What type of organization is this:
   - Government Agency,
   - Private Firm,
   - Academia
   - Other [Indicate]

~~3. Your organization years of experience in BIM implementation in infrastructure projects:~~
   ~~0-2~~
   ~~2-5~~
   ~~5-10~~
   ~~>10~~

4. Approximate number of infrastructure projects that, to your knowledge, your organization has developed or is developing using BIM:
   - 1-10
   - 11-20
   - 21-30
   - 31-40
   - 41-50
   - ≥ 50

5. Types of infrastructure projects that your organization has applied BIM *[multiple answers]*
   - Roads/Highways
   - Rails
   - Bridges
   - Buildings
   - Tunnels
   - Underground construction
   - Other: [indicate]

6. Phases of the project where you have been involved in BIM *[multiple answers]*
   - Planning
   - Design

- Construction¶
- Maintenance and Operations¶

¶

7. What groups/divisions from within your organization have involvement in the BIM Process? *[multiple answers]*¶
   - Design¶
   - Construction¶
   - Right of Way¶
   - Surveys¶
   - Structures¶
   - Environmental¶
   - Utilities¶
   - Encroachment Permit¶
   - Asset Management¶
   - Maintenance¶
   - Traffic Operations¶
   - Data Governance¶
   - Innovation¶
   - Safety¶
   - Aeronautics¶
   - Accounting¶
   - Budgets¶
   - Financial Programming¶
   - Transportation Planning¶
   - Modal Programs¶
   - Pavement Engineering¶
   - Drainage/Culverts¶
   - IT¶
   - External Affairs¶
   - Risk and Strategic Management¶
   - Procurement/Contracts¶
   - Legal¶
   - Equipment¶
   - Local Assistance¶
   - Other¶

8. Of the divisions you checked in the previous question, who has been the lead in your organization for implementing BIM? *[Provide dropdown menu with same options as questions 7]*¶

9. ¶

10. Who is the owner of the data (Data Steward)? *[Provide dropdown menu with same options as questions 7]*¶

¶

2. BIM IMPLEMENTATION¤

¶

Organizational, Information Technology (IT) infrastructure¶

¶

In your organization:¶

¶

11. Is the design of infrastructure done in-house? *[yes/no/no apply]*¶

12. Is the IT infrastructure in-house, rather than by an external contractor? *[yes/no/partially/no apply]*¶

13. If in the previous question the answer is "partially", please indicate what components are contracted out. *[text question]*

14. If in question 11 the answer is "yes", please indicate what group in the organization manages the IT infrastructure *[Multiple choice]*.
    - IT
    - Group within the BIM team
    - Other (please specify)

15. ~~How is the IT infrastructure organized and supported? *[multiple choice +other OR text question]*~~

16. ~~How are IT needs are prioritized.~~ *[text question]*

Data standards and workflows

17. What data standards are you using? *[multiple answers]*
    - ISO 19650
    - ISO 16739
    - ISO 12006
    - SmartBIM
    - None
    - XXX
    - Other

18. Has the Organization used open data standards such as IFC, DIGGS, etc.? *[Yes/No]*

19. What software does your organization use for Common Data Environment when sharing information with others? *[Multiple Answers]*
    - Autodesk BIM 360
    - Trimble Connect
    - Trimble Quadri
    - Bentley Projectwise
    - Allplan Bimplus
    - OceanBIM
    - Other (Indicate)

20. How are the data stored? *[multiple choice]*
    - Single point
    - Cloud based with server in your country
    - Cloud based with server outside your country
    - Inside your Firewall
    - XXX
    - Other

21. In the process of BIM implementation, please select the option that best apply to your agency/organization *[Multiple choice]*
    - My organization have developed new project delivery workflows incorporating BIM.
    - My organization is still using old workflows and trying to fit in technologies from BIM.

- → Other (Please, elaborate)¶

¶

3D model use¶

¶

22. Has the Organization used 3D model as a legal document? *[Yes/No]*¶

23. Has the organization used 3D model for asset management/maintenance *[Yes/No]*¶

¶

¶

Communications ¶

¶

If your organization does not own the transportation facility (road, rail, etc.) please skip this section]. ***Will Have SKIP function in the Qualtrics survey.***¶

¶

As the owner of a transportation facility on which BIM is used in project design, construction or operations:¶

¶

24. What tools do you use with **environmental review agencies, utilities, or other reviewing/permitting agencies** to communicate project information?¶

- → Design¶
  - → Autodesk Civil 3D¶
  - → Autodesk BIM 360¶
  - → Autodesk Navisworks¶
  - → Autodesk Infraworks¶
  - → Bentley Open Roads CE¶
  - → Bentley PowerGeopak¶
  - → Bentley ITwin¶
  - → Bentley Navigator¶
  - → Bentley LumenRT¶
  - → Trimble Connect¶
  - → Trimble Quadri¶
  - → Trimble Prospect¶
  - → Other (please, specify)¶
- → Construction, Maintenance, Operation¶
  - → Acrobat reader¶
  - → Bluebeam revu¶
  - → Kofax PowerPDF¶
  - → Trimble Connect¶
  - → Topcon Magnet¶
  - → Carlson Construct¶
  - → Google Earth¶
  - → Esri ArcGIS¶
  - → AutoCAD Map 3D¶
  - → Bentley Opencities MAP¶
  - → Other (please, specify)¶

25. In your case, do the **environmental review agencies, utilities, or other reviewing/permitting agencies** need training? *[Yes/No]*¶

26. Do private design firms ~~contractors~~ participate in the development of digital delivery to environmental review agencies ? *[yes/no]*¶

27. Has your agency submitted any Industry Foundation Classes (IFC) or shared any model via Common Data Environment (CDE) with the Environmental review agencies? *[Yes/No]*

In the review process with permitting agencies using a 3D model:

28. Have these agencies requested additional information to be included in the model? *[Yes/No]*
29. If the previous question is "yes", what kind of information was requested to be included in the model? *[Essay type]*
30. Does the review process require additional iterations as compared to the traditional 2D process? *[Yes/No]*

Use of technology partners

In your organization

31. What technology partners have you worked with in BIM4I implementation?
[provide option to add several technology partners, each one with all these fields]
    - Company Name[Autodesk, Bentley, Trimble, other(specify)
    - Contact Name
    - Contact email/telephone
    - Products used [Autodesk-Infraworks, Autodesk-civil 3D, Bentley-openrail, Bentley-roads, Bentley-site, Bentley-bridge, Bentley-openflows, other (specify)
    - Scope of work required/assigned:
    - Tools used/what department used them

~~Are the partnerships working today? *[Text question]*~~

Use of consultants

In your organization, for the process of BIM4I implementation

32. Did you use consultants to advise you in BIM implementation? *[Yes/No]*
33. If yes, please, indicate which consultants you worked with:
[provide option to add consultants, each one with all these fields]
For each consultant:
    A. General information
        - Company Name:
        - Contact Name
        - Contact email/telephone.
        - Scope of work required/assigned:
        - Tools used/what department used them

    - B. Is the company currently active and contributing to your projects? *[Yes/No]*

- → C. How would you rate the effectiveness of the company in achieving your BIM4I objectives *[Likert Scale 1-5]*¶

¶
¶
¶
¶

Training & implementation processes¶

¶

34. Have you implemented a training program and/or staff development plan for BIM4I implementation? *[Yes/No]*¶

35. If the answer to the previous question is "Yes", who has implemented it? *[Multiple choice]*¶

- → Through consultants¶
- → Develop internal training/manuals.¶
- → Hybrid (combination of consultant and internal)¶
- → Other (Please, elaborate)¶

36. Does your organization have a BIM implementation plan? *[Yes/No]*¶

¶
¶

¶

3. LESSONS LEARNED

¶

As an owner using BIM4I in design, construction of infrastructure projects, please *~~[Skip if not owner]~~*¶

¶

37. Provide lessons learned on organizational and/or IT structure. *[text question]*¶

38. Provide lessons learned about how to manage communications with environmental agencies and other stakeholders. *[text question]*¶

39. Provide lessons learned on the integration of software technology partners *[text question]*¶

34.1 → What improvements you would like to see in your partnerships with technology vendors?" *[text question]*¶

¶

- → ¶

40. Provide lessons learned on the integration of BIM4I advice consultants *[text question]*¶

35.1 Can you share specific outcomes or successes that have resulted from the partnership?¶

¶

As a professional involved in BIM4I infrastructure projects, please.¶

¶

41. Provide lessons learned about obstacles you faced and the resolution of those obstacles in the process of BIM4I implementation during the planning, design, construction, and operation phases. *[text question]*¶

¶

4. GENERAL COMMENTS AND REMARKS¶

¶

42. Please, provide any additional comments and remarks on the topics addressed in the survey that might help in the process of BIM for infrastructures implementation.¶

¶

Essay Text [Allow attachments]¶

¶

Caltrans:·General·comment:¶

- ⇒ This·is·a·very·high-level·survey·with·very·broad,·open-ended·questions·that·require·very·qualitative,·essay-type·responses.·¶

¶

MTI·team:·Yes,·usually·essay-type·responses·have·the·ability·to·gather·richer·information·about·a·topic.·The·MTI·team·is·open·to·creating·or·re-formulating·questions·in·an·open-choice·format·in·coordination·with·Caltrans.¶

¶

- ⇒ Will·the·MTI·team·follow-up·with·an·interview·and·steer·the·discussion·to·produce·information·most·relevant·for·Caltrans?¶

¶

MTI·Team:·Yes,·the·task·order·includes·follow-up·interviews·with·selected·respondents·based·on·the·survey·results·(Task·9).¶

¶

- ⇒ Will·the·survey·be·sent·to·the·organization/consultants'·BIM·Program·managers·with·a·broad·perspective·of·BIM·implementation·in·the·whole·organization?·The·long·responses·to·the·survey·questions·may·not·work·well·for·them.¶

¶

MTI·Team:·The·list·of·target·agencies·will·be·agreed·and·approved·by·Caltrans·and·might·or·might·not·include·BIM·program·managers.¶

¶

Caltrans:·Additional·questions:¶

¶

MIT·Team:·Included·in·this·Questionnaire·draft·(version·040124)—in·blue¶

¶

- ⇒ Has·the·Organization·used·open·data·standards·such·as·IFC,·DIGGS,·etc.?¶

¶

MTI·team:·we·have·incorporated·this·question·in·sub-section·*Data·Standards·&·Workflows*:·Question·17¶

¶

- ⇒ Has·the·Organization·used·model·as·a·legal·document?¶

¶

MTI·team:·we·have·incorporated·this·question·in·sub-section·*3D·model·use*:·Question·21¶

¶

- ⇒ Add·question·about·Digital·As-Builts·for·Asset·management·/·maintenance¶

¶

MTI·team:·we·have·incorporated·this·question·in·sub-section·*3D·model·use*:·Question·22¶

¶

- ⇒ The·survey·mentions·environmental·review·agencies.·This·may·be·a·bit·narrow.·We·are·also·interested·in·railroad·agencies,·public·transportation,·city/county·among·other·interfacing·stakeholders·/·regulatory·agencies·as·well·as·public·outreach.¶

¶

MTI·team:·we·have·incorporated·this·question·in·sub-section·*Communications*:·Questions·23·&·24¶

¶

- How do they implement a training program and/or staff development plan for BIM, through consultants, develop internal training manuals, or hybrid?

MTI team: we have incorporated this question in sub-section *Training*: Questions 33 & 34

- Do they develop new project delivery workflows incorporating BIM, or still using old workflow and try to fit in technologies from BIM?

MTI team: we have incorporated this question in sub-section *Data Standards and workflows*: Question 20

- What software the organization used for CDE (Common Data Environment) when sharing information with others?

MTI team: we have incorporated this question in sub-section *Data Standards and Workflows*: Question 18

- Consider asking: Does your organization have a BIM implementation plan? Are you willing to share it?

MTI team: we have incorporated this question in sub-section *Training and Implementation Processes*: Question 35

Thank you for taking the survey.

A.3 Draft Questionnaire for Caltrans Review 3—04192024

BIM FOR INFRASTRUCTURE (BIM4I)
BIM4I Implementation Questionnaire
Sharing Best Practices and Lessons Learned

Survey Questions

1. GENERAL INFORMATION

1. Full name:
Title or role in your organization: *[List of Targeted Potential Roles + Other]*
Email:
Telephone:
In what country and region are you currently employed:
- Country *[Pick List of Countries + Other Option]*
- State, Province, or Region

2. Name of your organization:
What type of organization is this:
- Government Agency,
- Private Firm,
- Academia
- Other [Indicate]

~~**3.** Your organization years of experience in BIM implementation in infrastructure projects:~~
- ~~0-2~~
- ~~2-5~~
- ~~5-10~~
- ~~>10~~

4. Approximate number of infrastructure projects that, to your knowledge, your organization has developed or is developing using BIM:
- 1-10
- 11-20
- 21-30
- 31-40
- 41-50
- >50

5. Types of infrastructure projects that your organization has applied BIM *[multiple answers]*
- Roads/Highways
- Rails
- Bridges
- Buildings
- Tunnels
- Underground construction
- Other: [indicate]

6. Phases of the project where you have been involved in BIM *[multiple answers]*
- Planning
- Design

- Construction¶
- Maintenance·and·Operations¶

¶

7. What groups/divisions from within your organization have involvement in the BIM Process? *[multiple answers]*¶
   - Design¶
   - Construction¶
   - Right·of·Way¶
   - Surveys¶
   - Structures¶
   - Environmental¶
   - Utilities¶
   - Encroachment·Permit¶
   - Asset·Management¶
   - Maintenance¶
   - Traffic·Operations¶
   - Data·Governance¶
   - Innovation¶
   - Safety¶
   - Aeronautics¶
   - Accounting¶
   - Budgets¶
   - Financial·Programming¶
   - Transportation·Planning¶
   - Modal·Programs¶
   - Pavement·Engineering¶
   - Drainage/Culverts¶
   - IT¶
   - External·Affairs¶
   - Risk·and·Strategic·Management¶
   - Procurement/Contracts¶
   - Legal¶
   - Equipment¶
   - Local·Assistance¶
   - Other¶

8. Of the divisions you checked in the previous question, who has been the lead in your organization for implementing BIM? *[Provide dropdown menu with same options as questions 7]*¶

9. ¶

10. Who is the owner of the data (Data Steward)? *[Provide dropdown menu with same options as questions 7]*¶

¶

2. BIM IMPLEMENTATION

¶

Organizational, Information Technology (IT) infrastructure¶

¶

In your organization:¶

¶

11. Is the design of infrastructure done in-house? *[yes/no/no apply]*¶
12. Is the IT infrastructure in-house, rather than by an external contractor? *[yes/no/partially/no apply]*¶

13. If in the previous question the answer is "partially", please indicate what components are contracted out. *[text question]*

14. If in question 11 the answer is "yes", please indicate what group in the organization manages the IT infrastructure *[Multiple choice].*
    - IT
    - Group within the BIM team
    - Other (please specify)

~~15. How is the IT infrastructure organized and supported? *[multiple choice +other OR text question]*~~

16. ~~How are IT needs are prioritized.~~ *[text question]*

Data standards and workflows

17. What data standards are you using? *[multiple answers]*
    - ISO 19650
    - ISO 16739
    - ISO 12006
    - ISO 9001
    - ISO 7817
    - ISO 23387
    - SmartBIM
    - None
    - XXX
    - Other

18. Has the Organization used open data standards such as IFC, DIGGS, etc.? *[Yes/No]*

19. What software does your organization use for Common Data Environment when sharing information with others? *[Multiple Answers]*
    - Autodesk BIM 360
    - Trimble Connect
    - Trimble Quadri
    - Bentley Projectwise
    - Allplan Bimplus
    - OceanBIM
    - Other (Indicate)

20. How are the data stored? *[multiple choice]*
    - Single point
    - Cloud based with server in your country
    - Cloud based with server outside your country
    - Inside your Firewall
    - XXX
    - Other

21. In the process of BIM implementation , please select the option that best apply to your agency/organization *[Multiple choice]*

- My organization have developed new project delivery workflows incorporating BIM.
- My organization is still using old workflows and trying to fit in technologies from BIM.
- Other (Please, elaborate)

3D model use

22. Has the Organization used 3D model as a legal document? *[Yes/No]*
23. Has the organization used 3D model for asset management/maintenance *[Yes/No]*

Communications

If your organization does not own the transportation facility (road, rail, etc.) please skip this section]. ***Will Have SKIP function in the Qualtrics survey.***

As the owner of a transportation facility on which BIM is used in project design, construction or operations:

24. What tools do you use with **environmental review agencies, utilities, or other reviewing/permitting agencies** to communicate project information?

- Design
  - Autodesk Civil 3D
  - Autodesk BIM 360
  - Autodesk Navisworks
  - Autodesk Infraworks
  - Bentley Open Roads CE
  - Bentley PowerGeopak
  - Bentley ITwin
  - Bentley Navigator
  - Bentley LumenRT
  - Trimble Connect
  - Trimble Quadri
  - Trimble Prospect
  - Other (please, specify)
- Construction, Maintenance, Operation
  - Acrobat reader
  - Bluebeam revu
  - Kofax PowerPDF
  - Trimble Connect
  - Topcon Magnet
  - Carlson Construct
  - Google Earth
  - Esri ArcGIS
  - AutoCAD Map 3D
  - Bentley Opencities MAP
  - Other (please, specify)

25. In your case, do the environmental review agencies, utilities, or other reviewing/permitting agencies need training? *[Yes/No]*

26. Do private design/consulting firms ~~contractors~~ participate in the development of digital delivery to environmental review agencies ? *[yes/no]*

27. Has your agency submitted any Industry Foundation Classes (IFC) or shared any model via Common Data Environment (CDE) with the Environmental review agencies? *[Yes/No]*

In the review process with permitting agencies using a 3D model:

28. Have these agencies requested additional information to be included in the model? *[Yes/No]*

29. If the previous question is "yes", what kind of information was requested to be included in the model? *[Essay type]*

30. Does the review process require additional iterations as compared to the traditional 2D process? *[Yes/No]*

Use of technology partners

In your organization

31. What technology partners have you worked with in BIM4I implementation?

[provide option to add several technology partners, each one with all these fields]

- Company Name[Autodesk, Bentley, Trimble, other(specify)
- Contact Name
- Contact email/telephone
- Products used [Autodesk Infraworks, Autodesk civil 3D, Bentley opencivil, Bentley-roads, Bentley-site, Bentley-bridge, Bentley openflows, other (specify)
- Scope of work required/assigned:
- Tools used/what department used them

~~Are the partnerships working today? *[Text question]*~~

Use of consultants

In your organization, for the process of BIM4I implementation

32. Did you use consultants to advise you in BIM implementation? *[Yes/No]*

33. If yes, please, indicate which consultants you worked with:

[provide option to add consultants, each one with all these fields]

For each consultant:

A. General information

- Company Name:
- Contact Name
- Contact email/telephone.
- Scope of work required/assigned: .

- ⇒ Tools used/what department used them

- ⇒ B. Is the company currently active and contributing to your projects? *[Yes/No]*
- ⇒ C. How would you rate the effectiveness of the company in achieving your BIM4I objectives *[Likert Scale 1-5]*

Training & implementation processes

34. Have you implemented a training program and/or staff development plan for BIM4I implementation? *[Yes/No]*
35. If the answer to the previous question is "Yes", who has implemented it? *[Multiple choice]*
    - ⇒ Through consultants
    - ⇒ Develop internal training/manuals.
    - ⇒ Hybrid (combination of consultant and internal)
    - ⇒ Other (Please, elaborate)
36. Does your organization have a BIM implementation plan? *[Yes/No]*

3. LESSONS LEARNED

As ~~an owner using~~ BIM4I user in design, construction of infrastructure projects, please ~~*[Skip if not owner]*~~

37. Provide lessons learned on organizational and/or IT structure. *[text question]*
38. Provide lessons learned about how to manage communications with environmental agencies and other stakeholders. *[text question]*
39. Provide lessons learned on the integration of software technology partners *[text question]*
    34.1 ⇒ What improvements you would like to see in your partnerships with technology vendors?" *[text question]*

    - ⇒

40. Provide lessons learned on the integration of BIM4I advice consultants *[text question]*
    35.1 Can you share specific outcomes or successes that have resulted from the partnership?

As a professional involved in BIM4I infrastructure projects, please.

41. Provide lessons learned about obstacles you faced and the resolution of those obstacles in the process of BIM4I implementation during the planning, design, construction, and operation phases. *[text question]*

4. GENERAL COMMENTS AND REMARKS

42. Please, provide any additional comments and remarks on the topics addressed in the survey that might help in the process of BIM for infrastructures implementation.¶

¶

Essay Text [Allow attachments]¶

¶

Caltrans: General comment:¶

- This is a very high-level survey with very broad, open-ended questions that require very qualitative, essay-type responses.¶

¶

  MTI team: Yes, usually essay-type responses have the ability to gather richer information about a topic. The MTI team is open to creating or re-formulating questions in an open-choice format in coordination with Caltrans.¶

¶

- Will the MTI team follow up with an interview and steer the discussion to produce information most relevant for Caltrans?¶

¶

  MTI Team: Yes, the task order includes follow-up interviews with selected respondents based on the survey results (Task 9).¶

¶

- Will the survey be sent to the organization/consultants' BIM Program managers with a broad perspective of BIM implementation in the whole organization? The long responses to the survey questions may not work well for them.¶

¶

  MTI Team: The list of target agencies will be agreed and approved by Caltrans and might or might not include BIM program managers.¶

¶

Caltrans: Additional questions:¶

¶

MIT Team: Included in this Questionnaire draft (version 040124)—in blue¶

¶

- Has the Organization used open data standards such as IFC, DIGGS, etc.?¶

¶

  MTI team: we have incorporated this question in sub-section *Data Standards & Workflows*: Question 17¶

¶

- Has the Organization used model as a legal document?¶

¶

  MTI team: we have incorporated this question in sub-section *3D model use*: Question 21¶

¶

- Add question about Digital As-Builts for Asset management / maintenance¶

¶

  MTI team: we have incorporated this question in sub-section *3D model use*: Question 22¶

¶

- The survey mentions environmental review agencies. This may be a bit narrow. We are also interested in railroad agencies, public transportation, city/county among other interfacing stakeholders / regulatory agencies as well as public outreach.¶

¶

MTI team: we have incorporated this question in sub-section *Communications*: Questions 23 & 24

- How do they implement a training program and/or staff development plan for BIM, through consultants, develop internal training manuals, or hybrid?

MTI team: we have incorporated this question in sub-section *Training*: Questions 33 & 34

- Do they develop new project delivery workflows incorporating BIM, or still using old workflow and try to fit in technologies from BIM?

MTI team: we have incorporated this question in sub-section *Data Standards and workflows*: Question 20

- What software the organization used for CDE (Common Data Environment) when sharing information with others?

MTI team: we have incorporated this question in sub-section *Data Standards and Workflows*: Question 18

- Consider asking: Does your organization have a BIM implementation plan? Are you willing to share it?

MTI team: we have incorporated this question in sub-section *Training and Implementation Processes*: Question 35

Thank you for taking the survey.

A.4 Final Survey Questionnaire—05102924

Introduction

Q1.1. Survey of Building Information Modeling for Infrastructure (BIM4I)

NAMES OF RESEARCHERS

- Nigel Blampied, Ph.D., Research Associate, Mineta Transportation Institute, San José State University
- Maria Calahorra-Jimenez, Ph.D., Assistant Professor, California State University, Fresno
- Elhami Nasr, Ph.D., Professor, California State University, Long Beach
- Tariq Shebab, Ph.D., Professor, California State University, Long Beach

PURPOSE

The California Department of Transportation (Caltrans) through the San José State University Research Foundation is developing research to investigate the implementation of Building Information Modelling for Infrastructure (BIM4I), especially for transportation projects such as roads, rail, and bridges. The aim of the research is to gather best practices and lessons learned

from international, national, and local infrastructure agencies and stakeholders who have implemented Building Information Modeling (BIM) in their infrastructure projects. This study focuses on aspects such as asset life-cycle data standards, interoperable technology standards, organizational structure, development methodologies, use of consultants, schedules, costs, and tools used in BIM4I implementation.

PROCEDURES

We would like to know about the implementation of BIM4I in your agency or firm. To this end, we would like to request that you complete the questionnaire below. The questionnaire should take less than 20 minutes to complete.

COMPENSATION

There is no compensation for participation. We would be most happy, however, to share our report with you. If you wish to receive the report, please indicate this in the final question of the questionnaire.

CONFIDENTIALITY

We ask for the following information about you: name, e-mail, telephone number, and employer. Your name, e-mail, and telephone number will not be included in any reports, except that the participation of your organization will be acknowledged unless you prefer that it not be

acknowledged. Our reports will identify categories of organizations, but not normally individual organizations. (Categories include US states, counties, cities, countries, etc.) In some cases, however, we might find that you have provided exceptional information, and we may wish to associate that information with your organization. In that event, we will provide you with the statement that we intend to make, ask you to verify our statement, and ask you to obtain agreement with our statement from your management. We will not make the statement in our report without your concurrence. Our report will be submitted to Caltrans and made public on the San José State University website. Our expected audience consists of people in transportation agencies who are interested in the potential use of building information modelling by their agencies. As noted above, the report will not name you or your organizations other than to acknowledge your organization and, in exceptional cases only, with concurrence from you and your management, to describe what you are doing.

YOUR RIGHTS: Your participation in this study is completely voluntary. You can refuse to participate in the entire study or any part of the study without any negative effect on your relations with San José State University, other California State Universities, or the California Department of Transportation. You also have the right to skip any question you do not wish to answer.

CONTACT INFORMATION

We deeply appreciate your time and consideration in responding to this questionnaire.

Should you have any questions or comments, please contact Dr. Nigel Blampied

nigel.blampied@sjsu.edu

AGREEMENT TO PARTICIPATE

Your completion of the study indicates your willingness to participate. If you would like to save or print a copy of our consent notice containing the above information, please follow this link https://drive.google.com/file/d/11bQ056fWSkV8sWPW3EKOqLT2rLSYleDV

General Information:

Q2.1. General Information

Full Name [Last, First]	
Name of Your Organization	
Your title or role in your organization	

Your phone #

Your email

Q2.2. Your location

Country

State, Province, or Region

City

Q2.3. Type of Your Organization

- [ ] Government Agency
- [ ] Academia

- [ ] Private Firm
- [ ] Other [Please Indicate]

Q2.4. Approximate number of infrastructure projects that, to your knowledge, your organization has developed or is developing using Building Information Modeling (BIM)

- ○ 1 - 10
- ○ 11 - 20
- ○ 21 - 30
- ○ 31 - 40
- ○ 41 - 50
- ○ > 50

Q2.5. Types of infrastructure projects in which your organization has applied BIM

- [ ] Roads/Highways
- [ ] Rails
- [ ] Buildings
- [ ] Tunnels
- [ ] Underground construction
- [ ] Other: [Please, indicate]

- [ ] Bridges

Q2.6. Phases of the project where you have been involved in BIM

- [ ] Planning
- [ ] Construction
- [ ] Other
- [ ] Design
- [ ] Maintenance and Operations

Levels of implementation

Q3.1. What level best defines how your organization's has implemented BIM?

- ○ Level 1. Transition from 2D to 3D for plan production.
- ○ Level 3. Deliver 3D model contractually with conventional plans
- ○ Level 5. Produce Digital As-builts.

- ○ Level 2. Deliver 3D model for information only.
- ○ Level 4. Deliver 3D model contractually without plans.

Q3.2. What is your organization's approach to BIM Implementation? Please specify what types or categories of projects your organization is using for the implementation.

- ○ My organization is implementing BIM in all types of projects

  [ ]
- ○ My organization is implementing BIM in selected projects

  [ ]

General Comments and Remarks

Q4.1. What groups / divisions from within your organization have involvement in the BIM Process?

- ☐ Design office for highways and other transportation facilities

- [ ] Construction Administration/engineering office (e.g., Resident Engineer, Inspection or Clerk of Works)
- [ ] Property acquisition office
- [ ] Land surveying office
- [ ] Bridges/Structures design office
- [ ] Environmental studies and approvals office
- [ ] Utility Identification/clearance office
- [ ] Office issuing permits for work by other organizations on highways and other transportation facilities
- [ ] Transportation asset management (US Federal requirement that might not exist in other countries)
- [ ] Maintenance office for highways and other transportation facilities
- [ ] Office of traffic control and operations
- [ ] Data governance office
- [ ] Research and innovation office
- [ ] Safety office
- [ ] Airport planning office
- [ ] Accounting office
- [ ] Budgeting office
- [ ] Programming office, responsible for the commitment of transportation funds to projects
- [ ] Transportation system planning office

- [ ] Office of rail, bus, and similar passenger transportation services
- [ ] Office of pavement design
- [ ] Office of drainage design, hydraulics and hydrology
- [ ] Information Technology (IT) office
- [ ] External, public affairs, and press office
- [ ] Office of risk and strategy management
- [ ] Office of procurement and contracting
- [ ] Office of legal affairs and litigation
- [ ] Office of construction and maintenance equipment management
- [ ] Office managing transportation funding assistance for cities, counties, municipalities, and other local government agencies

Q4.2. Of the offices you checked in the previous / above question, who has been the lead in your organization for implementing BIM?

- [ ] Design office for highways and other transportation facilities
- [ ] Construction Administration/engineering office (e.g., Resident Engineer, Inspection or Clerk of Works)
- [ ] Property acquisition office
- [ ] Land surveying office

- [ ] Bridges/Structures design office
- [ ] Environmental studies and approvals office
- [ ] Utility Identification/clearance office
- [ ] Office issuing permits for work by other organizations on highways and other transportation facilities
- [ ] Transportation asset management (US Federal requirement that might not exist in other countries)
- [ ] Maintenance office for highways and other transportation facilities
- [ ] Office of traffic control and operations
- [ ] Data governance office
- [ ] Research and innovation office
- [ ] Safety office
- [ ] Airport planning office
- [ ] Accounting office
- [ ] Budgeting office
- [ ] Programming office, responsible for the commitment of transportation funds to projects
- [ ] Transportation system planning office
- [ ] Office of rail, bus, and similar passenger transportation services
- [ ] Office of pavement design
- [ ] Office of drainage design, hydraulics and hydrology

- [ ] Information Technology (IT) office
- [ ] External, public affairs, and press office
- [ ] Office of risk and strategy management
- [ ] Office of procurement and contracting
- [ ] Office of legal affairs and litigation
- [ ] Office of construction and maintenance equipment management
- [ ] Office managing transportation funding assistance for cities, counties, municipalities, and other local government agencies

Q4.3. Who is the owner of the data (Data Steward)?

- [ ] Design office for highways and other transportation facilities
- [ ] Construction Administration/engineering office (e.g., Resident Engineer, Inspection or Clerk of Works)
- [ ] Property acquisition office
- [ ] Land surveying office
- [ ] Bridges/Structures design office
- [ ] Environmental studies and approvals office
- [ ] Utility Identification/clearance office
- [ ] Office issuing permits for work by other organizations on highways and other transportation facilities

- [ ] Transportation asset management (US Federal requirement that might not exist in other countries)
- [ ] Maintenance office for highways and other transportation facilities
- [ ] Office of traffic control and operations
- [ ] Data governance office
- [ ] Research and innovation office
- [ ] Safety office
- [ ] Airport planning office
- [ ] Accounting office
- [ ] Budgeting office
- [ ] Programming office, responsible for the commitment of transportation funds to projects
- [ ] Transportation system planning office
- [ ] Office of rail, bus, and similar passenger transportation services
- [ ] Office of pavement design
- [ ] Office of drainage design, hydraulics and hydrology
- [ ] Information Technology (IT) office
- [ ] External, public affairs, and press office
- [ ] Office of risk and strategy management
- [ ] Office of procurement and contracting
- [ ] Office of legal affairs and litigation

- [ ] Office of construction and maintenance equipment management
- [ ] Office managing transportation funding assistance for cities, counties, municipalities, and other local government agencies

BIM Implementation: Data standards and workflows

Q5.1. What data standards is your organization using?

- [ ] ISO 12006
- [ ] ISO 16739
- [ ] ISO 19650
- [ ] ISO 23387
- [ ] Smart BIM
- [ ] DIGGS
- [ ] IFC
- [ ] None
- [ ] _____ Other

Q5.2. What software does your organization use for Common Data Environment when sharing information with others?

- ☐ Autodesk Construction Cloud
- ☐ Bentley Project wise
- ☐ Ocean BIM
- ☐ Trimble Connect
- ☐ Allplan Bimplus
- ☐ Other (Indicate)
- ☐ Trimble Quadri

Q5.3. How are the data stored?

- ☐ Single point (Not Cloud Based)
- ☐ Cloud based with server outside your country
- ☐ Other
- ☐ Cloud based with server in your country
- ☐ Inside your Firewall

Q5.4. In the process of BIM implementation, please select the

option that applies to your agency/organization

- ○ My organization have developed new project delivery workflows incorporating BIM.
- ○ My organization has developed old workflows and trying to fit in technologies from BIM.
- ○ [ ] Other (Please, elaborate)

BIM Implementation: 3D Model Use

Q6.1. Has your organization used 3D model as a legal construction document?

- ○ Yes
- ○ No

Comments

○ [ ]

Q6.2. Has your organization used a 3D model for asset management/maintenance?

- ○ Yes
- ○ No
- ○ Comments

BIM Implementation: Communications

Q7.1. What tools do you use with environmentally responsible agencies, utilities, or other regulatory/permitting agencies to communicate project information in the design stage?

- ☐ Autodesk-Civil 3D
- ☐ Autodesk-BIM 360
- ☐ Autodesk-Naviswork
- ☐ Bentley-Open Roads CE
- ☐ Bentley-PowerGeopak
- ☐ Bentley-ITwin
- ☐ Bentley-Navigator
- ☐ Bentley-LumenRT
- ☐ Trimble-Connect
- ☐ Trimble-Quadri
- ☐ Trimble-Prospect
- ☐ Other (Please, Specify)

- [ ] Autodesk-Infraworks

Q7.2. What tools do you use with environmentally responsible agencies, utilities, or other regulatory/permitting agencies to communicate project information in the construction, operation, and maintenance stages?

- [ ] Acrobat reader
- [ ] Bluebeam revu
- [ ] Kofax PowerPDF
- [ ] Trimble Connect
- [ ] Topcon Magnet
- [ ] Carlson Construct
- [ ] Google Earth
- [ ] Ersi ArcGIS
- [ ] AutoCAD Map 3D
- [ ] Bentley Opencities MAP
- [ ] Other (Please, Specify)

Q7.3. In your case, do the environmentally responsible agencies, utilities, or other regulatory/permitting agencies need training?

○ Yes ○ No

Q7.4. Do private design firms participate in the development of digital delivery to environmentally responsible agencies?

○ Yes ○ No

Q7.5. Has your agency submitted any Industry Foundation Classes (IFC) files or shared any model via Common Data Environment (CDE) with a regulatory agency that will issue a permit?

○ Yes ○ No

Q7.6. In the review process with permitting agencies using a 3D model: Have these agencies requested additional information to be included in the model?

○ Yes ○ No

Q7.7. If the previous question is "yes", what kind of information was requested to be included in the model?

Q7.8. In the review process with permitting agencies using a 3D model, does the review process require additional iterations as compared to the traditional 2D process?

○ Yes ○ No

BIM Implementation: Use of Technology Partners

Q8.1. In your organization, what technology partners have you worked with in BIM implementation?

	Partner 1	Partner 2	Partner 3
Company Name			
Contact Name			
Contact email			
Contact Telephone			
Product Used			
Scope of Work / Assignment			
Tools used/what department used them			

Q8.2. In your organization, what consultants have you worked with in BIM implementation?

	Consultant 1	Consultant 2	Consultant 3
Company Name			
Contact Name			
Contact email			
Contact Telephone			

	Consultant 1	Consultant 2	Consultant 3
Scope of Work / Assignment			
Tools used/what department used them			
Is the company currently active and contributing to your projects? (Yes/No)			
How would you rate the effectiveness of the company in achieving your BIM4I objectives (1 - 5 Scale)			

BIM Implementation: Training & Implementation Processes

Q9.1. Have you implemented a training program and/or staff development plan for BIM implementation?

- ○ Yes
- ○ Some What
- ○ No

Q9.2. If the answer to the previous question is “Yes” or "Some What", who has implemented it?

- ○ Through consultants
- ○ Hybrid (combination of consultant and internal)
- ○ Develop internal training/manuals.
- ○ Other (Please, elaborate)

Q9.3. Does your organization have a BIM implementation plan?

- ○ Yes
- ○ Maybe
- ○ No

Lessons Learned

Q10.1. As a BIM user, please provide your lessons learned on one or more of the following:

1. Organizational and/or IT structure

2. How to manage communications with environmental agencies and other stakeholders.

3. Integration of software technology partners

4. What improvements you would like to see in your partnerships with technology vendors?"

5. Integration of BIM advice consultants

6. Share specific outcomes or successes that have resulted from the partnership with BIM

advice consultants?	
7. Obstacles you faced and the resolution of those obstacles in the process of BIM implementation during the planning, design, construction, and operation phases	

Q10.2. Please, provide any additional comments and remarks on the topics addressed in the survey that might help in the process of implementation.

A.5 Human Subjects Protocol Approval and Consent Notice

Attachments:
- BIM4I_~1.DOC.pdf
- SJSU IRB: Protocol Submission Approved – 24-103.pdf

SJSU SAN JOSÉ STATE UNIVERSITY

Institutional Review Board
Office of Research
Division of Research and Innovation

SJSU IRB: Protocol Submission Approved – 24-103

04/23/2024

Dear Nigel Blampied,

Your IRB submission has been approved by the San José State University Institutional Review Board. Please keep this letter for your records and note any conditions of approval and investigator responsibilities that apply to your research. If you have any questions, please do not hesitate to contact our office.

Study Title: Survey of Building Information Modeling for Infrastructure (BIM4I)

IRB Protocol ID Number: 24-103

SJSU Principal Investigator: Dr. Nigel Blampied

Review Type: Exempt 2ii

Date of Approval: 04/23/2024

Submission Type: Initial

Special Conditions (applicable if checked):

(X) Waiver of signed consent approved (minimal risk study)

( ) Waiver of some or all elements of informed consent approved

( ) Risk determination for device:

( ) Other:

IRB Contact Information:
Alena Filip
Human Protections Analyst
Office of Research – Human Subjects Institutional Review Board
alena.filip@sjsu.edu

IRB Chair:
Dr. Areum Jensen

Institutional Official:
Dr. Richard Mocarski
Associate Vice President of Research

Primary Investigator Responsibilities:

- Any significant changes to the research must be submitted for review and approval prior to the implementation of the changes via a modification request.
- Incident reports of unanticipated problems, injuries, or adverse events involving risks to participants must be submitted to the IRB within seven calendar days of the primary investigator's knowledge of the event.
- Comply with an SJSU IRB or Institutional Official (IO) decision to suspend or withdraw approval for the study.
- Ensure that any other compliance-related approvals are fulfilled:

Human subjects research that also includes biological materials derived from humans may require approval from the Institutional Biosafety Committee (IBC).

Human subjects research that also includes animals must be approved by the Institutional Animal Care and Use Committee (IACUC).

Human subjects research that involves certain information and technologies that will be transferred internationally may be subject export control regulations.

Financial conflicts of interest may need to be disclosed to the Office of Research.

Approval Limitations:

- Although your study has been approved by the IRB, both the IRB and the Institutional Official (IO) for SJSU has the right to audit any approved study and withdraw approval.
- This approval is no longer valid once the SJSU PI is no longer affiliated with SJSU, unless the study is re-assigned to an SJSU-affiliated PI via a modification request.
- SJSU investigators may list external personnel on their applications. However, the SJSU IRB does not assume responsibility for the compliance of external personnel. Instead external personnel should contact their IRB, either to coordinate a reliance agreement with the SJSU IRB as the IRB of record or to have their IRB conduct a separate review for their activities. External personnel who do not have the support of an external IRB and have not established a contract with SJSU should not receive access to individually identifying information about subjects. SJSU investigators are encouraged to be judicious about who they add as part of the study personnel, as responsibility for compliance rests with the SJSU PI in the event that external personnel do not have the support of an outside IRB.

IRB Mentor Login: https://www.axiommentor.com/login/shibLogin.cfm?i=sjsu

CONSENT NOTICE

TITLE OF STUDY

Survey of Building Information Modeling for Infrastructure (BIM4I)

NAMES OF RESEARCHERS

Nigel Blampied, Ph.D., Research Associate, Mineta Transportation Institute, San José State University

Maria Calahorra-Jimenez, Ph.D., Assistant Professor, California State University, Fresno

Elhami Nasr, Ph.D., Professor, California State University, Long Beach

Tariq Shebab, Ph.D., Professor, California State University, Long Beach

PURPOSE

The California Department of Transportation (Caltrans) through the San José State University Research Foundation is developing research to investigate the implementation of Building Information Modelling for Infrastructure (BIM4I), especially for transportation projects such as roads, rail, and bridges.

The aim of the research is to gather best practices and lessons learned from international, national, and local infrastructure agencies and stakeholders who have implemented Building Information Modeling (BIM) in their infrastructure projects. This study focuses on aspects such as asset life-cycle data standards, interoperable technology standards, organizational structure, development methodologies, use of consultants, schedules, costs, and tools used in BIM4I implementation.

PROCEDURES

We would like to know about the implementation of BIM4I in your agency or firm. To this end, we would like to request that you complete the questionnaire below. The questionnaire should take less than 20 minutes to complete.

COMPENSATION

There is no compensation for participation. We would be most happy, however, to share our report with you. If you wish to receive the report, please indicate this in the final question of the questionnaire.

CONFIDENTIALITY

We ask for the following information about you: name, e-mail, telephone number, and employer. Your name, e-mail, and telephone number will not be included in any reports, except that the participation of your organization will be acknowledged unless you prefer that it not be acknowledged. Our reports will identify categories of organizations, but not normally individual organizations. (Categories include US states, counties, cities, countries, etc.) In some cases, however, we might find that you have provided exceptional information, and we may wish to associate that information with your organization. In that event, we will provide you with the statement that we intend to make, ask you to verify our statement, and ask you to obtain agreement with our statement from your management. We will not make the statement in our report without your concurrence.

Our report will be submitted to Caltrans and made public on the San José State University website. Our expected audience consists of people in transportation agencies who are interested in the potential use of building information modelling by their agencies. As noted above, the report will not name you or your organizations other than to acknowledge your organization and, in exceptional cases only, with concurrence from you and your management, to describe what you are doing.

Appendix B: Interview Protocol

Introductory Protocol

To facilitate our notetaking, we would like to record our conversation today. For your information, only researchers on the project will be privy to the recordings which will be eventually destroyed after they are transcribed. Also, we would like to assure you: (1) your personal information will be held confidential, (2) your participation is voluntary, and you may stop at any time if you feel uncomfortable, and (3) we do not intend to inflict any harm. Thank you for agreeing to participate.

We have planned this interview to last no longer than one hour. During this time, we have several questions that we would like to cover. If time begins to run short, it may be necessary to interrupt you in order to push ahead and complete this line of questioning.

Notes for the interviewer:

- Don't forget to record the meeting
- Probes: are sub-questions that aim to gather more information from the interviewee. Please, use them as a way of collect richer information from each question.

Introduction

You have been selected to speak with us today because you and your organization have knowledge and experience in Building Information Modeling for Infrastructures (BIM4I). Our research project for Caltrans focuses on understanding how other agencies are implementing BIM and how they are making BIM4I a process and not a set of systems. We are interested to know what your approach to BIM implementation is, the tools you are using, what standards you are employing with the tools, what process you are following for guidance and consistency, and how you are establishing processes on workflows, among other things. The interview includes five groups of questions: (1) introduction, (2) setting up the implementation process, (3) technology, (4) processes, and (5) people

1. INTERVIEWEE BACKGROUND

1.1. What is your current position? _____

1.1. How long have you been …

_____ in your present position?

_____ at your organization?

_____ using BIM for infrastructures (BMI4I)?

1.3. Briefly describe your role as it relates to BIM4I implementation in your organization.

Setting up the implementation process

2. BIM IMPLEMENTATION APPROACH

2.1. Could you provide some background about the use of BIM in infrastructure in your organization?

Probes:

- When did you start?
- What were the first steps you took?

2.2. In the implementation process, what do you wish you (or your organization) had known before starting to make the initial stages of the implementation process easier?

2.3. Do you use BIM in specific selected projects or deliver all the projects using BIM? Why?

2.3.1. If the organization only delivers certain projects using BIM, the question is:

- What are the criteria for deciding whether a project will be delivered using BIM? Is it based on size, complexity, others?

2.3.2 If the organization delivers all projects using BIM, the question is:

- To your knowledge, what was the tipping point between delivering only selected projects using BIM and delivering all the projects using BIM?
- How long did it take in your organization to transition to a full BIM4I delivery?
- What main advice could you provide to organizations that are currently in the transition process to full digital delivery?

3. BIM IMPLEMENTATION/EXECUTION PLANS

3.1. What kind of policies have you used to implement BIM processes?

3.2. Who is the owning department of the BIM implementation/execution plans?

Probes:

- How are changes or modifications in the plan managed?
- Do you have external support for managing the BIM implementation/execution?

3.3 What key information is included in your BIM implementation/execution plans?

3.4. Do you use BIM implementation/execution plans for project information models and asset information models separately or together?

Probe:

- Why?

3.4. What approach do you follow to integrate the organization processes with the technology requirements?

4. SUPPORT FOR BIM IMPLEMENTATION

4.1 How did your organization structure the support of BIM implementation practices?

Probes:

- Do you have specific support groups or experts spread amongst the different subject areas?
- If so, could you elaborate on the roles that each support group/expert takes to support BIM implementation in your organization

4.2 Did you hire specific staff to support BIM implementation practices?

Probe

- If so, could you share what type of profile(s) you hired: Engineers, surveyors, data scientists/experts, analysts, IT specialists, etc.?

Technology

5. DATA STANDARDS

5.1 What standards for BIM implementation do you use? (ISO, others)

Probes:

- If they mention the use of an ISO standard, the question is:
  - What specific sections do you use from the standard you mentioned?
  - Could you elaborate on how you apply the standards in your projects?

5.2 How are you implementing the standards across the organization? (Given that for BIM implementation different departments need to be involved)

5.3 Who is responsible for updating and maintaining data standards? IT? Design Office? Construction? Joint Efforts?

6. COMMON DATA ENVIRONMENT (CDE) USE

6.1. Are you using a Common Data Environment (CDE)?

6.2 If yes, please tell me how it is implemented and used. (if not, please skip to question 7.1)

Probes:

- Is the same CDE used in different project phases (for example, design and construction), or do you use a different CDE in each phase?
    - If they are different, could you elaborate on why you chose two and the main differences between them?

6.3 What software are you using in your CDE(s), and how are they working?

Probes:

- Why did you decide to use those?
- How do they work?
- Did you face challenges using the software you mentioned? How did you solve it?

6.4 Do you use different design tools before passing through a CDE? For example, design in Civil 3D but use the Trimble CDE to share information.

Probes:

- If using different tools,
    - Why?
    - Are you planning to change in the near future? Why?

7. TECHNOLOGY ISSUES

7.1 What are the main technology issues you have faced in BIM implementation, and how have you solved them?

Processes

8. ORGANIZATIONAL STRUCTURE

8.1 Who does your organization manage the cross-functional/interdepartmental collaboration required for an adequate BIM implementation?

9. WORKFLOWS

9.1 In the survey, you mentioned that <you created new business workflows/fit technology in old workflows>; is this correct?

9.2 **Option 1.** For the organizations that developed new business workflows to BIM tools, the question is:

- How is that going?

Probe:

- What kind of change management strategies did you implement for success?

Option 2. For the organizations fitting BIM technologies into old workflows, the question is

- How is that going?

Probe:

- Are you having struggles with the tools meeting your business needs?
- Are you finding you are duplicating work or missing opportunities for streamlining?
- Do you wish you had created new workflows?

10. 2D-3D MODEL USE

10.1 In the projects delivered using BIM, is there any instance where you use 2D format? For example: for permits with external stakeholders in the design, or in the procurement using 2D drawings as contractual documents, other...?

10.2 Are you using the post-project 3D information for asset management as part of a complete infrastructure, or does it stay in a project-by-project setup?

10.3 For the companies using BIM practices in maintenance/operations,

- **10.3.1** How are your maintenance and operations areas modifying and updating the information? Using GIS? Using CDE? Working with the design/construction engineers or surveyors to update?
- **10. 3.2** What standards do you use? (ISO, other)

Probes:

- If they mention the use of an ISO standard, the question is:
  - What specific sections do you use from the standard you mentioned?
  - Could you elaborate on how you apply the standards in your projects?

11. COORDINATION WITH PERMITTING/REGULATORY AGENCIES

11.1 How does your organization manage the review process with permitting/regulatory agencies (environmental, utilities…) in BIM projects during the design stage?

Probes:

- Could you elaborate on how the review process is conducted?

11.2 How does your organization manage the review process with permitting/regulatory agencies (environmental, utilities…) in BIM projects during the construction stage?

Probes:

- Could you elaborate on how the review process is conducted?

People

12.1 Are your organization providing internal training to the staff involved in BIM implementation?

If so,

12.1.1. Could you elaborate on the topics that the training offers?

12.1.2. Is it one-time training or is there a training plan?

If a training plan:

12.1.2.1. Could you elaborate on how the plan is designed?

12.1.3. Is the training internal or outsourced?

12.2 Are you willing to share your training information?

12.3 How has your organization managed the shift from a "departmental mindset" to a "common data environment mindset"?

12.4 Do you have a plan to manage organizational change due to BIM implementation?

Probes:

- Could you elaborate on it?

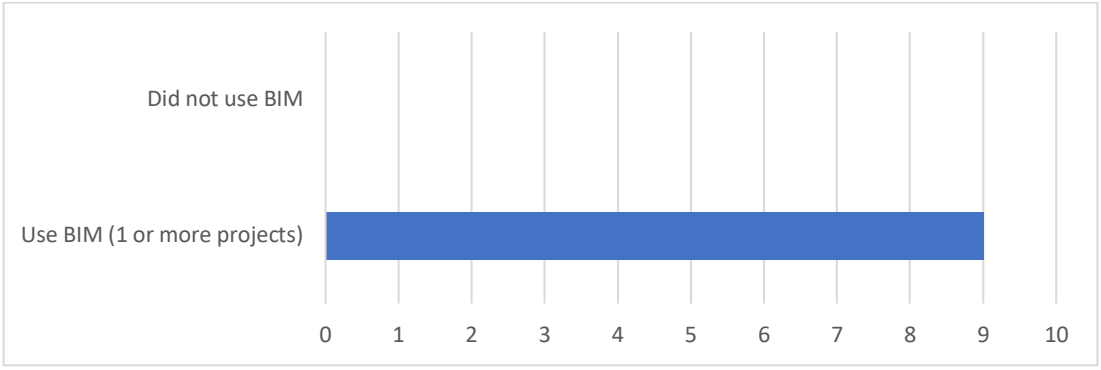
Final Remarks

13. Do you have any suggestions/advice for an organization that is starting to implement BIM4I?

Appendix C: Caltrans Survey Responses Analysis

Of the nine responses received from Caltrans respondents, all reported they have used BIM in one or more projects (Figure 42).

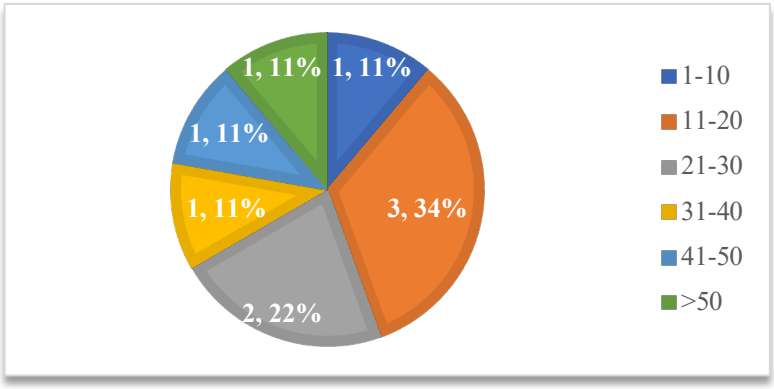
Figure 42. BIM4I use in DOTs.



**Data shown based on a total of 9 responses*

Among Caltrans that have completed more than one project, 11% of the respondents indicated that they had used BIM in 1–10 projects in their organization. Thirty-four percent (34%) reported the use of BIM in 11–20 projects in their organization. Twenty-two percent (22%) responded the use of BIM in 21–30 projects, and 11% indicated they use BIM in 31–40 projects and >50 projects, respectively.

Figure 43. Number of Projects Developed Using BIM. Caltrans.

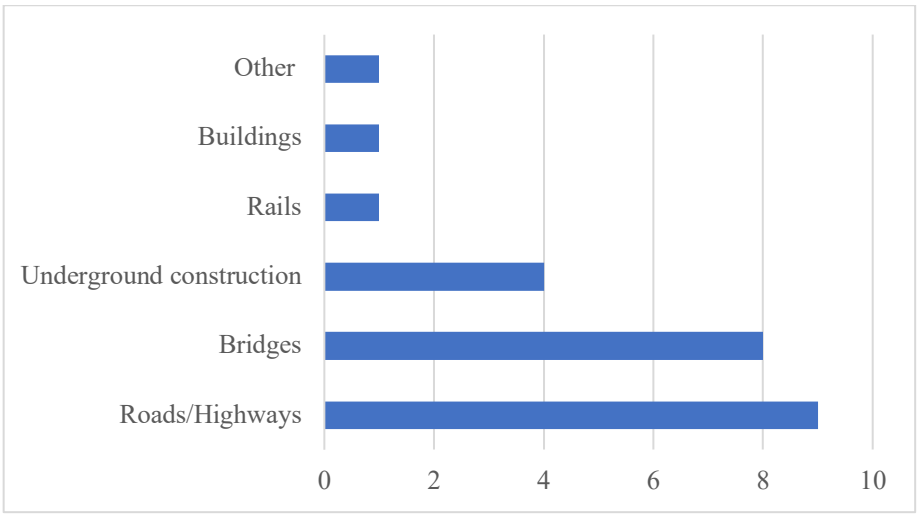


**Percentages calculated based on a total of 9 responses*

Caltrans reported the use of BIM in roads/highways, bridges, underground construction, rail, tunnels, and buildings. Roads/highways projects were developed using BIM by all nine

respondents, followed by bridge projects reported by eight and underground construction reported by 4. Rails, buildings, and others were reported by 1 person each (Figure 44).

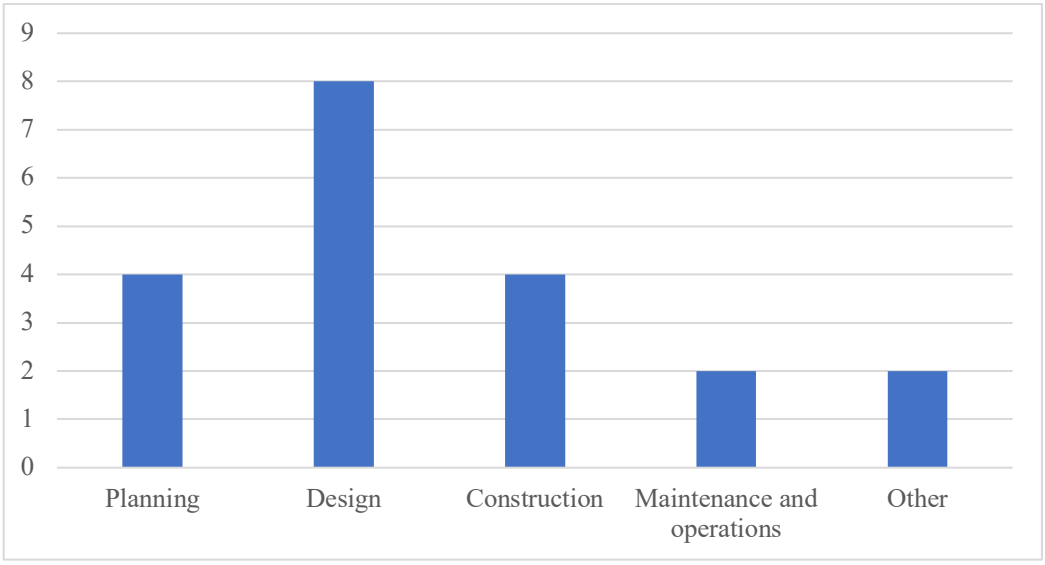
Figure 44. Type of Projects Developed Using BIM. Caltrans.



**Data shown based on a total of 9 responses*

Respondents also reported on the phases of the project lifecycle in which they use BIM. Eight out of nine respondents indicated the use of BIM in the design stage, followed by four respondents who reported the use in the construction and planning stage. Two respondents reported use in maintenance and operations as well as in other (Figure 45).

Figure 45. Project Phases when BIM is Used. Caltrans.

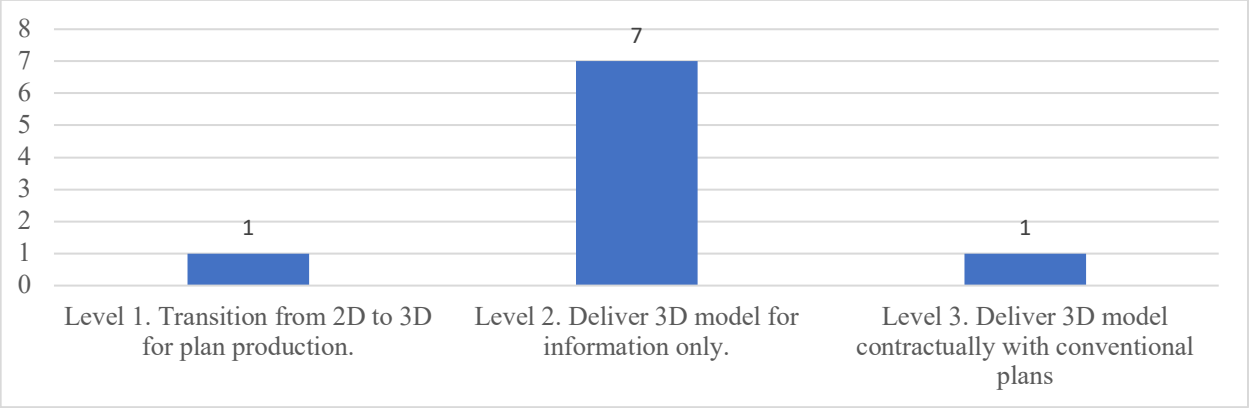


**Data shown based on a total of 9 responses*

Levels of implementation & implementation approach

Target agencies were asked to self-report the level of implementation they think their organization can be categorized in. The levels included: level 1: transition from 2D to 3D for plan production; level 2: Deliver 3D model for information only; level 3: Deliver 3D model contractually with conventional plans; level 4: deliver 3D model contractually without plans; and level 5: produce digital as-builts. One out of nine reported to be in level 1, seven in level 2, and one in level 3 (Figure 46).

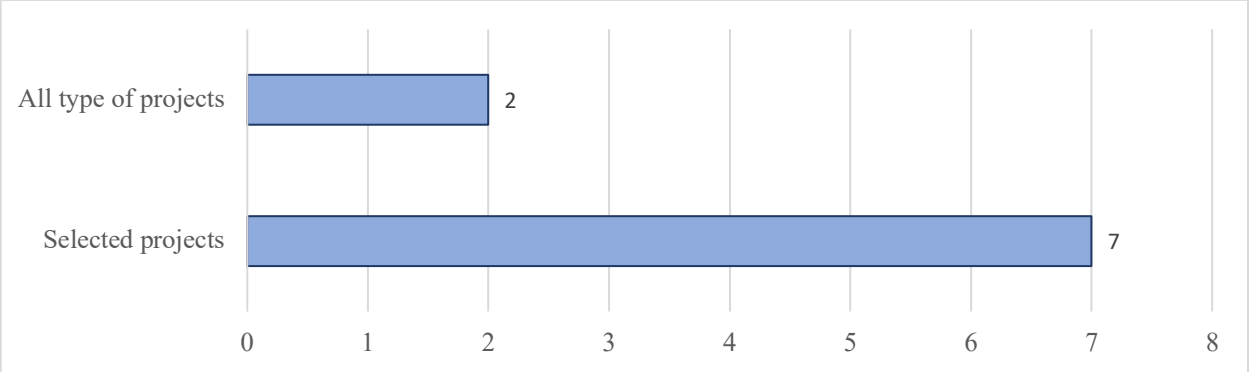
Figure 46. Levels of BIM Implementation. Caltrans.



**Data shown based on a total of 9 responses*

The survey asked the agencies to report whether they implement BIM in all types of projects or only in selected projects. Seven responders indicated that they use BIM in selected projects, while two reported the use of BIM in all types of projects (Figure 47).

Figure 47. BIM4 Implementation Approach. Caltrans.

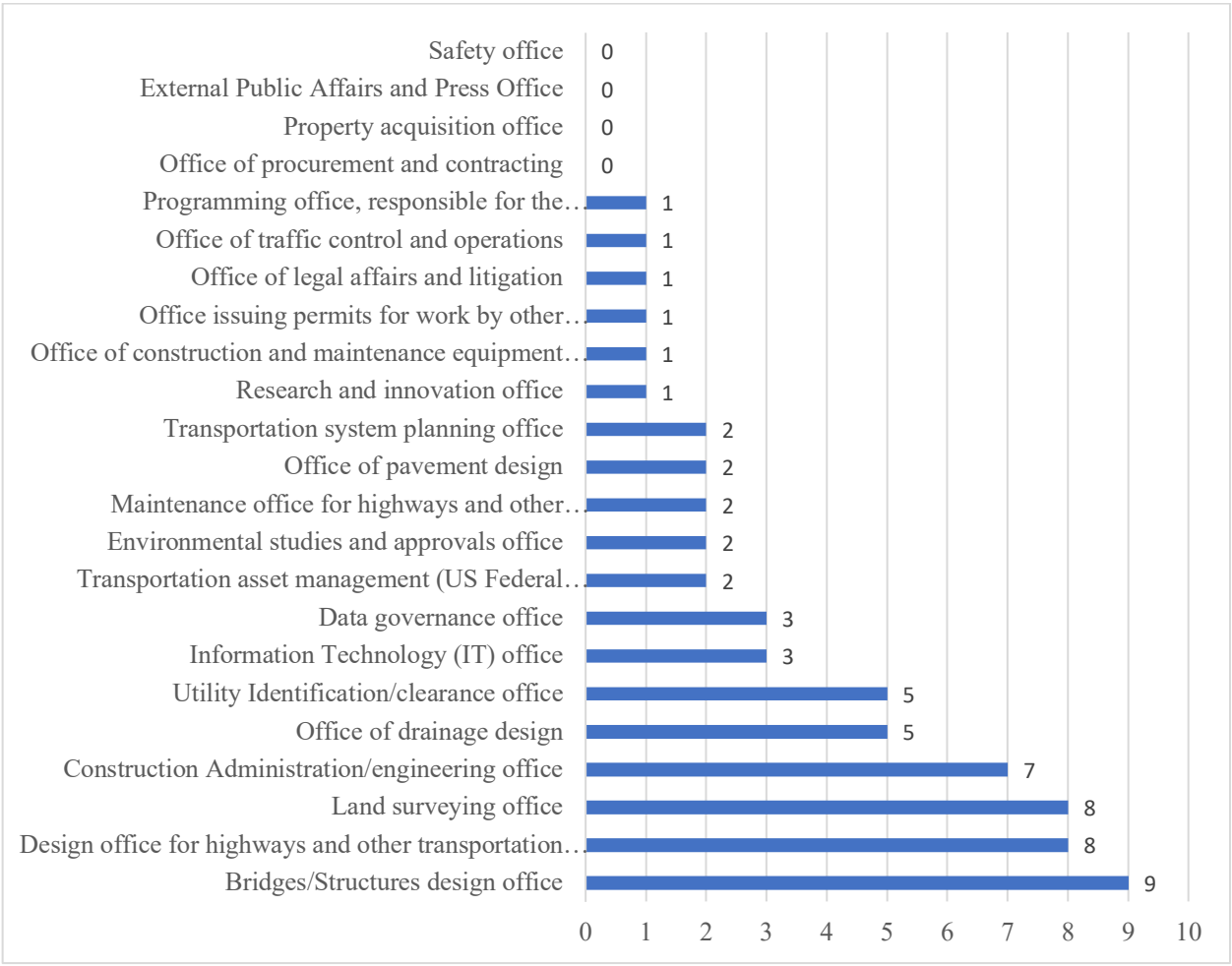


**Data shown based on a total of 9 responses*

Respondents had the opportunity to report more details about their implementation approach in a follow-up open-ended question. In this instance, Caltrans respondents reported the use of BIM in roads, bridges, rails, utility conflict, and electrical design.

Several departments in the organization are involved in the BIM4I implementation process. In the survey, target agencies were asked three questions: what groups/divisions are involved in the BIM implementation process, which of these groups/divisions are the leaders in the implementation, and finally, who the owner of the data (data steward) is. Responses to these questions are shown in figures Figures 29, 30, and 31. As shown in Figure 29, the three divisions most frequently mentioned by DOTs are "Bridge/Structures office," "Design office for Highways and other transportation facilities," and "Land Surveying Office."

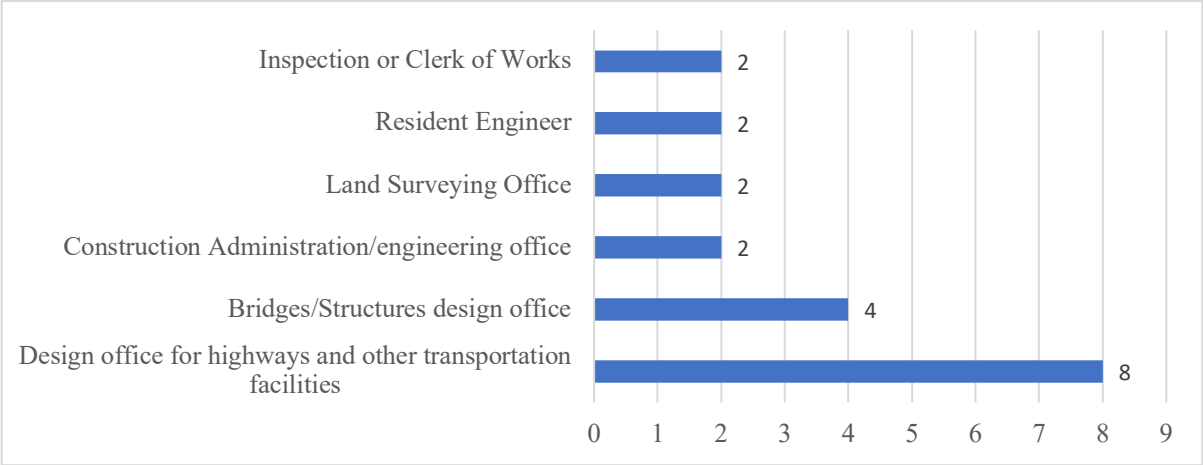
Figure 48. Groups/Division from within the Organization Involved in the BIM Implementation Process. Caltrans.



**Data shown based on a total of 9 responses*

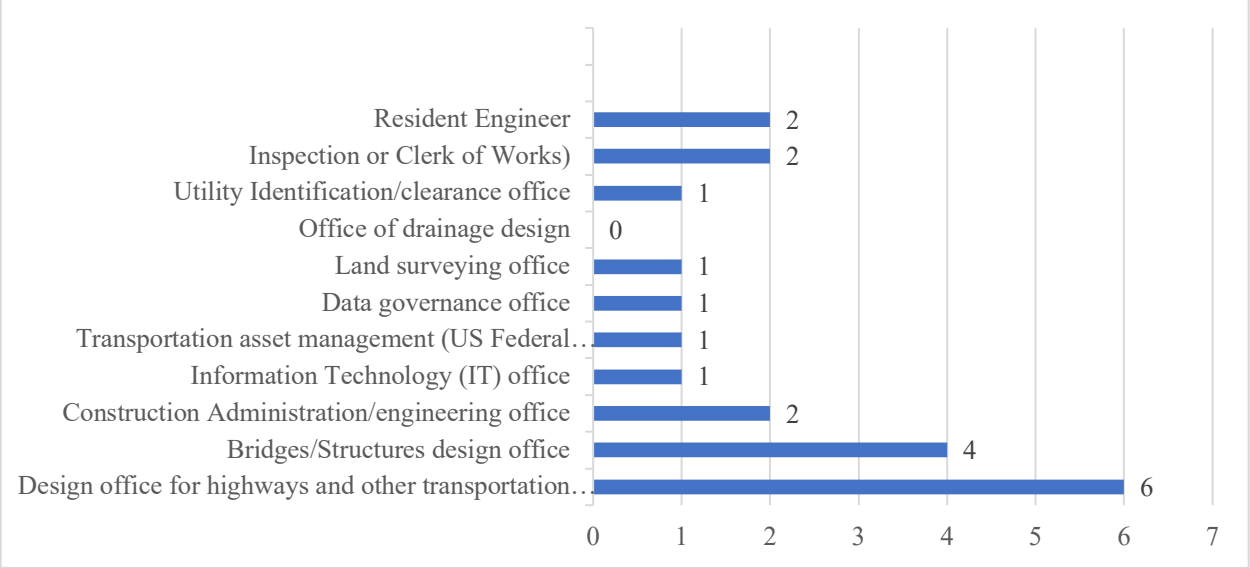
The "Design Office for highways and other transportation facilities" was reported by 8 of 9 respondents as the office that leads the BIM implementation process (Figure 49). This office was also identified as the owner of the data by six respondents (Figure 50).

Figure 49. Groups/Division Leading the BIM Implementation Process. Caltrans.



**Data shown based on a total of 9 responses*

Figure 50. Groups/Divisions Identified as the Owner of the Data. Caltrans.



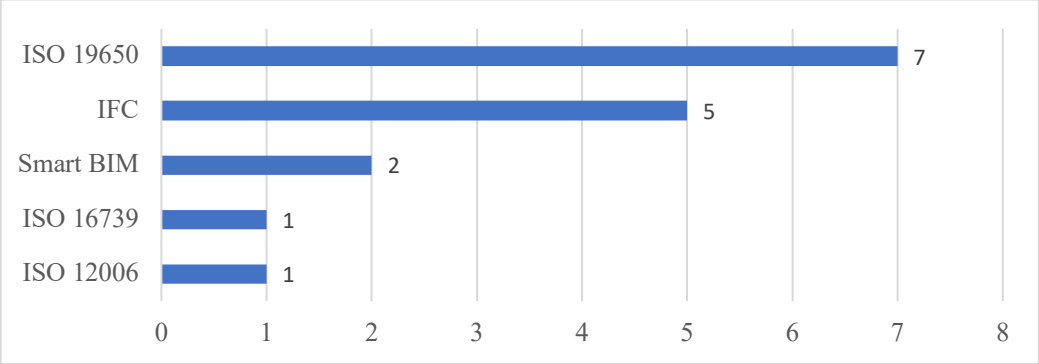
**Data shown based on a total of 9 responses*

Data standards and workflows

Caltrans respondents were asked to indicate the data standards they are using in their process of BIM implementation. Options provided included ISO 12006, ISO 16739, ISO 19650, ISO

23387, Smart BIM, DIGGS, IFC, None, or Other, with space for an open-ended answer, also provided to allow more detailed explanations. Seven out of nine respondents indicated the use of ISO 19650, five indicated the use of IFC, two mentioned Smart BIM and two respondents indicated the use of ISO 16739 and 12006.(Figure 51).

Figure 51. Data Standards Used in BIM Implementation. Caltrans.

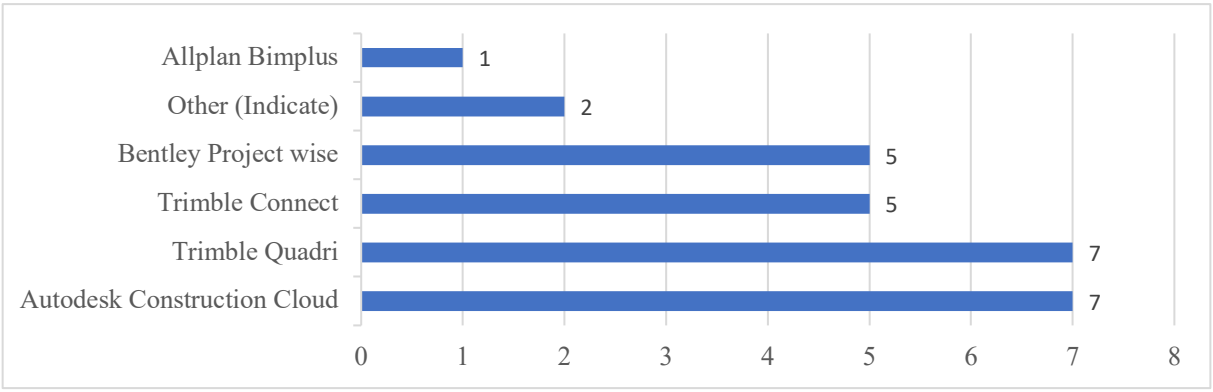


**Data shown based on a total of 9 responses*

Two Caltrans respondents provided some explanation regarding the answer "Other." For example, one respondent indicated that they use "Tekla" and another stated that they use "Sketchup." Further, other responses include "not sure" and using "Trimble Business Center."

Respondents were also asked about what software their organization used for a CDE when sharing information with others. Seven out of nine respondents reported using "Autodesk Construction Cloud," and seven reported using "Trimble Quadri.". Five out of 9 respondents reported the use of Trimble Connnect and Bentley Project Wise. Two out of 9 respondents reported the use of "other" software (Figure 52).

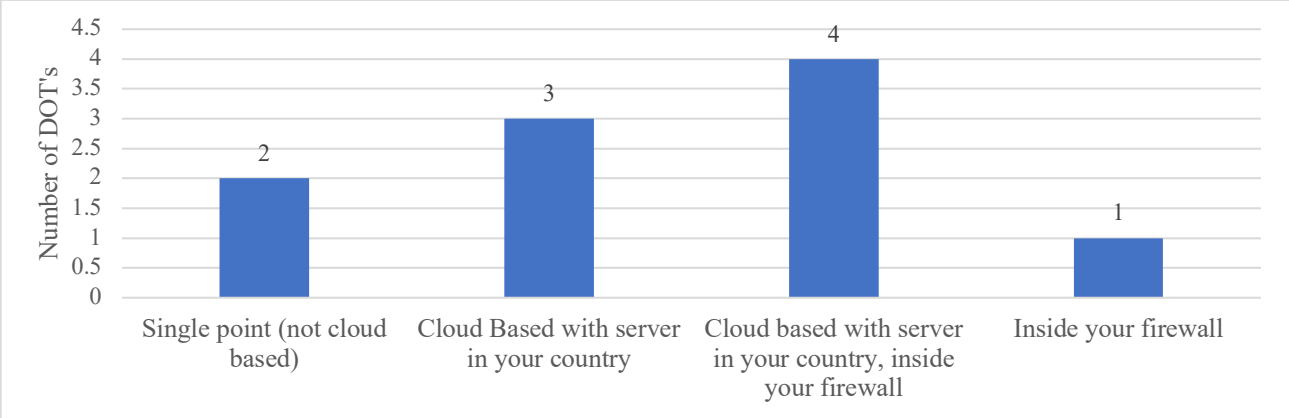
Figure 52. Software used in CDE to Share Information. Caltrans.



**Data shown based on a total of 9 responses*

Caltrans respondents were asked about how the data is stored, providing the options of "single point (not cloud-based)," "cloud-based with a server in your country," "cloud-based with server outside your country," and "inside your firewall." Four respondents indicated that their data storage is "cloud-based with server in your country." Two reported "single point, not cloud-based," and three indicated that they use "cloud-based with server in your country." Only one respondent selected only the option "inside your firewall" (Figure 53).

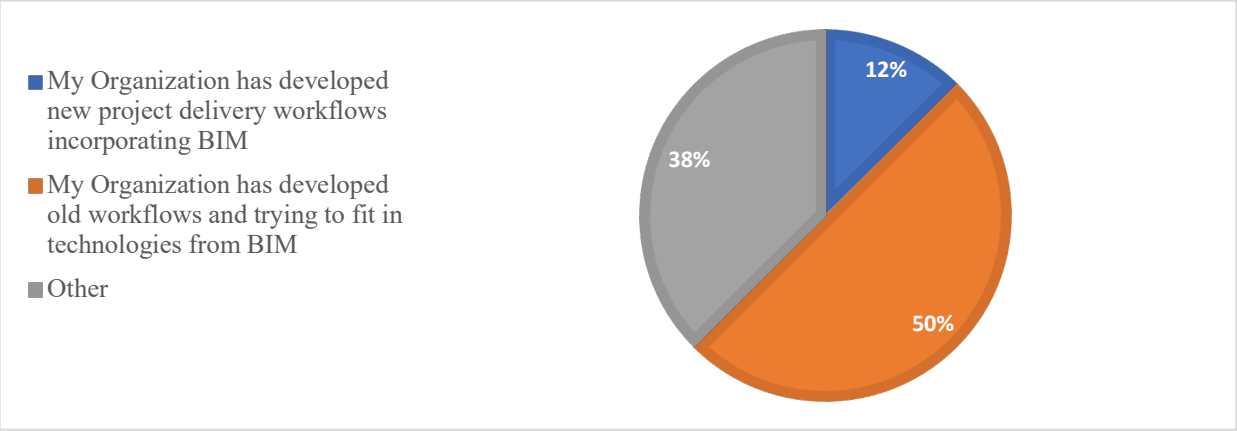
Figure 53. Types of Data Storage. Caltrans.



**Data shown based on a total of 8 responses*

About workflows, Caltrans respondents were asked to report whether their organization is "developing new project delivery workflows incorporating BIM" or "developing old workflows and trying to fit in technologies from BIM." As shown in Figure 54, twelve percent (12%) of the respondents indicated that they are developing new workflows, while 50% reported using old workflows. Interestingly, 38% of respondents selected the option "other." Other approaches include a mix of both new and old workflows, workflows in development, "a hybrid of both situations," "process of new delivery workflows," and "old workflows with new technologies for new workflows."

Figure 54. Type of Workflows used in BIM Implementation. Caltrans.



**Percentages calculated based on a total of 9 responses*

Use of 3D models

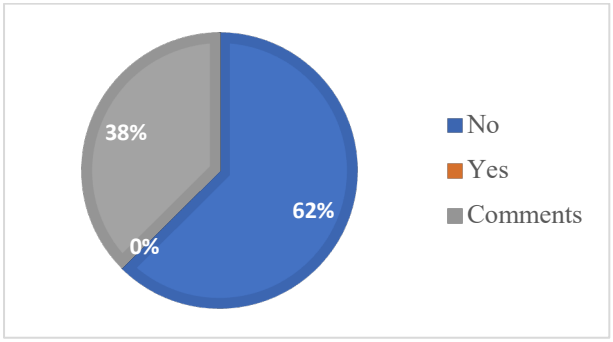
The survey asked participants to report on the use of 3D models as legal construction documents and for asset management/maintenance. Sixty-two percent (62%) of respondents indicated that they had not used BIM as a legal document, while 50% reported not having used BIM for asset management/maintenance (Figure 55). Some comments provided on the use of 3D models as a legal document include "only partially," "working towards that objective," and "a goal we are looking towards."

Five Caltrans respondents did not select "yes" or "no" in the question about the use of 3D models for asset management/maintenance. Instead, they provided the following comments: "working with our asset division," "working towards," and "goal looking towards."

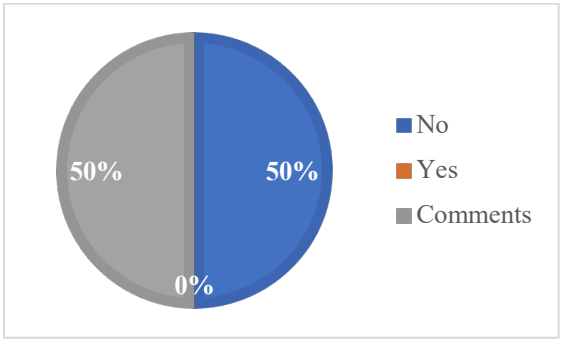
Figure 55. 3D Models Use. Caltrans.

Has your organization used 3D models…

As a legal construction document?



For asset management/maintenance?



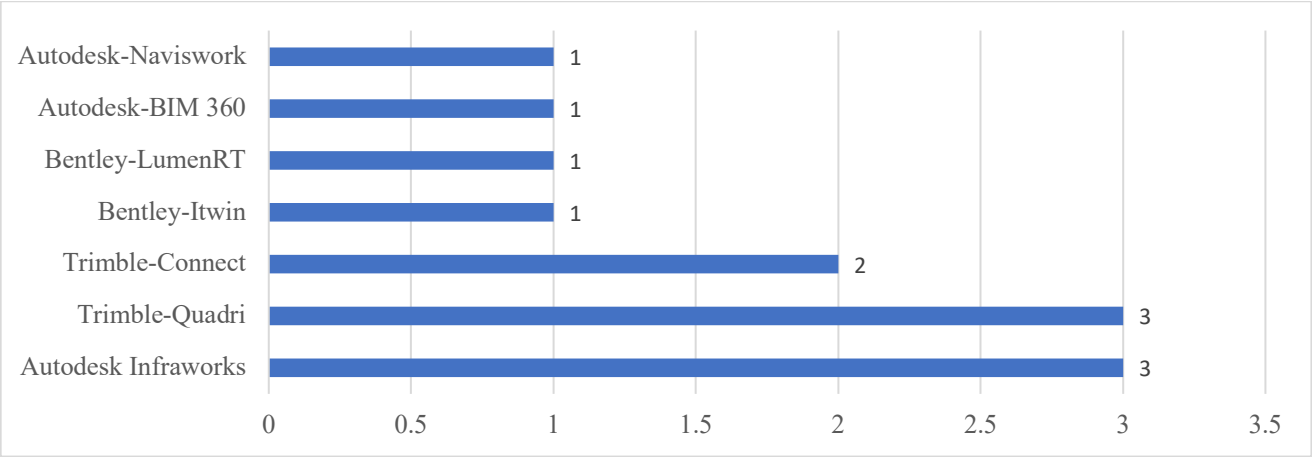
**Percentages calculated based on a total of 9 responses*

Communications

This section of the survey focuses on communication with environmentally responsible agencies, utilities, or other regulatory agencies. It included questions about the software used to communicate information, the need for training, the involvement of private engineering firms with delivering information to external agencies, the use of Industry Foundation Classes (IFC) when sharing this information, and the review process using 3D models.

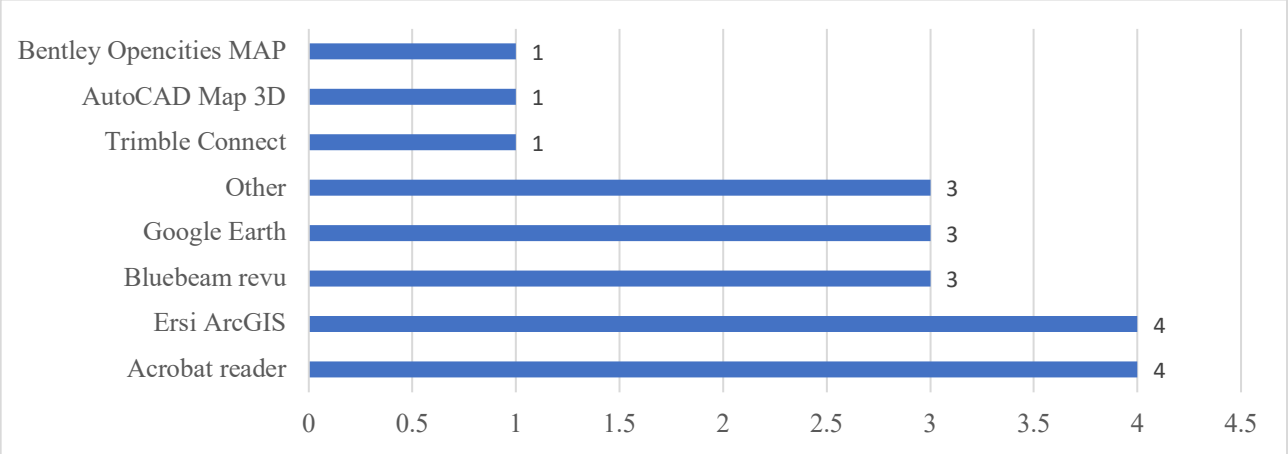
With respect to the software products used to communicate information with environmentally responsible agencies, utilities or other regulatory/permitting agencies, Caltrans respondents were asked to report the software they use in the design stage and in the construction, operation, and maintenance stages. Three out of seven agencies reported using Autodesk-Civil, and Autodesk Infraworks), to communicate information in the design stage (Figure 56). Other tools reported are Trimble-Quadri, Trimble-Connect, Bentley-Itwin, Bentley-LumenRT, Autodesk-BIM360, and Autodesk-Naviswork, shown in (Figure 56).Four out of seven respondents reported the use of Acrobat reader as the software tool to communicate information in the construction, operation, and maintenance stages, followed by Ersi ArcGIS (four respondents) with Bluebeam Revu, Google Earth, and Other(three respondents) (Figure 57). Other tools reported are Trimble Connect. AutoCAD Map 3D, and Bentley Opencities MAP.

Figure 56. Software Products Used to Communicate Information in the Design Stage. Caltrans.



**Data shown based on a total of 7 responses*

Figure 57. Software Products Used to Communicate Information in the Construction, Operation and Maintenance Stages. Caltrans.



**Data shown based on a total of 7 responses*

To the question "Do environmentally responsible agencies, utilities, or other regulatory/permitting agencies need training?" Seven out of 7 agreed that yes, these external agencies need training.

To the question "Do design firms participate in the development of digital delivery to environmentally responsible agencies?," 86% of respondents agreed that yes, design firms participate in the development of digital delivery (6 out of 7 Caltrans respondents).

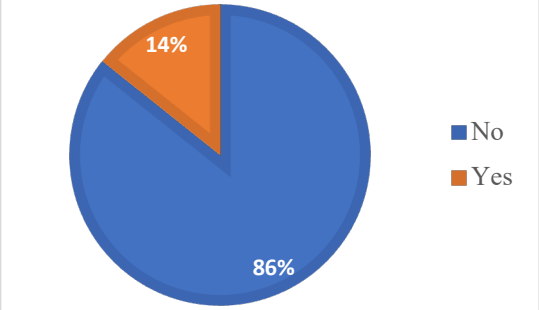
To the question "Has your agency submitted any Industry Foundation Classes (IFC) files or shared any model via a CDE with a regulatory agency that will issue a permit?," 86% of the respondents did not share IFC files or shared models with regulatory agencies (6 out of 7 Caltrans respondents).

To conclude this section about communications, agencies were asked about the review process with external agencies, shown in Figure 17. Eighty percent (86%) of respondents reported that, during the review process with permitting agencies, they were asked for additional information to include in the model. Further, 20% of respondents indicated that the review process using 3D models does not require more iterations as compared to the traditional 2D process.

Figure 58. Review Process with External Agencies. Caltrans.

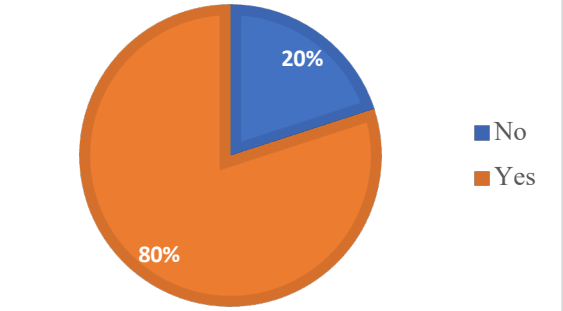
In the review process with permitting agencies using a 3D model

Have these agencies requested additional information to be included in the model?



*Percentages calculated based on a total of 18 responses

Does the review process require additional iterations as compared to the traditional 2D process?



*Percentages calculated based on a total of 16 responses

Use of technology partners and consultants

Target agencies were asked about the technology partners and products they have used in their BIM implementation process. To these questions, one Caltrans respondent out of nine provided a response. In total, they reported the use of Bentley, Autodesk, and Trimble. Products used from these technology partners include Civil 3D, ACC, Infraworks, Connect, Quadri, and drafting. About the scope of work assigned to the technology partners, the respondents mentioned "roadway design software and CDE," "surveying, construction, CDE," "microstation for roadway and structures design," and "surveyors and construction inspectors."

Another question was asked relating to the use of consultants during the BIM implementation process. Two Caltrans respondents out of nine provided responses to this question. In total, they reported using five different consultants.

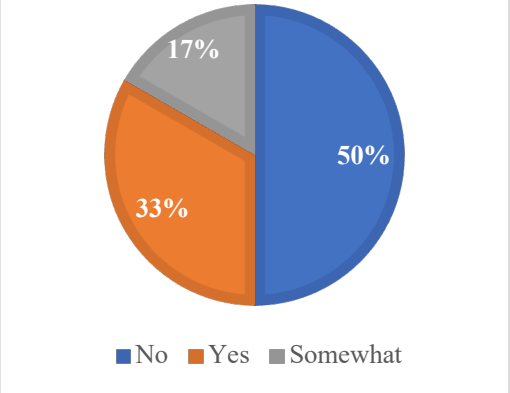
Training and implementation processes

Caltrans was asked to report about training aspects such as having a training program and/or staff development plan for BIM implementation.

As shown in Figure 18, 50% of the respondents indicated that they do not have a training program and/or staff development plan for BIM implementation. Thirty-three percent (33%) of respondents reported "yes" or "somewhat." Of the three agencies that reported having training or something similar, two respondents reported the training was conducted in a hybrid format combining internal resources and consultants. One respondent stated that they develop the training through external consultants.

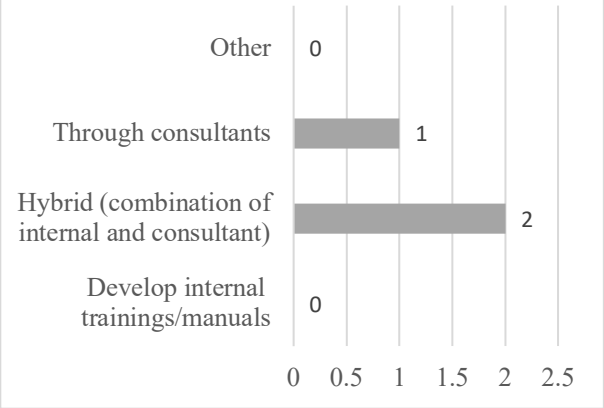
Figure 59. Training Program and/or Staff Development Plan. Caltrans.

Have you implemented a training program and/or staff development plan for BIM implementation?



*Percentages calculated based on a total of 6 responses

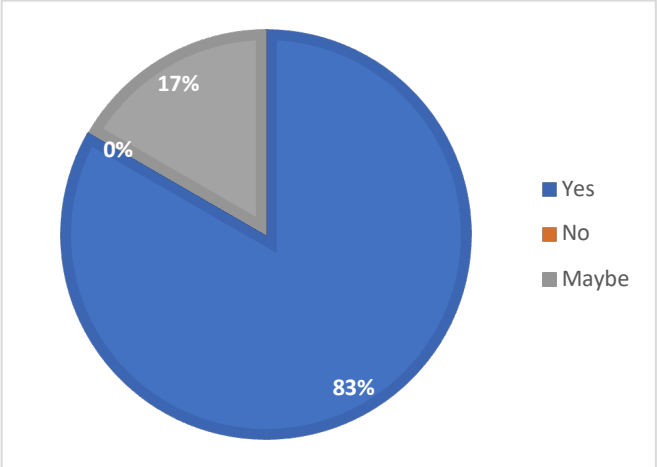
If "yes" or "somewhat," how is the training?



*Data shown based on a total of 3 responses

Figure 60 shows the responses to the question "does your organization have a BIM implementation plan?" Eighty-three percent (83%) of respondents indicated that they have a BIM implementation plan, none stated that they do not have it, and 17% of respondents selected the option "maybe."

Figure 60. BIM Implementation Plan. Caltrans.



**Percentages calculated based on a total of 6 responses*

Lessons learned

This section provides a summary of the lessons learned as provided by different Caltrans respondents regarding (1) organizational and/or IT structure, (2) how to manage communications with environmental agencies and other stakeholders, (3) integration of software technology partners, (4) improvements you would like to see in your partnership with technology vendors, (5) integration of BIM advice consultants, (6) specific outcomes or successes that have resulted from the partnership with BIM advice consultants, (7) obstacles faced and resolution of those obstacles in the process of BIM implementation, and (8) additional comments and remarks that might help in the process of implementation.

Organization and/or IT structure

The key topics emerging from the Caltrans responses are the importance of creating an implementation plan for guidance and being able to change the management and workflow across the organization to implement BIM successfully.

How to manage communications with environmental agencies and other stakeholders

Some Caltrans responses proposed the use of CDE and cloud-based environments for communication.

Integration of software technology partners

Key advice for integrating technology partners in BIM implementation, based on Caltrans responses, includes (1) willing to assist others with software needs and enhancements for 3D modeling, (2) direct guidance from vendor for certain software needs, and (3) establishing systematic framework for pilot projects and analytics.

Improvements you would like to see in your partnership with technology vendors

Respondents would like to see more willingness to listen for improvements, adding new capabilities in the vendor software to ensure models are correctly located into their workflow, and transparency with better collaboration for developments in BIM4I functionalities.

Integration of BIM advice consultants

According to the respondents, there is a need to get a consultant on board for advice on the creation of implementation plans and on changing architectural and engineering contract task language to allow consultants to deliver 3D information models.

Specific outcomes or successes that have resulted from the partnership with BIM advice consultants

Based on respondents' answers, having a better integration of CDE for production project delivery process.

Obstacles faced and resolution of those obstacles in the process of BIM implementation

Based on the segments provided, the main obstacles respondents have faced in BIM implementation include:

- Funding for software and equipment within the organization: the ability to receive a financial letter with approved funds. Management allowed to overcome obstacles with more staff and dollars being provided for BIM4I.

- Lack of BIM4I standards for horizontal infrastructure: implementing ISO19650.

Appendix D: Additional Resources

During the course of the research, the research team found several policies, guides, and websites that could be adapted and used as models by agencies that are starting on the path of BIM adoption. These are tabulated in Table 5. In general, the research team found that oversight agencies issue policies while transportation departments issue more detailed guides, as might be expected.

This is publicly available information that was not gathered from individuals through surveys or interviews. Specific agencies can therefore be listed without breaching the Human Subjects Protocol.

Table 5. List of Additional Resources

Agency	ISO Country Code	Policy	Guide	Website	Web address
Queensland Department of Transport and Main Roads	AU		✓	✓	https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Building-Information-Modelling
Queensland Government (all Departments)	AU	✓			https://www.statedevelopment.qld.gov.au/infrastructure/infrastructure-industry/building-information-modelling
Bundesministerium für Digitales und Verkehr (Federal Ministry of Transport and Digital Infrastructure)	DE	✓			https://bmdv.bund.de/SharedDocs/EN/publications/road-map-for-digital-design-and-construction.html
Deutsche Einheit Fernstraßenplanungs-und-bau GmbH (German Unit for Street Planning and Construction)	DE		✓	✓	https://www.deges.de/building-information-modeling-bim/
National Highways (England)	GB	✓	✓	✓	https://nationalhighways.co.uk/our-work/digital-data-and-technology/digital-roads/
Network Rail	GB	✓			https://www.networkrail.co.uk/running-the-railway/railway-upgrade-plan/digital-railway/digital-railway-strategy/
Statens vegvesen (Norwegian Road Administration)	NO		✓		https://viewers.vegnorm.vegvesen.no/product/859973/en
Arizona Department of Transportation	US			✓	https://azdot.gov/adot-digital-delivery-program
Idaho Department of Transportation	US	✓			https://publications.iowa.gov/41902/

Appendix E: ISO Summary

A significant challenge in the development of any form of information technology is the potential lack of compatibility between systems. To address this challenge for BIM, several firms joined together to create the Industry Alliance for Interoperability which has since been renamed buildingSMART International, an association that has chapters in the countries or regions in which there are buildingSMART participants (Bazjanac, 1997). The buildingSMART International website lists thirty-three such chapters (buildingSMART international, 2024a). The original function of buildingSMART International is to produce standards known as Industry Foundational Classes (IFCs) (buildingSMART international, 2024b). The standard for these IFCs has been transferred to the ISO and, specifically, to subcommittee 13 (SC 13) of ISO's Technical Committee 59 (TC 59). ISO is an association of the national standard-setting bodies of 172 countries (ISO, 2024b), and the adoption of standards by ISO ensures their widest-possible worldwide acceptance. The full name of SC 13 is "Organization and digitization of information about buildings and civil engineering works, including building information modeling (BIM)." The standard-setting bodies of 30y countries are participating in SC 13, and another 22 countries are observer of the SC (ISO, 2024a).

Each ISO committee consists of experts appointed by the participating countries. Experts from the US are appointed by the American National Standards Institute (ANSI) and are nominated by committees called US Technical Advisory Groups (US TAGs). Each US TAG is coordinated by one of the many standards-setting associations in the US. In the case of ISO TC 59/SC 13, the US TAG is coordinated by the American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc (ASHRAE). ASHRAE informed the research team that it is looking for another association to take this role.

In the interviews with agencies abroad, some respondents indicated that they participate in their countries' counterparts to US TAGs. Similarly, Caltrans could consider participating in the US TAG for ISO TC 59/SC 13. If not Caltrans, then it would be advisable for AASHTO to participate because US transportation agencies have interests that differ from those of other US participants.

So far, SC 13 has published twenty-two standards, four of which are undergoing revision. Another ten new standards were in the course of development. These are listed below.

E.1 Twenty-Two Standards, Four of Which are Undergoing Revision.

- ISO 7817-1:2024 Building information modelling – Level of information need – Part 1: Concepts and principles

- ISO 12006-2:2015 Building construction – Organization of information about construction works – Part 2: Framework for classification [currently being revised]
- ISO 12006-3:2022 Building construction – Organization of information about construction works – Part 3: Framework for object-oriented information
- ISO 12911:2023 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Framework for specification of BIM implementation
- ISO 16354:2013 Guidelines for knowledge libraries and object libraries
- ISO 16739-1:2024 Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries – Part 1: Data schema
- ISO 16757-1:2015 Data structures for electronic product catalogues for building services – Part 1: Concepts, architecture and model
- ISO 16757-2:2016 Data structures for electronic product catalogues for building services – Part 2: Geometry
- ISO 19650-1:2018 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 1: Concepts and principles
- ISO 19650-2:2018 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 2: Delivery phase of the assets
- ISO 19650-3:2020 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 3: Operational phase of the assets
- ISO 19650-4:2022 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 4: Information exchange
- ISO 19650-5:2020 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 5: Security-minded approach to information management

- ISO 21597-1:2020 Information container for linked document delivery – Exchange specification – Part 1: Container
- ISO 21597-2:2020 Information container for linked document delivery – Exchange specification – Part 2: Link types
- ISO 22263:2008 Organization of information about construction works – Framework for management of project information
- ISO/TR 23262:2021 GIS (geospatial) / BIM interoperability
- ISO 23386:2020 Building information modelling and other digital processes used in construction – Methodology to describe, author and maintain properties in interconnected data dictionaries
- ISO 23387:2020 Building information modelling (BIM) – Data templates for construction objects used in the life cycle of built assets – Concepts and principles [currently being revised]
- ISO 29481-1:2016 Building information models – Information delivery manual – Part 1: Methodology and format [currently being revised]
- ISO 29481-2:2012 Building information models – Information delivery manual – Part 2: Interaction framework [currently being revised]
- ISO 29481-3:2022 Building information models – Information delivery manual – Part 3: Data schema

E.2 Ten New Standards in the Course of Development

- ISO/AWI TS 7817-2 Building information modelling – Level of information need – Part 2: Guidance for application
- ISO/AWI 7817-3 Building information modelling – Level of information need – Part 3: Schema
- ISO/CD TR 16214 Geospatial and BIM review of vocabularies
- ISO/DIS 16757-4 Data structures for electronic product catalogues for building services – Part 4: Dictionary structures for product catalogue
- ISO/DIS 16757-5 Data structures for electronic product catalogues for building services – Part 5: Product catalogue exchange format

- ISO/FDIS 19650-6 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 6: Health and safety information
- ISO/AWI 23143-1 Information exchange between BIM and GIS – Part 1: Core principles and specifications
- ISO/AWI 23143-2 Information exchange between BIM and GIS – Part 2: Part 02: Facilitating data exchange through metadata
- ISO/AWI 23143-3 Information exchange between BIM and GIS – Part 3: Linking abstract concepts in BIM and GIS standards
- ISO/AWI TS 25055 Compatibility policy for ISO 16739-1 revisions

Bibliography

Bazjanac, V. (1997). The implementation of industry foundation classes in simulation tools for the building industry. Lawrence Berkeley National Laboratory.

Blanco, F. G. B., & Chen, H. (2014). The implementation of building information modelling in the United Kingdom by the transport industry. *Procedia – Social and Behavioral Sciences*, *138*, 510–520. https://doi.org/10.1016/j.sbspro.2014.07.232

Bradley, A., Li, H., Lark, R., & Dunn, S. (2016). BIM for infrastructure: An overall review and constructor perspective. *Automation in Construction*, *71*, 139–152. https://doi.org/10.1016/j.autcon.2016.08.019

Bråthen, K., & Moum, A. (2016). Bridging the gap: Bringing BIM to construction workers. *Engineering, Construction and Architectural Management*, *23*(6), 751–764. https://doi.org/10.1108/ECAM-01-2016-0008

buildingSMART international. (2024a). *Building SMART chapters*. buildingSMART International. https://www.buildingsmart.org/community/chapter-directory/

buildingSMART international. (2024b). *What we do*. buildingSMART International. https://www.buildingsmart.org/about/what-we-do/.

Caltrans. (2021). *Caltrans 2020–2024 strategic plan.*

Chen, D., Wang, S., Zhang, W., Yang, Y., & Chen, P. (2022). Design and implementation of bridge information management system based on BIM. *Journal of Intelligent & Fuzzy Systems*, *43*(3), 2973–2984. https://doi.org/10.3233/JIFS-211988

Chen, L., Shi, P., Tang, Q., Liu, W., & Wu, Q. (2020). Development and application of a specification-compliant highway tunnel facility management system based on BIM. *Tunnelling and Underground Space Technology*, *97*, 103262. https://doi.org/10.1016/j.tust.2019.103262

Chen, Q., Adey, B. T., Haas, C. T., & Hall, D. M. (2022). Exploiting digitalization for the coordination of required changes to improve engineer-to-order materials flow management. *Construction Innovation*, *22*(1), 76–100. https://doi.org/10.1108/CI-03-2020-0039

Cheng, J. C. P., Lu, Q., & Deng, Y. (2016). Analytical review and evaluation of civil information modeling. *Automation in Construction*, *67*, 31–47. https://doi.org/10.1016/j.autcon.2016.02.006

Eadie, R., Browne, M., Odeyinka, H., McKeown, C., & McNiff, S. (2013). BIM implementation throughout the UK construction project lifecycle: An analysis. *Automation in Construction*, *36*, 145–151. https://doi.org/10.1016/j.autcon.2013.09.001

Ghasemzadeh, B., Celik, T., Karimi Ghaleh Jough, F., & C. Matthews, J. (2022). Road map to BIM use for infrastructure domains: Identifying and contextualizing variables of infrastructure projects. *Scientia Iranica*, *0*(0), 0–0. https://doi.org/10.24200/sci.2022.56935.4998

Guo, X., Tian, C., Chen, Y., & Zhang, J. (n.d.). Case study of building information modeling implementation in infrastructure projects. *Transportation Research Record*.

Hartmann, T., van Meerveld, H., Vossebeld, N., & Adriaanse, A. (2012). Aligning building information model tools and construction management methods. *Automation in Construction*.

HDR. (2023). *ADOT Digital delivery program guidance document*.

Hetemi, E., Ordieres-Meré, J., & Nuur, C. (2020). An institutional approach to digitalization in sustainability-oriented infrastructure projects: The limits of the building information model. *Sustainability*, *12*(9), 3893. https://doi.org/10.3390/su12093893

Honghong, S., Gang, Y., Haijiang, L., Tian, Z., & Annan, J. (2023). Digital twin enhanced BIM to shape full life cycle digital transformation for bridge engineering. *Automation in Construction*, *147*, 104736. https://doi.org/10.1016/j.autcon.2022.104736

Huang, Y., Shi, Q., Pena-Mora, F., Lu, Y., & Shen, C. (2020). Exploring the impact of information and communication technology on team social capital and construction project performance. *Journal of Management in Engineering*, *36*(5), 04020056. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000804

ISO. (2024a). *ISO*. ISO/TC 59/SC 13 Organization and digitalization of information about buildings and civil engineering works, including Building Information Modelling (BIM). : https://www.iso.org/committee/49180.html

ISO. (2024b, August 24). Members. https://www.iso.org/about/members.

Jiang, F., Ma, L., Broyd, T., & Chen, K. (2021). Digital twin and its implementations in the civil engineering sector. *Automation in Construction*, *130*, 103838. https://doi.org/10.1016/j.autcon.2021.103838

Jobidon, G., Lemieux, P., & Beauregard, R. (2021). *Building information modeling in Quebec's procurement for public infrastructure: A case for integrated project delivery*.

Juszczyk, A. (2022). *BIM in the construction process – Selected problems at the stage of implementation in Polish road engineering*.

Kostesha, V. A., Shapovalov, D. A., Kolesnikova, I. K., Biryukov, D. A., & Chetverikova, A. A. (2021). Information modeling in the context of highways property complex management. *Journal of Physics: Conference Series*, *2142*(1), 012010. https://doi.org/10.1088/1742-6596/2142/1/012010

Liu, Z., Wang, Y., Osmani, M., & Demian, P. (2020). Leveraging micro-level building information modeling for managing sustainable design: United Kingdom experience. *Advances in Civil Engineering*, *2020*, 1–11. https://doi.org/10.1155/2020/3641950

Mallela, Jan, Blackburn, April, Grant, Roger, Kennerly, Michael, Petros, Katherine, & Yew, Connie. (2021). *Building Information Modeling (BIM) practices in highway infrastructure* (No. FHWA-PL-21-024; p. 121). Federal Highway Administration.

Miettinen, R., Kerosuo, H., Metsälä, T., & Paavola, S. (2018). Bridging the life cycle: A case study on facility management infrastructures and uses of BIM. *Journal of Facilities Management*, *16*(1), 2–16. https://doi.org/10.1108/JFM-04-2017-0017

Murguia, D., Demian, P., & Soetanto, R. (2023). The role of the industry's cultural-cognitive elements on actors' intention to adopt BIM: An empirical study in Peru. *Engineering, Construction and Architectural Management*, *30*(3), 1183–1200. https://doi.org/10.1108/ECAM-08-2021-0743

Murphy, M. E., & Nahod, M.-M. (2017). Stakeholder competency in evaluating the environmental impacts of infrastructure projects using BIM. *Engineering, Construction and Architectural Management*, *24*(5), 718–735. https://doi.org/10.1108/ECAM-07-2015-0106

Semeraro, F., Rapetti, N., & Osello, A. (2018). Contract obligations and award criteria in public tenders for the case study of ANAS BIM implementation. In J. Karlshøj & R. Scherer (Eds.), *eWork and eBusiness in Architecture, Engineering and Construction* (1st ed., pp. 473–478). CRC Press. https://doi.org/10.1201/9780429506215-59

Shirowzhan, S., Sepasgozar, S. M. E., Edwards, D. J., Li, H., & Wang, C. (2020). BIM compatibility and its differentiation with interoperability challenges as an innovation factor. *Automation in Construction*, *112*, 103086. https://doi.org/10.1016/j.autcon.2020.103086

Siebelink, S., Voordijk, H., Endedijk, M., & Adriaanse, A. (2021). Understanding barriers to BIM implementation: Their impact across organizational levels in relation to BIM maturity. *Frontiers of Engineering Management*, *8*(2), 236–257. https://doi.org/10.1007/s42524-019-0088-2

Tawelian, L. R., & Mickovski, S. B. (2016). The Implementation of Geotechnical Data into the BIM Process. *Procedia Engineering*, *143*, 734–741. https://doi.org/10.1016/j.proeng.2016.06.115

Zak, J., & Macadam, H. (2017). Utilization of building information modeling in infrastructure's design and construction. *IOP conference series: Materials science and engineering*, *236*, 012108. https://doi.org/10.1088/1757-899X/236/1/012108

About the Authors

Maria Calahorra-Jimenez, PhD

Dr. Calahorra-Jimenez is an Assistant Professor in the Department of Construction Management at California State University, Fresno. Maria holds a Ph.D. in Civil Engineering from the University of Colorado Boulder and a Ph.D. in Engineering Science from the Catholic University of Chile. Before earning her doctorates, Maria worked in international engineering firms for 14 years. She served as a project engineer, project manager, and technical director in the design and construction oversight of more than a hundred infrastructure projects—totaling nearly $2 Billion—in Spain, Mexico, Panama and Chile. Dr. Calahorra-Jimenez's research lines focus on alternative and digital project delivery, sustainability, and diversity, equity and inclusion in infrastructure project delivery.

Nigel Blampied, PhD

Nigel Blampied's research and teaching focuses on project management in public transportation agencies. He teaches in the Master of Science in Transportation Management program at San José State University and is a Research Associate at the Mineta Transportation Institute. He spent most of his career in the California Department of Transportation, where he was employed in various positions in Los Angeles, Marysville, Sacramento, and Oakland. He retired as Division Chief for Project Management and BATA Support in Oakland (District 4). Dr. Blampied has co-authored several national and international project management-related standards, and he is one of the representatives of the United States on the international committee for project, program, and portfolio management standards (ISO/TC 258). Dr. Blampied holds a B.Sc. in Engineering from the University of Natal, a B.A. in Geography and Economics from the University of South Africa, an M.A. in Cross-Cultural Studies from Fuller Theological Seminary, and an M.S. and Ph.D. in Engineering and Project Management from the University of California, Berkeley.

Elhami Nasr, PhD

Dr. Nasr is a Subject Matter Expert in Construction and Project Management. He built his career of over three decades with dual careers in academia and industry. He is a Professor of Construction Engineering Management at California State University, Long Beach (SCULB). Previously, he served as Vice Provost, Interim Provost, and Vice President of Academic Affairs at Florida Polytechnic University. He also worked in industry (Caltrans) and in various national and international consulting roles, where he initiated, developed, and delivered hundreds of specialized and customized companywide project management training programs for large-scale professional organizations, in both private and government sectors.

Tariq Shehab, PhD

Dr. Shehab is a full professor of Construction Engineering Management at CSULB. He has 25 years of experience in research and teaching activities at leading universities in the United States and Canada. He worked in the construction industry for ten years, during which he gained experience in a number of areas, including inspection techniques, construction practices, cost estimating, project management, risk assessment, and construction claims. His research experience includes construction technologies, automation in construction, inspection techniques, cost estimation, applications of artificial intelligence (AI) techniques in the construction industry, development of infrastructure management systems, decision support systems (DSS), prioritization systems, and inspection of infrastructure facilities. He is the author and co-author of numerous articles that were published in many ASCE journals and other equally prestigious periodicals.

MTI FOUNDER

Hon. Norman Y. Mineta

MTI BOARD OF TRUSTEES

Directors

MTI MINETA TRANSPORTATION INSTITUTE