National BIM Standard-US 2025 Implementation Study

An Independent Review of the State of the Practice

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Executive Summary

This report summarizes the findings of a study led by the University of Washington's Communication, Technology, and Organizational Practices (CTOP) lab, in collaboration with John Messner (Penn State) and Johnny Fortune (AECO Digitech). The US construction industry continues to define and implement standards for Building Information Management (BIM). The National Institute of Building Sciences (NIBS) released its latest National BIM Standard-US (NBIMS-US), Version 4.0, with four modules, in 2023, to support the implementation BIM in the US construction industry. The survey findings suggest that some industry organizations are considering the implementation of the NBIMS-US V4 standard and its modules, while others have implemented some of the V4 modules as of 2025. This reports summarizes these findings and lessons learned during the industry's implementation of the standard, and feedback from the industry. In addition to the survey results, this report includes use cases of NBIMS-US V4 implementation by different organizations. These use cases provide a roadmap for the industry, offer insight into the implementation process through lessons learned, and motivate owner organizations to standardize BIM-based project delivery.

The key takeaways from the use cases and participatory observations during the implementation process of an owner organization are:

- The implementation process should include all project stakeholders, so that it brings value to all industry partners;
- BIM Execution Plan (BEP) should be considered a live and collaborative documentation process, updated throughout the project, and submitted to owners as a BIM deliverable;
- There is a gap of awareness and guidance about NBIMS-US V4 and more research work should be conducted to support implementation;
- More BIM Uses can be included, considering emerging technologies like AI and digital twins;
- There is comprehensive information available in the standard, but simplification of the standard would support implementation;
- COBie is challenging and complex to implement, more effort is needed to support stakeholders' understanding of the significance of COBie and its benefits for facility management and operations.

The industry has numerous opportunities, such as standardizing BIM practices, which would lead to improved quality and delivery of construction projects. Therefore, based on the guidance through the use cases, this report urges the construction industry, particularly owner organizations, to implement the National BIM Standard- US V4.

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1 Introduction

The National Institute of Building Sciences (NIBS) released NBIMS-US V4, having four modules, in September 2023 to support the adoption of BIM in the US construction industry. As the release of the standard approached its second anniversary in 2025, this team set out to assess its implementation across the US construction industry. We evaluated the implementation status of NBIMS-US V4 across the industry and documented the implementation process and lessons learned in the US construction industry. This report aims to address the need for support in organizations implementing the NBIMS-US V4 and to share success stories as use cases for the broader construction industry. Additionally, this effort will also provide a feedback loop from the industry to improve and update the standard.

The primary problem the research team aimed to investigate was: What aspects of the NBIMS-US V4 were being implemented by the US construction industry, and what lessons had been learned and feedback associated with this implementation?

There were four objectives of this study:

1) Assess the current implementation status of NBIMS-US V4 in the US construction industry.
2) Document the implementation process as a roadmap for the industry and lessons learned during the implementation of the standard.
3) Document implemented use cases to provide guidance and motivation for the industry.
4) Collect feedback from the industry regarding the NBIMS-US V4 standard.

The benefits of this research study include:

1) Advocacy and promotion of NBIMS-US V4 standard.
2) Support for the construction industry in implementing the NBIMS-US V4 standard.
3) Encourage the industry to adopt standards that facilitate better project delivery and enhanced compliance with contract requirements.

This report is organized into the following sections: methods followed by how to use this report, key takeaways, survey results, six use cases, and acknowledgments. The method for the study is elaborated along with how to use this report. The key takeaways section highlights the most significant findings from the surveys and use cases, focusing on the implementation process, lessons learned, and feedback. The survey results reflect the

status of implementing different versions and modules of NBIMS-US, as well as the utilization of resources offered by the standard. Use cases provide a detailed, explanatory single-case analysis of the NBIMS-US V4 implementation process for an organization, including lessons learned during implementation and feedback on the standard. Acknowledgements of the study participants and industry partners for their time, efforts, and contributions are furnished in the last section.

1.1 Methods

The research team conducted a practice-to-theory-based investigation to determine the implementation status of NBIMS-US V4 in the US construction industry. We adopted a qualitative research approach for this study. We employed a survey (n=21), interviews (n=6), and participant-observation research to collect data from the industry. First, in the summer of 2025, we developed a survey tool to capture the implementation status of NBIMS-US, particularly version 4, and its modules, namely: Project BIM Requirements (PBR), BIM Execution Planning (BEP), BIM Use Definitions (BUD), and Construction to Building Operations (COBie). The survey also asked which NBIMS-US V4 module components organizations were using and what resources the industry is utilizing from the standard. Second, we used the survey as a recruitment tool to conduct interviews. Additionally, we recruited interview participants through outreach to established industry connections. We developed an hour-long interview tool to more deeply explore how and why people implement NBIMS-US V4 modules and resources. Third, we had the opportunity to participate in USACE's workshops and meetings for their work to implement NBIMS-US V4. We observed teams of USACE staff and representatives from the private sector companies that support design and construction services. We attended three full-day workshops (n=3), and thirteen online follow-up meetings (n=13).

In this report, we present the information collected through the survey, interviews and the participatory observation as use cases for the implementation of NBIMS-US V4. In this report, we present 6 use cases. Each use case presents an organization, its role, such as owner, consultant, and designer, explaining the organization's typical implementation process, lessons learned, and feedback for each module of the NBIMS-US V4.

1.2 How to use this report

This report supports the understanding and implementation of the NBIMS-US V4. This report supports the industry in understanding the modules, components, and resources of NBIMS-US V4 and provides examples of how their peers are using it in practice. Section 2 presents the results from the Survey where we see results from a variety of industry

members (designers, buildings, and owners) and some of the ways people are exploring the use of NBIMS-US V2, V3, and V4. Section 3 provides a summary of the key takeaways from the interviews and case studies. These include reflections on implementation processes, lessons learned, and feedback for NBIMS-US. Section 4 provides summaries of 6 organizations and their implementation of NBIMS-US.

We hope that this work becomes the basis for annual or bi-annual assessment of NBIMS-US adoption across the construction industry. We look forward to working with NIBS and other stakeholders to further support national standards for BIM adoption.

2 Summary of Key Takeaways

2.1 Survey

The survey was conducted to determine the implementation status of the NBIMS-US V4 in the US construction industry. The industry's consideration of implementing NBIMS-US V4 is increasing compared to its predecessors, versions 2.0/3.0 (Figures 9 & 10). Nevertheless, implementation is currently low overall (Figure 10). COBie is the least implemented or considered module by these organizations (Figures 11 and 12). Overall, greater awareness of the NBIMS-US V4 is needed so the industry can benefit from implementing the standard.

2.2 Case Studies

To contextualize the survey results, we conducted six interviews with industry organizations representing designers, builders, consultants, and owners. We developed case studies from these interviews. For one owner, the USACE, we observed their work with the USACE/Industry BIM Consortia to adopt the NBIMS-US, V4 standard.

In this section, we discuss general takeaways in three categories: implementation processes, lessons learned, and feedback for NBIMS-US V4.

2.3 General Takeaways

There is a need to support NBIMS-US implementation in the industry. The survey results showed an overall low implementation of the standard (Figures 9 & 10). Interviews with industry representatives across the sector yielded several recommendations. One approach is to present use cases to the construction industry that could guide and motivate owners to implement the standard. While design and construction firms emphasized that more research is needed to determine the value creation and cost savings that owners can achieve by implementing NBIMS-US V4, they also emphasized educating the rest of the industry and supporting peer-to-peer learning. Owners such as Massport believed that developing a modularized NBIMS V4 standard would facilitate easier adoption. WSP acknowledged that implementing the standard is a complex process that could be developed as a graduate-level university course. For instance, it could be explored how to create a BEP and RACI diagram for roles, responsibilities, and workflows, and work through a case study, such as a Navy base. Thus, there are research and educational opportunities that can provide guidance to the industry on implementing the NBIMS-US V4.

2.4 Implementation Process of NBIMS-US V4 Modules

While owners should take the lead to implement the standard, the implementation process of NBIMS-US V4 should include industry stakeholders from across the capital project delivery process and bring value to all project participants. The implementation of the standard may be initiated from scratch or by transitioning pre-existing documents to align with the NBIMS-US V4. In both cases, as a best practice, owners should include their project stakeholders in the implementation process (see USACE and Massport cases below). Ideally, everyone involved in the project should participate in the implementation process. To support compliance and feasibility, internal and external stakeholders must reach consensus when developing owner-specific BIM standard documents. The process should seek to deliver value to all stakeholders and recognize when that value may be distributed unevenly across the project delivery team.

2.5 Lessons Learned from Implementing NBIMS-US V4 Modules

One of the most important lessons learned related to PBR is to define the flow of information. Owner organizations can incorporate information from the NBIMS-US V4 PBR into their project BIM requirements but should be aware of the capabilities of the project delivery teams and the associated costs of the BIM requirements.

One key lesson learned is that BEP is a live, collaborative document as the project progresses. In their interviews, Massport and the design-build organization emphasized that the BEP is a dynamic document that would be updated throughout the project's life cycle. As Massport mentioned, this should be a contractual obligation for the parties involved to keep the BEP up to date at each project milestone and to submit it to the owners as a BIM deliverable. The design-build organization shared that they produce different versions of the BEP and keep it up to date as the project progresses. The responsibility for keeping the BEP updated would depend on the project phase and the lead party for that phase. For instance, the designer would be responsible for the design phase, and the general contractor would be responsible during the construction phase. This clarity of roles and responsibilities helps keep the document up to date, avoiding ambiguity and misunderstandings among the project team.

One of the key lessons learned from the BUD module is to define BIM uses earlier in the BEP and develop clear definitions about the benefits and implications of BIM uses in terms of time and cost. Further, identify and quantify the value created by using BIM uses, rather than utilizing it solely for the sake of technology implementation.

The biggest lesson learned about the COBie V3 module in NBIMS-US V4 is that it is perceived as too complex. The survey results also showed that COBie V2.3 and V3 were consistently not considered modules (Figures 11 & 12). There is a need to raise awareness and provide training on this standard, as there is limited understanding, and different stakeholders hold varying perspectives.

2.6 Feedback for NBIMS-US V4

There is a significant lack of awareness and guidance regarding NBIMS-US V4, and owners should be informed about the standard and its resources through industry conferences and other relevant channels. The survey results (Figures 13, 15, & 17) show the implementation status of items of each NBIMS-US V4 model (PBR, BEP, and BUD), and Figure 19 presents the status of resources leveraged from the NBIMS-US V4. One of the key benefits that should be communicated to owners is the terms and definitions shared across the standard. Another tool that could be utilized is the BEP template, which would help owners and project delivery teams better understand their projects by attracting higher-quality proposals and supporting a shared understanding of BIM requirements and uses. Additionally, it is essential to inform and inspire owners about the potential applications of BIM models and data for operations.

Although NBIMS-US V4 is a practical and beneficial resource for owner organizations, some found that it is too comprehensive and should be simplified so that any owner can implement it without requiring technical assistance.

Regarding future development, additional BIM applications can be considered, with emerging technologies such as AI and digital twins taken into account. The standard can address the utilization of AI for prediction and model generation. In the case of digital twins, what requirements should be added to the PBR, and how should COBie be used in view of the digital twin? These BIM use cases for future emerging trends should be incorporated into the standard.

3 Implementation Survey Results

We conducted a survey to determine the implementation status of the National BIM Standards-US in the US construction industry, including how people used different versions, modules, module elements, and resources. In total, we obtained 63 responses, but we had 21 valid responses. Only 100% completed survey responses were considered valid for the quantitative analysis.

Overall, the consideration of implementing NBIMS-US V4 by the sector is increasing compared to its predecessors, versions 2.0/3.0. Among the surveyed organizations, 13 reported adopting (considering, planning, in progress and implemented) NBIMS-US V4, compared with 9 organizations considering adoption of NBIMS-US V2.0/3.0. At the same time, the number of organizations not considering NBIMS-US standards decreased from 5 to 3, while those unaware of the standards decreased from 7 to 5 (refer to Figures 9 & 10). Nevertheless, implementation is currently low overall. Though almost all the components of Project BIM Requirements (PBR), BIM Execution Planning (BEP), and BIM Use Definitions (BUDs) are defined or in the process of being represented by most of the participating organizations, some organizations don't know or haven't defined those components. Of the four modules, COBie is the least implemented or considered module by these organizations. Overall, more awareness is needed about the NBIMS-US V4 so that the industry can benefit from implementing the standard.

3.1 Survey Respondents

This section provides demographic details of the organizations that participated in the survey. The BIM manager role had the highest number of participants (n = 4), and the remaining roles were represented by the same number (n = 1), as shown in Figures 1 and 2.

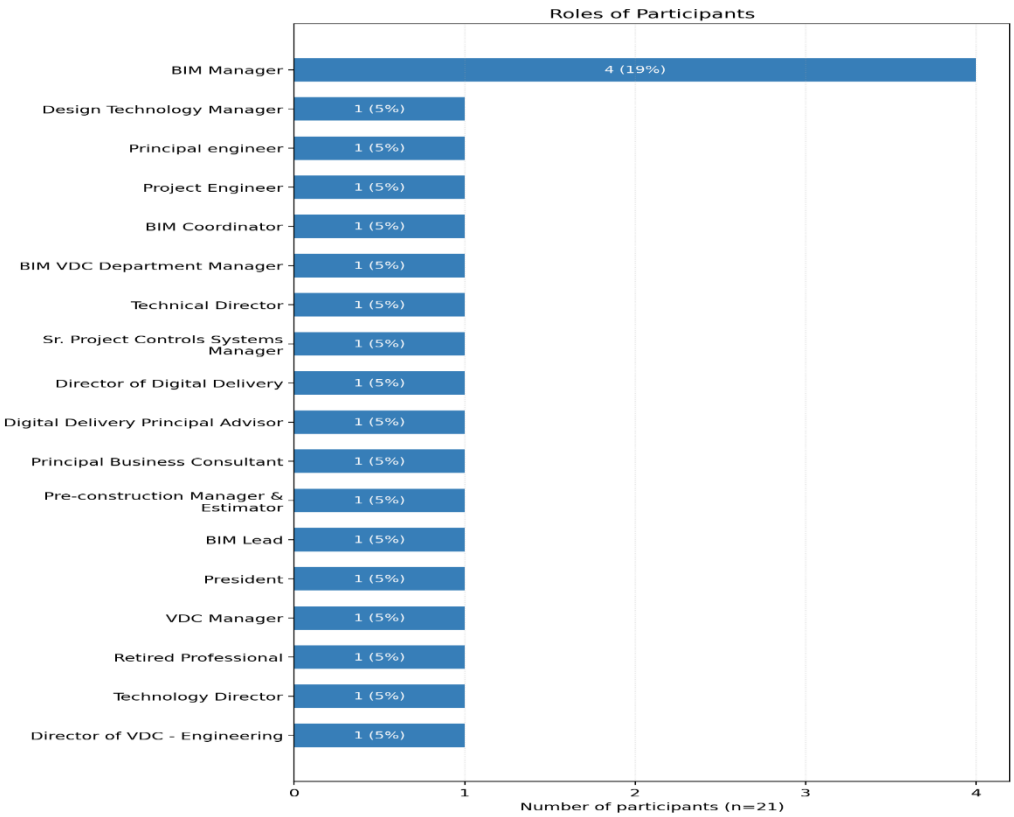

Figure 1: Roles of Respondents

Figures 2 and 3 exhibit the number of years of experience of the participants. The roles of the participants, along with their experiences, are shown in Figure 2. More participants (n = 15) have 15 or more years of experience, while the least experienced have 1 to 5 years, as shown in Figures 2 & 3.

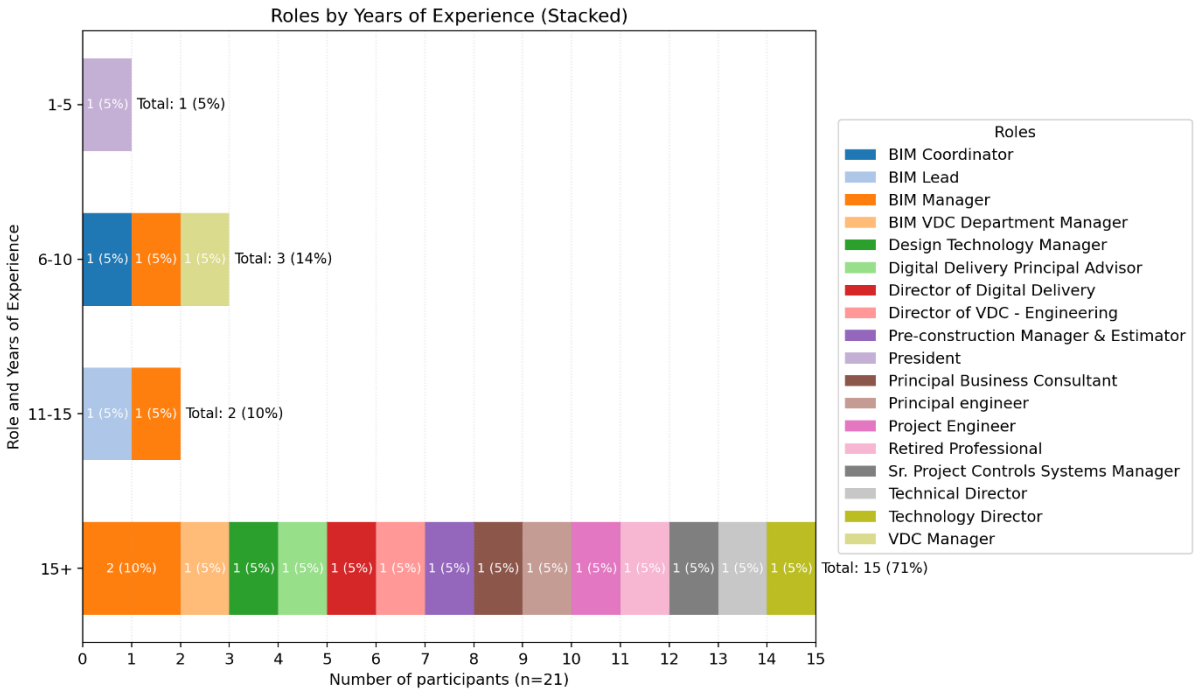

Figure 2: Respondents' Years of Experience with Roles

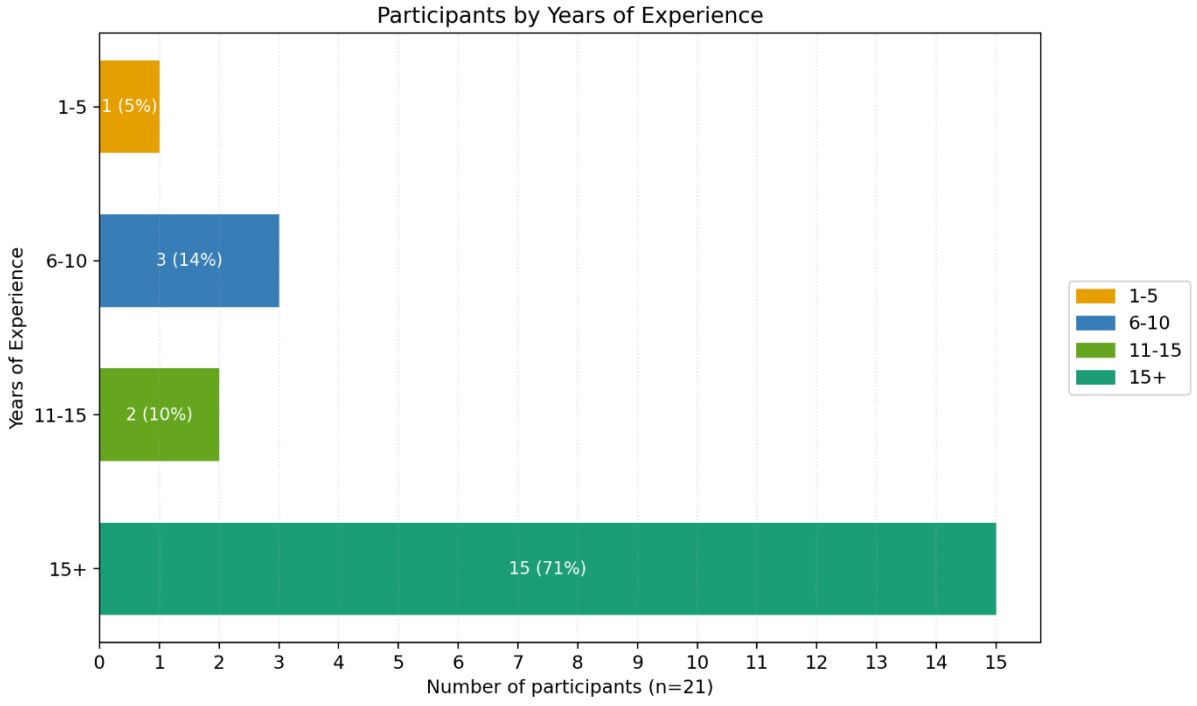

Figure 3: Overall Distribution of Experience

When asked about the primary function of the organization in terms of design, construction, and ownership, most participants were from design organizations (n = 9), followed by construction organizations (n = 6) and public ownership (n = 2). Some organizations list themselves as generalists, industry SME, rendering advisory services, and service providers. However, most of the organizations are from the design sector.

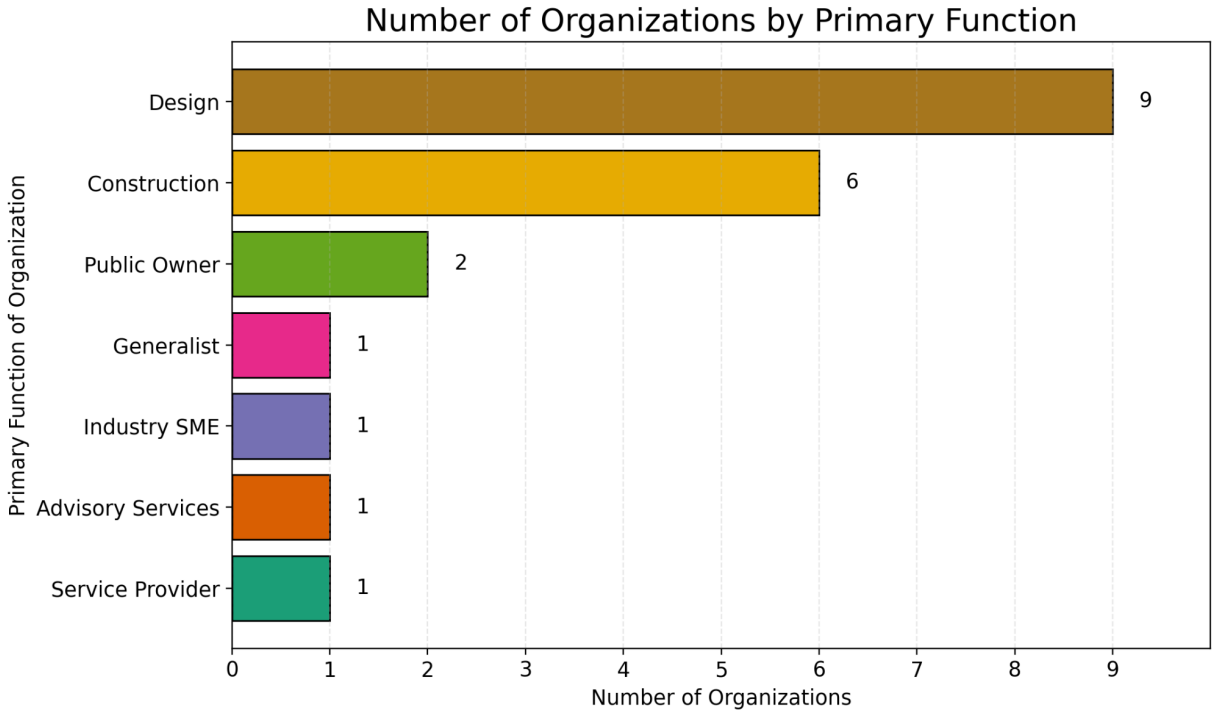

Figure 4: Number of Organizations by Primary Function

These organizations are further categorized by primary function: design, construction, or public owner. The graphs show that engineering-led multidisciplinary firms (E/A) constitute the highest number among design firms. However, construction organizations were all general contractors, and both public owners were major transportation facility owners.

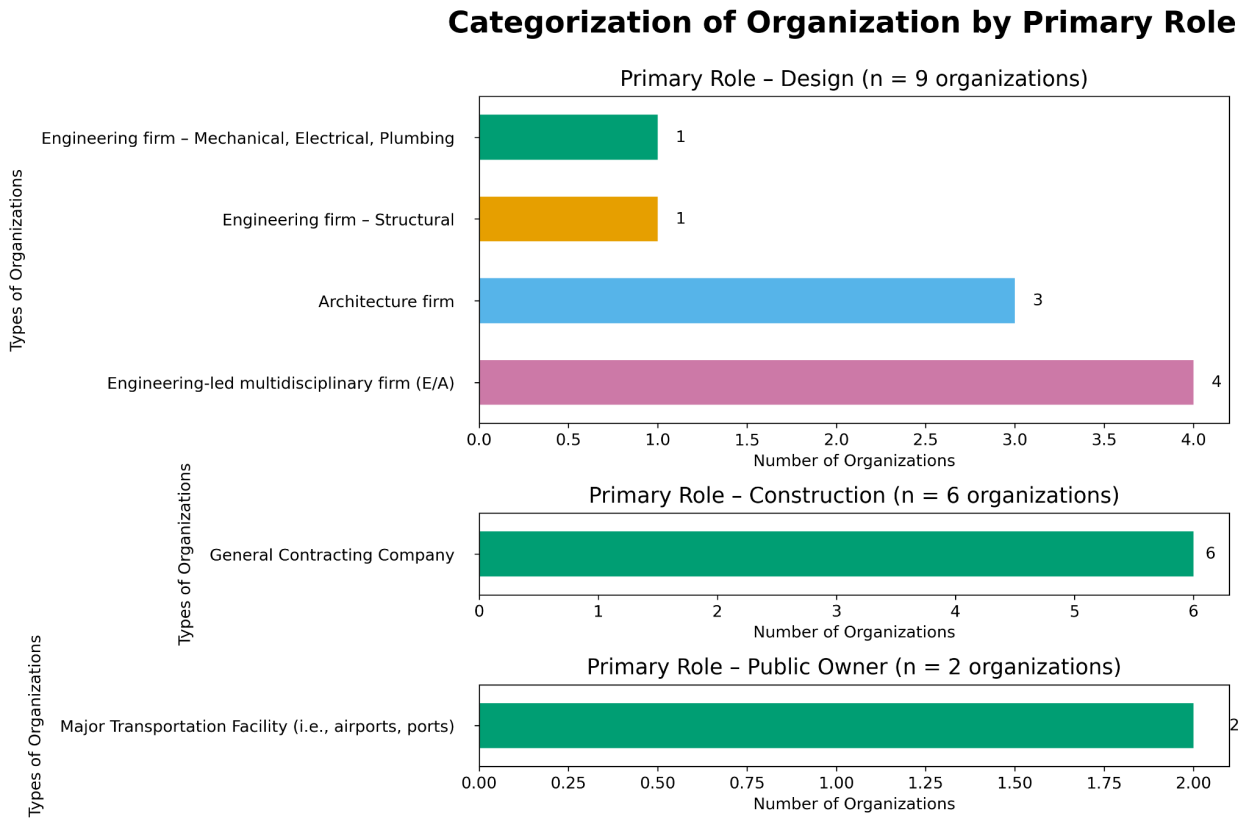

Figure 5: Categorization of Organizations by Primary Role

Additionally, we inquired about annual billing from design organizations and annual revenue from construction organizations; the results are illustrated in Figures 6 & 7, respectively.

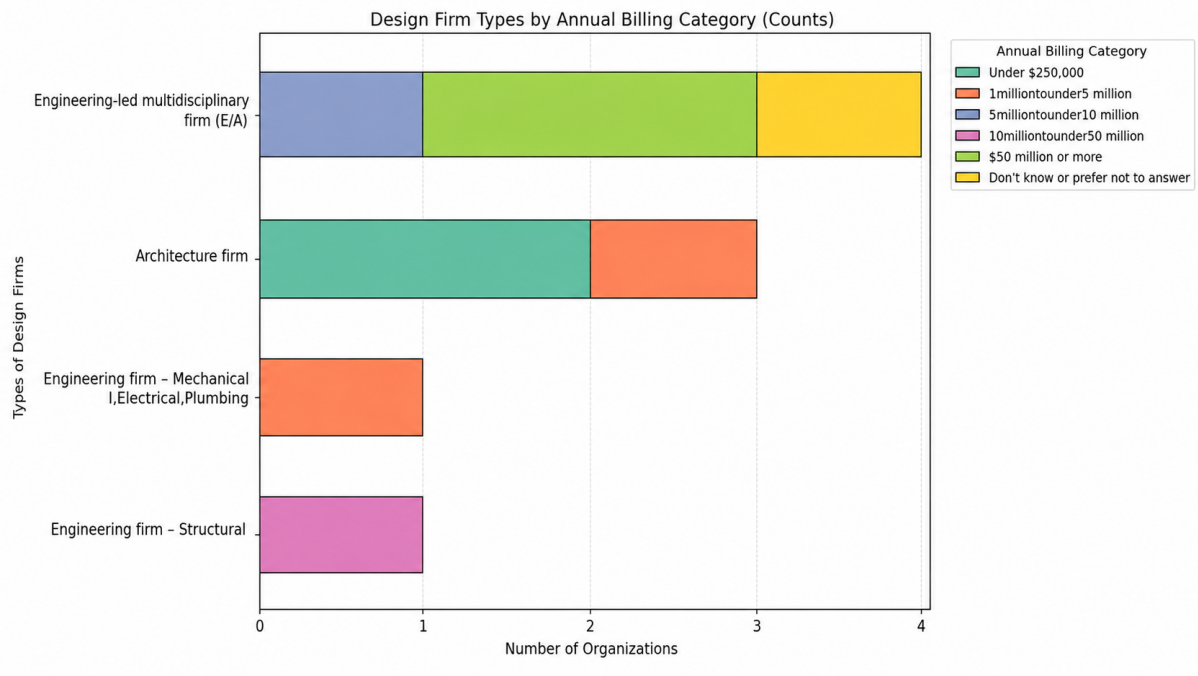

Figure 6: Design Firm Types by Annual Billing

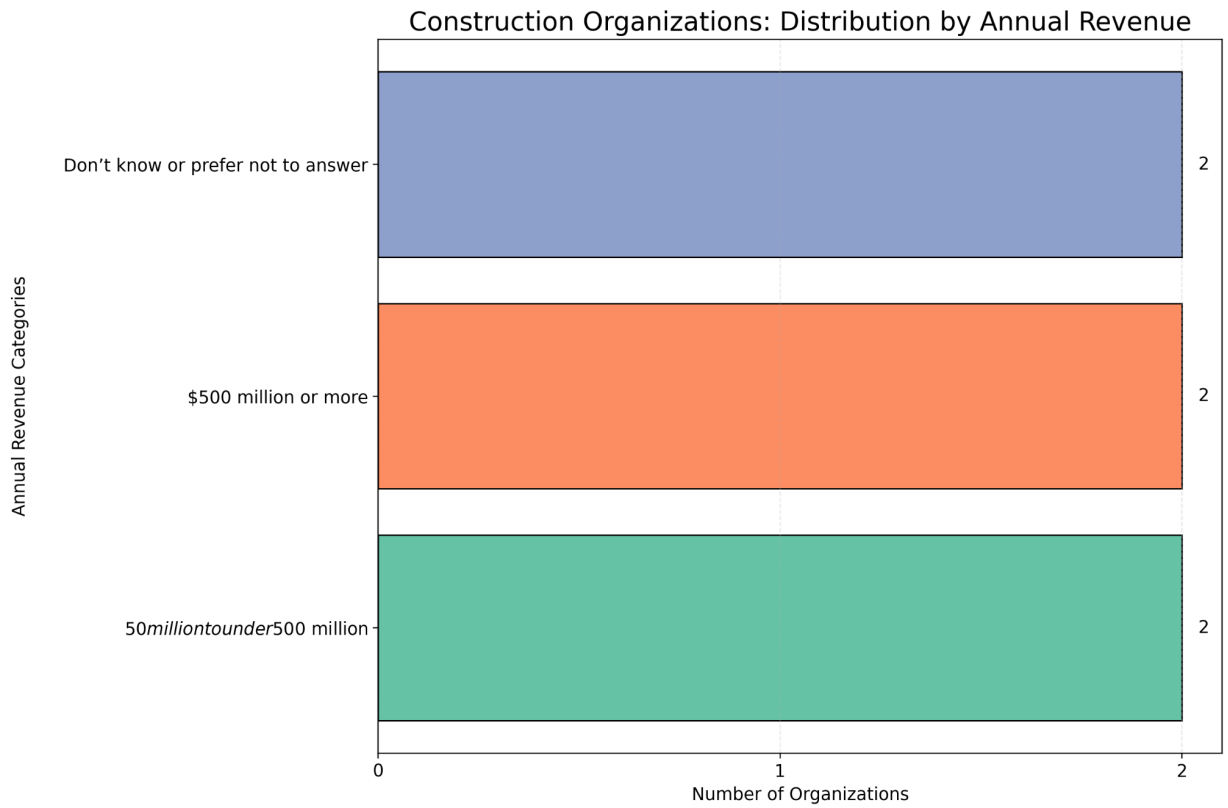

Figure 7: Construction Organizations Distribution by Annual Revenue

The survey also reveals the core markets in which these organizations are currently operating. Figure 8 illustrates the core markets of design, construction, public owners, and organizations classified as 'other', along with the core markets in which they operate.

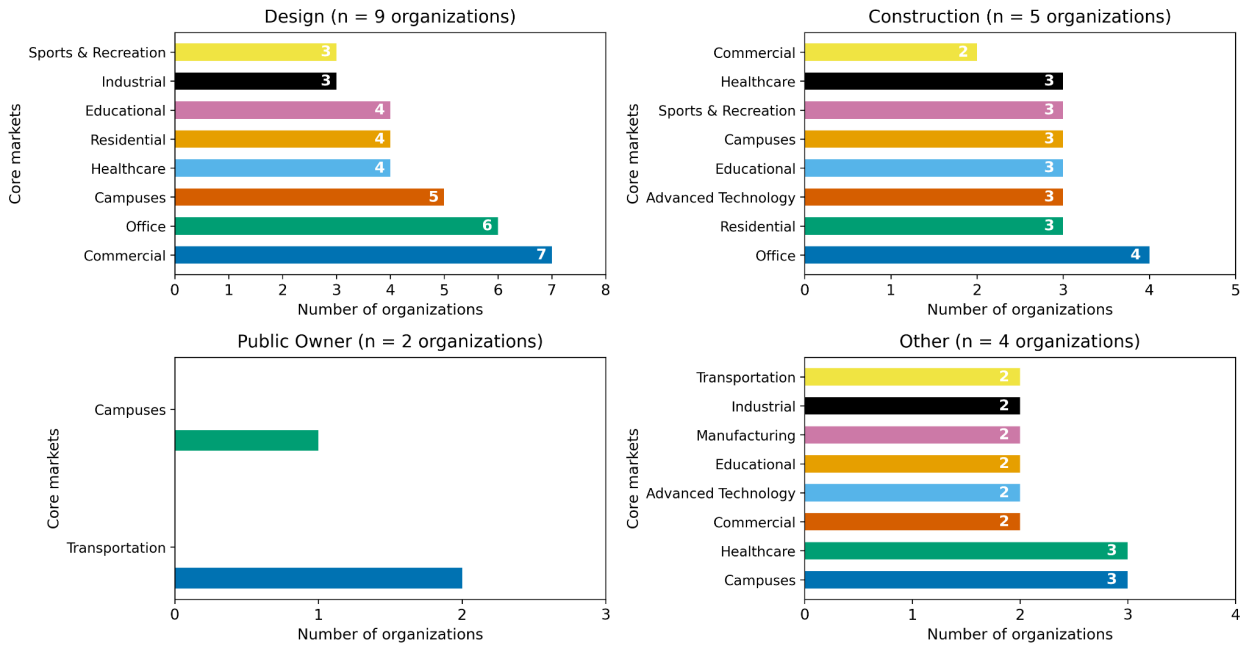

Figure 8: Core Markets of Organizations

3.2 Survey Results

The following section presents the main survey findings on the implementation of NBIMS versions 2.0/3.0/4.0, as well as modules such as PBR/BEP/BUD/COBie, their components, and the resources provided by NBIMS that are leveraged by the industry.

Figure 9 shows the adoption status of NBIMS-US V2.0/3.0, previous versions, on a scale of 0 (not aware) to 5 (implemented). Most participants (n = 7) were either unaware of previous standards or did not consider implementing them (n = 5). Only two organizations had implemented the standard, three were in progress, and one was in the planning stage. Overall, most participants were either unaware of or not considering adopting previous versions of the standard.

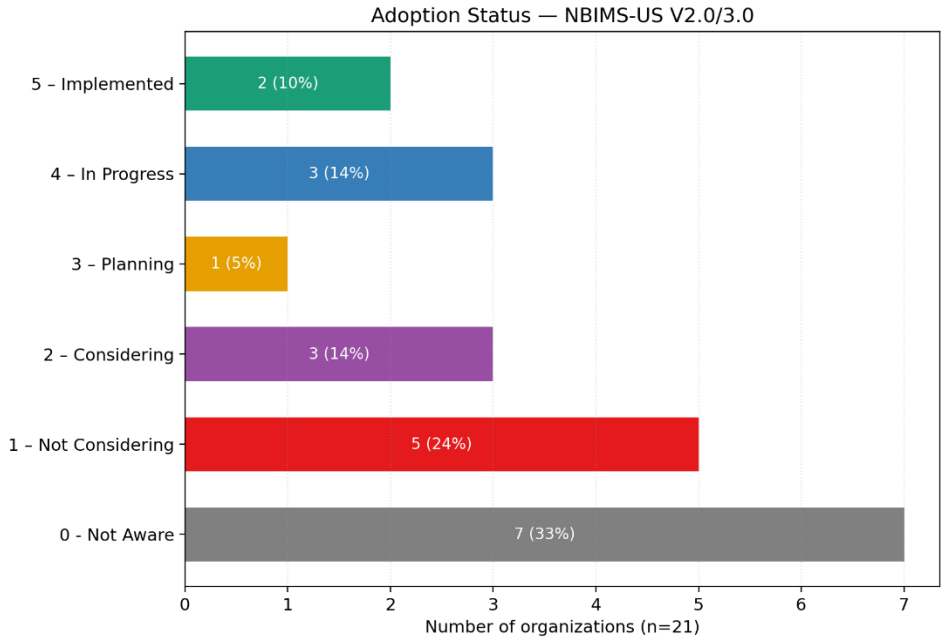

Figure 9: NBIMS-US V 2.0/3.0 Adoption Status

For the current NBIMS standard, NBIMS-US V4, shown in Figure 10, eight participants were considering adopting the standard; two have implemented it, two are in the process of implementation, and two are in the planning stage. Fewer participants, compared to the previous versions (V2.0/3.0), were unaware or did not consider implementing the latest version of the standard, while a larger number of participants are considering it. So, participants are aware and consideration has increased slightly, but the implementation and planning of implementation have remained essentially unchanged from the previous versions. Thus, there is a need to expand awareness of the standard and support for implementation.

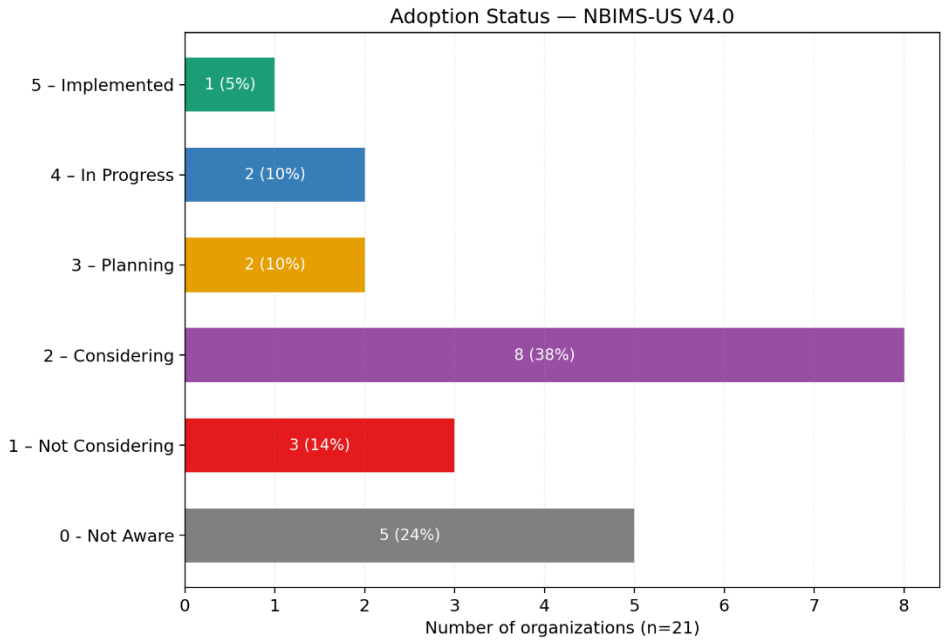

Figure 10: NBIMS-US V 4.0 Adoption Status

The adoption status of previous and latest versions of the BEP and COBie is illustrated in Figure 11. The earlier versions of BEP were V2.0 and V3.0, and the newest version is V4.0. In the case of COBie, the previous version is 2.4, and the latest version is 3.0. Ten participants did not consider COBie, whereas nine participants were considering BEP V4.0. However, the overall implementation rate of the latest NBIMS versions remains low among participants, and they have instead adopted previous BEP versions and have not yet updated to V4.0.

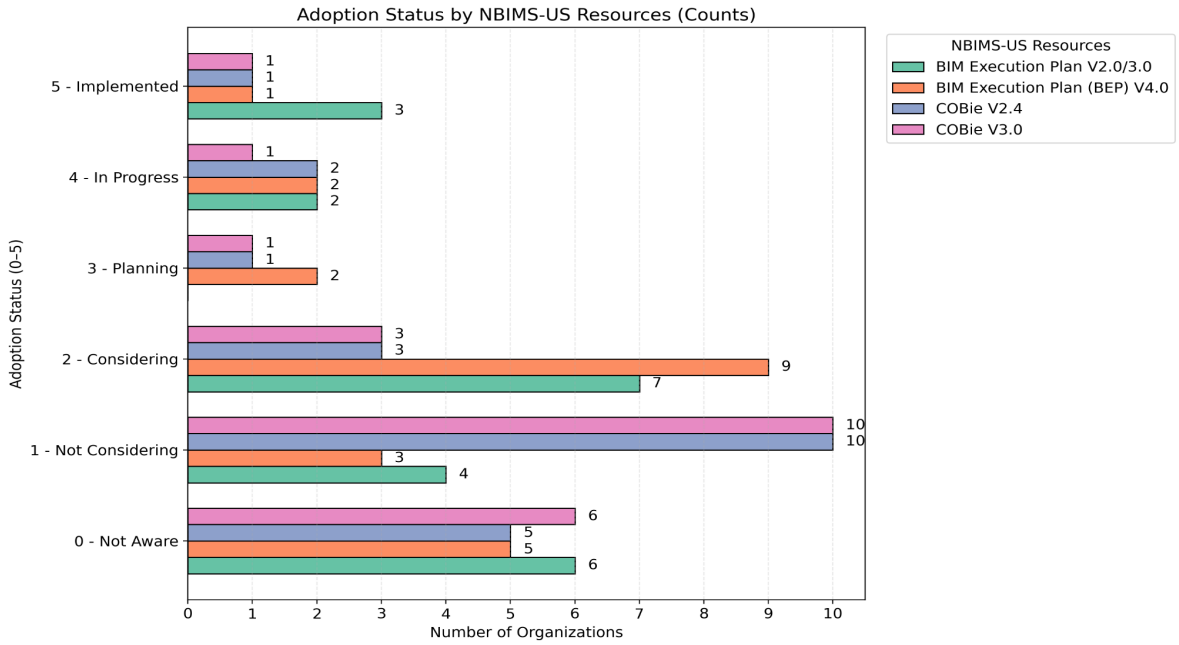

Figure 11: Adoption Status of Different Versions of BEP and COBie

When specifically asked about the modules, it was identified (Figure 12) that many participants plan to implement PBR (n = 8), BEP (n = 7), and BUD (n = 7) using NBIMS-US V4. Still, fewer participants are planning to implement COBie (n = 5). The implementation is again low for all modules, with none of the participants implementing COBie and PBR, and only two and one participants implementing BEP and BUD, respectively. Thus, while the industry is considering the implementation of all four modules of NBIMS V4, full implementation is currently low.

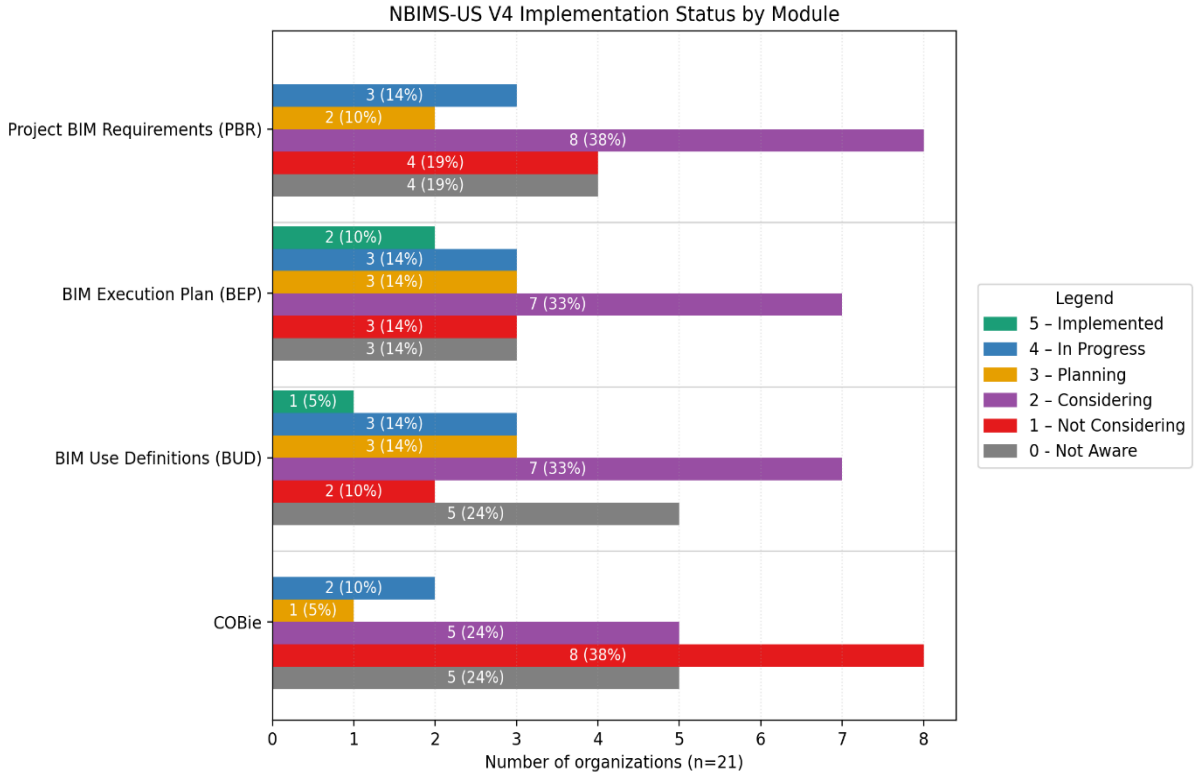

Figure 12: NBIMS-US V4 Implementation Status by Modules

Figure 13 shows that all elements of the NBIMS PBR V4 were defined in the Project BIM Requirements of most organizations. For instance, like modeling requirements (n = 11) and BEP (n = 11). Nevertheless, some organizations have either not defined these components or are unaware of them. For instance, some organizations have not defined model requirements (n = 6), BIM uses (n = 5), and intellectual property (IP) rights (n = 5). Some organizations are unaware of these components, like Quality Management Strategy (n = 3), but their number is relatively small. Thus, more organizations have either defined or are in the process of implementing those PBR components, while a smaller number of organizations haven't defined or are unaware of them.

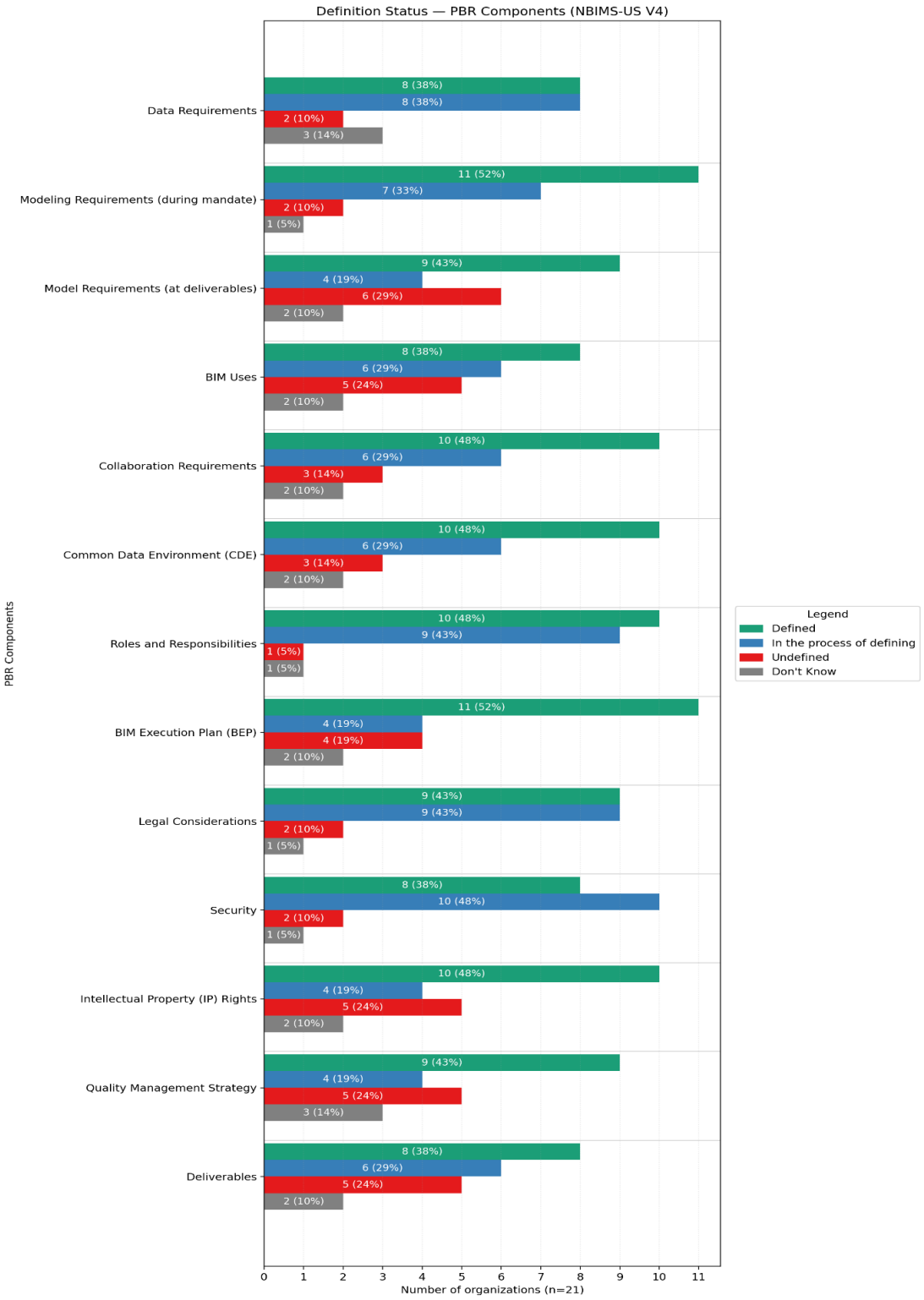

Figure 13: NBIMS-US V4 Implementation Status of PBR Items

Participants were asked which components their organizations have utilized directly from the NBIMS-US V4 related to PBR. Figure 14 shows that BIM Execution Planning (n = 12) is the most widely used component, followed by BIM Uses (n = 8). On the other hand, legal considerations (n = 2), security (n = 2), and intellectual property (IP) rights (n = 2) are the least adopted components.

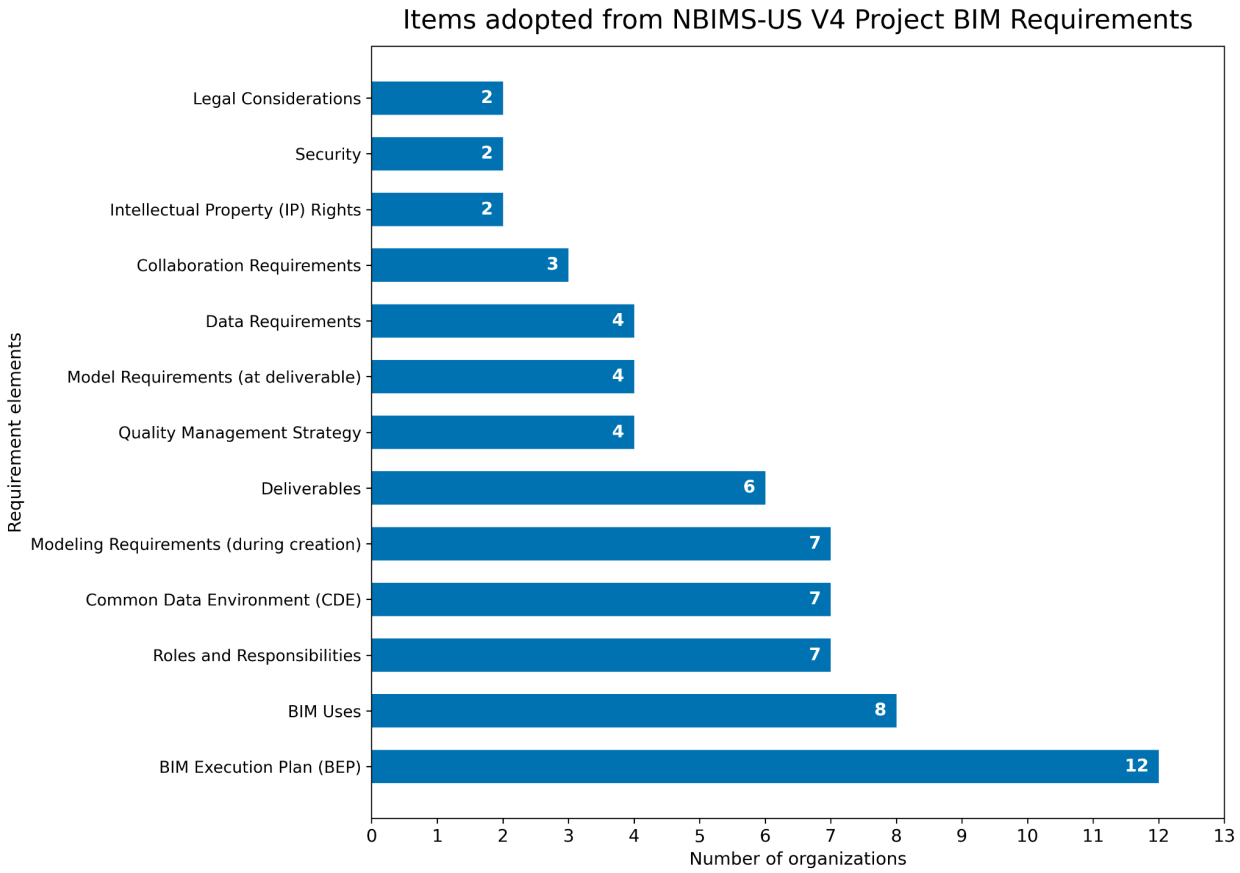

Figure 14: Items Adopted from NBIMS-US V4 PBR Module

Participants were asked about components of their BEP. All the participants have defined the components in their BEP, which are present in the NBIMS-US V4 BEP. For instance, as Figure 15 shows, set BIM goals (n = 11), BIM Execution Process (n = 10), information exchange (n = 10), supporting infrastructure (n = 9), and select BIM uses (n = 8). Conversely, some organizations are unaware of (n = 4) or haven't defined (n = 4) these requirements, such as the development of supporting infrastructure.

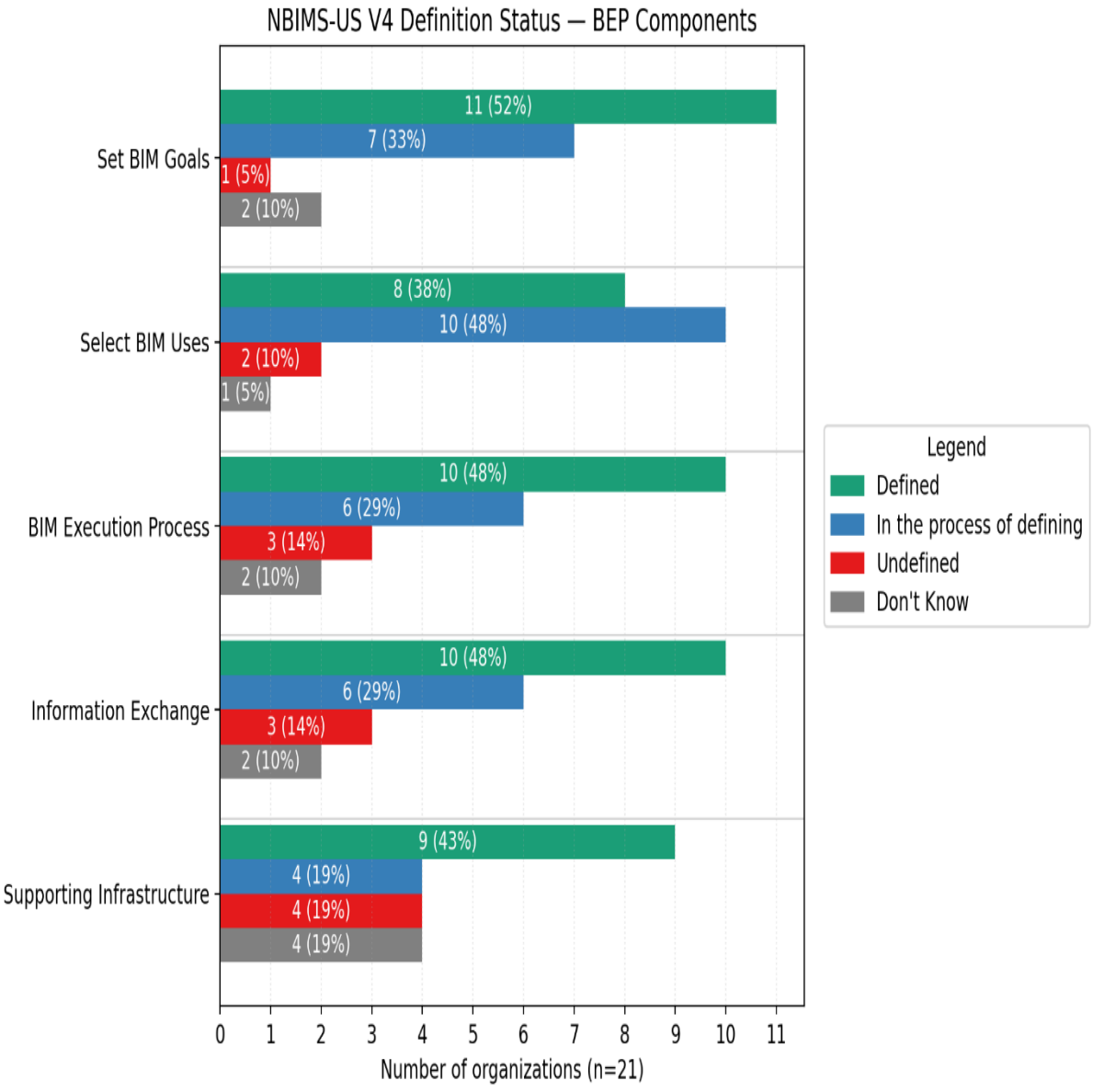

Figure 15: NBIMS-US V4 Implementation Status of BEP Items

Figure 16 shows the number of organizations that directly adopted those components from the NBIMS-US V4 BEP module. Again, the least adopted component is supporting infrastructure (n = 4). In contrast, BIM execution process (n = 11), information exchange (n = 9), setting BIM goals (n = 8), and selecting BIM uses (n = 8) are mainly adopted from the NBIMS-US V4 BEP module.

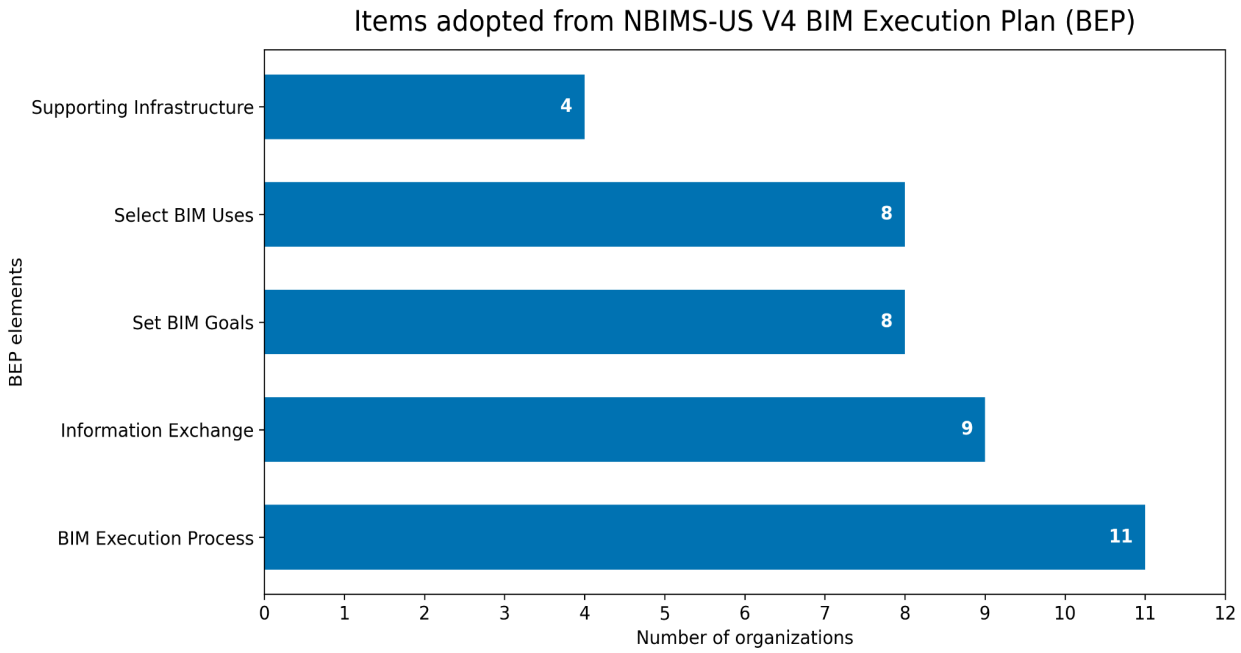

Figure 16: Items Adopted from NBIMS-US V4 BEP

Figure 17 exhibits the use of BIM by the participants. There is a small percentage of organizations that aren't aware of BUDs. Most organizations have defined or are in the process of defining their BUDs. For example, establishing project requirements (n = 11) and sequence construction (n = 11) were the most clearly defined BUDs. Whereas layout construction, compiling record deliverables, and producing construction documentation were the most undefined (n = 5) BUDs.

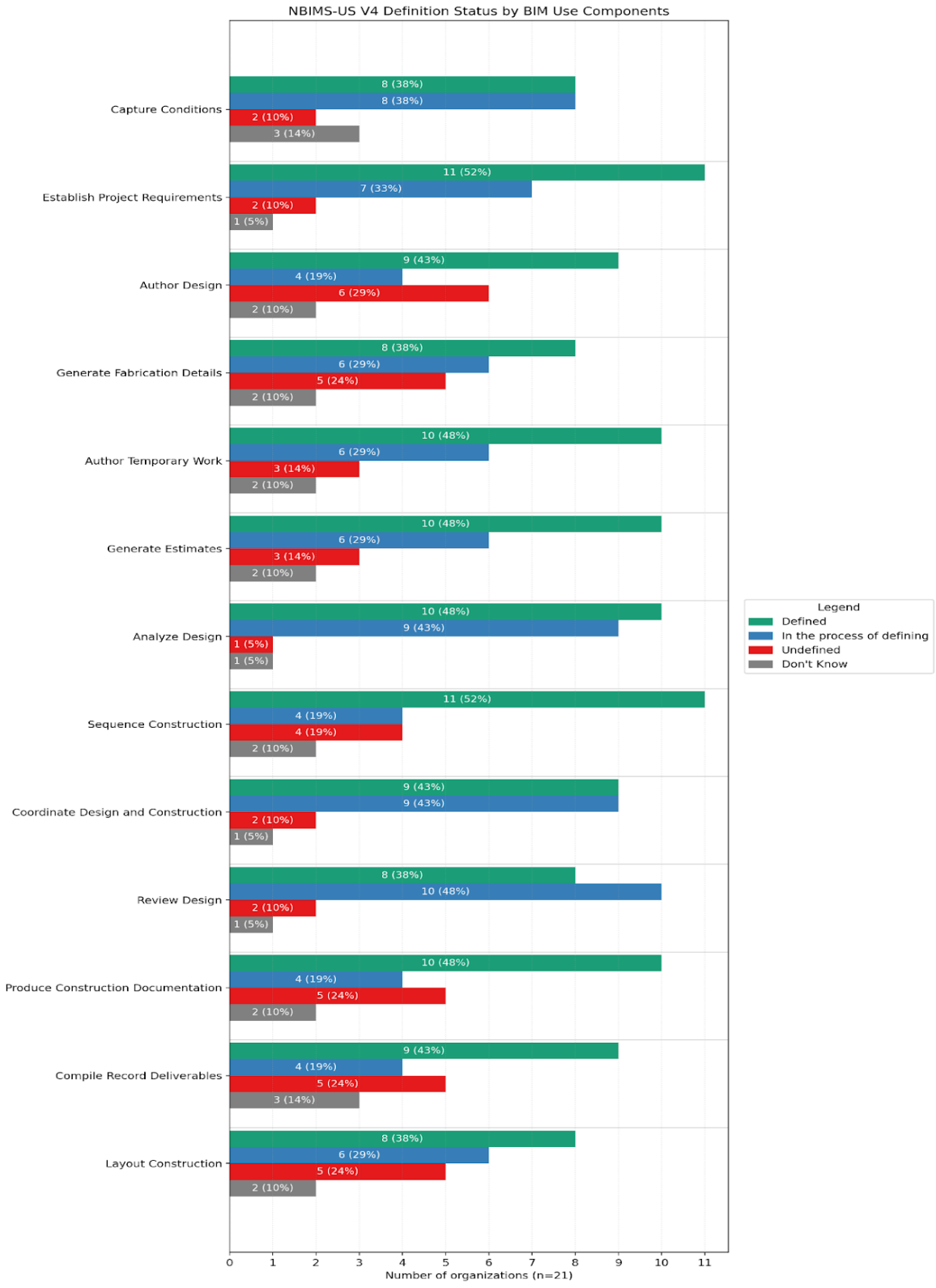

Figure 17: NBIMS-US V4 Implementation Status of BUD Items

Figure 18 shows the adoption rates of the BIM Use Definitions from the standard. Established project requirements (n = 9), reviewed design (n = 8), and captured conditions (n = 8) were mostly adopted, with the least adopted BUDs being temporary work (n = 2) and generating fabrication drawings (n = 2). However, overall implementation of the BUDs is on the lower side in the construction industry.

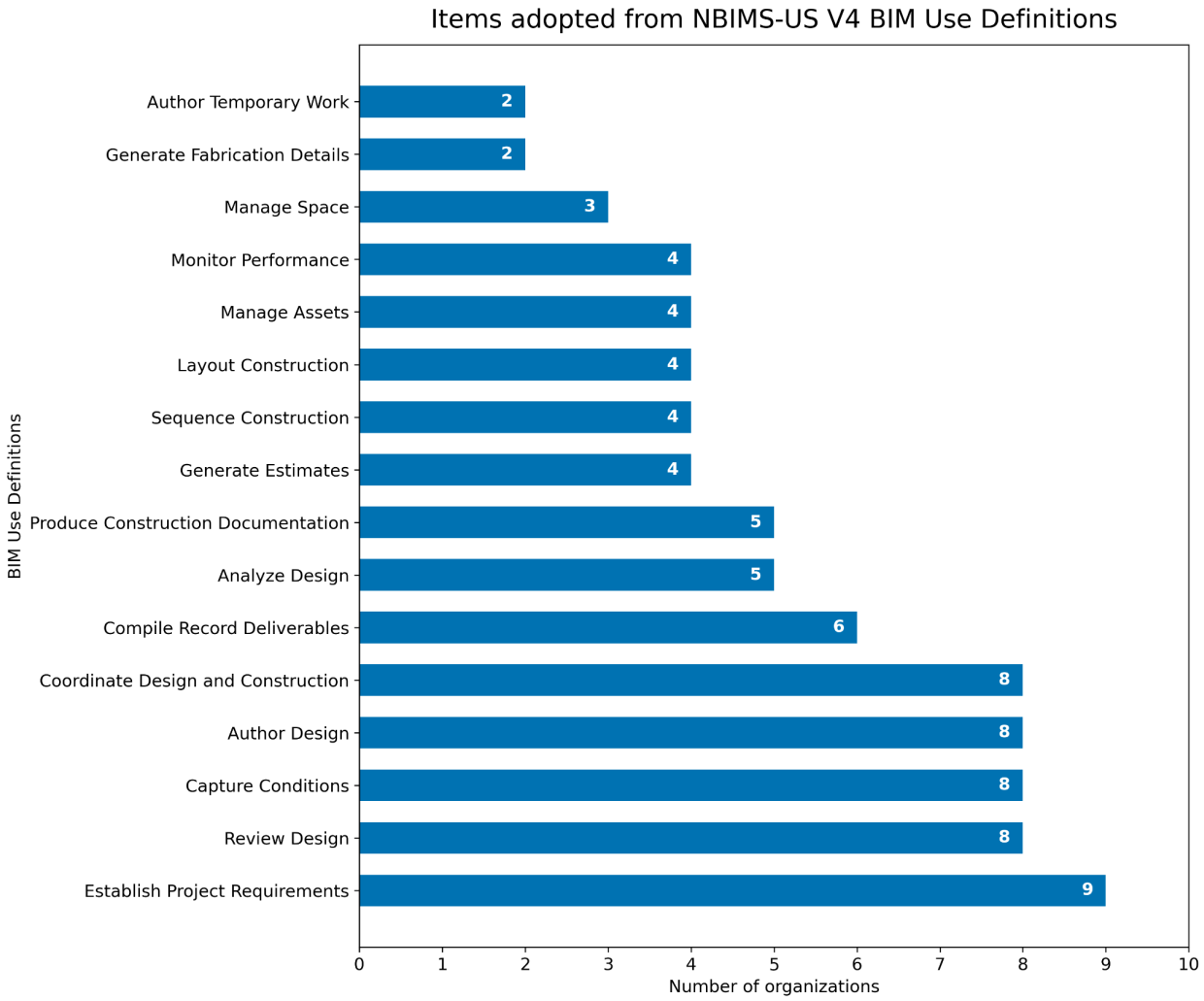

Figure 18: Items Adopted from NBIMS-US V4 BUD

The participants were asked about the resources they were using, as provided by the NBIMS-US V4. The industry is not using most of the resources that the standard has provided, as shown by Figure 19. Nonetheless, few organizations had downloaded and were using the BEP template and the BEP model element template. The industry can utilize the available resources from the NBIMS-US V4, which is currently lower.

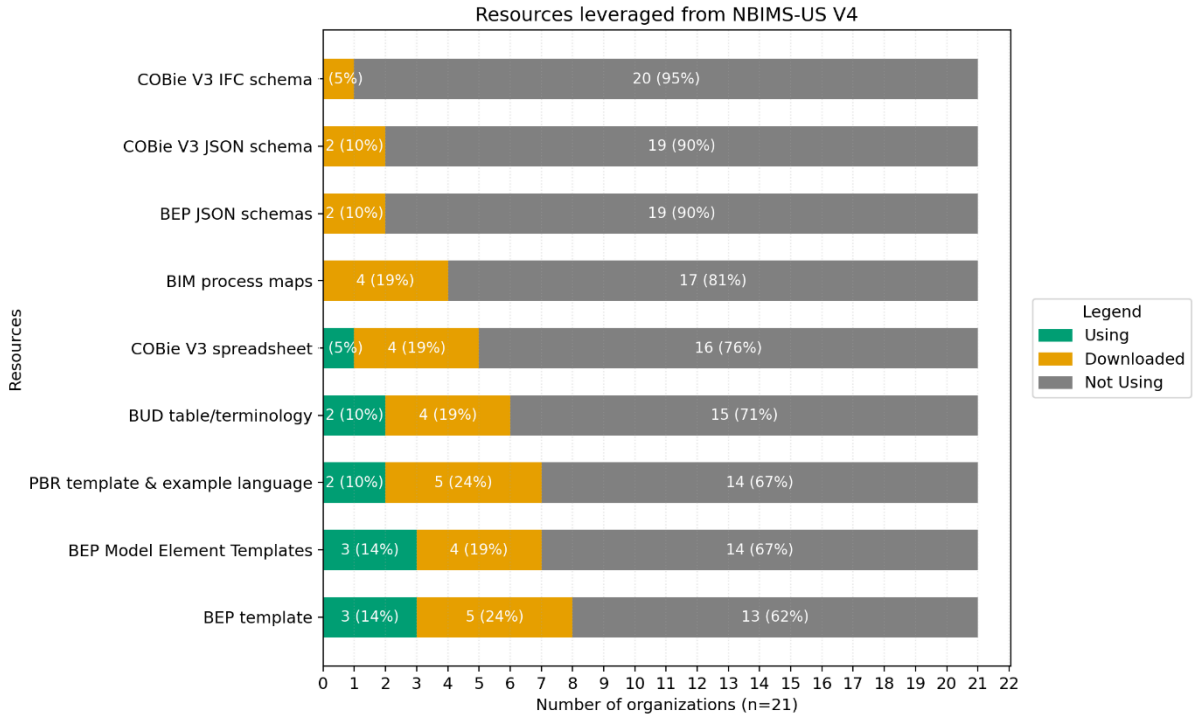

Figure 19: Resources Leveraged from NBIMS-US V4

4.0 Case Studies

In this section, we present implementation case studies from owner organizations as well as design, construction, and consulting companies. In the first case, USACE, the team participated in a series of meetings where USACE staff and industry stakeholders worked to update USACE standards. The other case studies in this collection were developed based on interviews with representatives from each of the organizations.

4.1 USACE (Owner) NBIMS-US V4 Implementation Use Case

4.1.1 Executive Summary

The U.S. Army Corps of Engineers (USACE) implemented the NBIMS-US V4 for its BIM-based project delivery. This implementation required revising existing documents, such as BIM PxP to BIM Execution Planning (BEP), to align them with the NBIMS-US V4. USACE collaborated with industry partners through its USACE/Industry BIM Consortium and undertook an extensive review of standard documents, involving internal and external stakeholder deliberations, to produce agreed-upon new working documents. The consortium developed an implementation process, added and removed information from the standard templates as required by the USACE (a large public owner organization), and revised a PxP checklist to a BEP checklist for the efficient submission and resubmission of Request for Proposals (RFPs) from bidders.

4.1.2 Organizational Overview

The USACE was established on March 16, 1802, and currently has nine divisions and 45 districts worldwide. USACE is committed to delivering Civil Works (CW), Military Programs (MP), Work for Others (WFO), Support for Others (SFO), Installation Support, and Environmental Programs through engineering, construction management, environmental protection and restoration, operations, maintenance, and repair activities. The breadth of operations worldwide makes the USACE one of the world's largest public design, engineering, and construction management agencies.

4.1.3 Implementation Logistics and Industry Engagement

The USACE coordinated an extended collaborative effort with its USACE/Industry BIM Consortium to revise contract requirements and process documents to bring them into alignment with NBIMS-US V4. The USACE established an Industry BIM Consortium in 2006 to engage industry partners. USACE conducts periodic three-day meetings of the Consortium, which are held every three months. As the USACE sought to overhaul its

documents and revise them in light of NBIMS-US V4, these three-day workshops evolved into a 10-week prolonged effort through online breakout meetings, involving six different teams (details provided below). The frequency of the meetings was twice a week, each lasting one hour. The purpose of these online meetings was to review existing documents and revise them using NBIMS-US V4, specifically Requests for Proposal, PxP, and the PxP checklist. USACE created six different teams, formed with specific tasks as listed below; however, this case study will focus only on efforts relevant to implementing NBIMS-US V4.

- TEAM 1 - Spec 01 33 39 Development
- TEAM 2 - Checklist & Checklist Guide Update
- TEAM 3 - Convert PxP & PxP-Checklist to BEP
- TEAM 4 - Update Record Package Guidance
- TEAM 5 – Prepare Model-Based Construction Coordination Guide for Publication (Postponed)
- TEAM 6 - Source Selection Evaluation Criteria

The moderator of the meetings (a USACE employee) informally outlined the agenda at the start of the meetings, discussed it with industry stakeholders, made changes to the template, and/or added comments to the working file to make adjustments after further clarification. These working files were posted on the Basecamp 2 platform for the USACE/Industry BIM Consortium, allowing industry partners to review and provide feedback on the working documents before and after meetings. This is a model other owners can use to engage relevant industry stakeholders when implementing and/or transitioning to BIM standard documents.

4.1.4 Implementation Process

4.1.4.1 RFP Alignment with NBIMS

One of the teams worked to establish a consolidated source selection approach that aligns USACE's RFP and evaluation materials with the NBIMS-US V4 workflow. The task of the team was: "*Development of the Source Selection Process with Contractor's BIM Qualifications as a Technical Evaluation Factor*". The purpose of the source selection process development was an attempt to create a USACE (an owner) specific BEP RFP document to enable the USACE to initiate Step 1: Create/Revise Owner-Specific Requirements Documents of the NBIMS workflow Figure 5.8-4 Process Map of Contract-Based Execution of BIM. The team had to reconcile and consolidate four different existing documents: RFP, Evaluation, SSEC, and Evaluation Scoring. For the sake of simplicity, the team combined all four documents into one, with two subsections: Part 1 and Part 2. Part 1 would be the RFP, and Part 2 would

be the rubrics to evaluate the RFP responses. The new names of the document at different stages of the bidding process would be: RFP BEP, Proposal BEP, and Project BEP, to maintain consistency with the terminology proposed by ISO 19650 and NBIMS-US V4. This change consolidated the scattered documentation and aligned them with the NBIMS-US V4, bringing clarity to all project stakeholders and ultimately leading to improved project delivery.

The team strengthened the RFP language to clearly enforce BEP requirements. While developing the document, it was suggested to use language like 'must/shall' in the RFP to implement a requirement on the bidder/offeror, rather than using words like 'should', which might give the impression that the bidder/offeror has an option. It is better to be more straightforward and assertive with the language to enforce the BEP requirements in the RFP.

Industry stakeholders emphasized the importance of explicit and well-signposted requirements in the RFP to reduce confusion, waste time, and improve efficiency. The bidders/offerors want to know all requirements in the RFP as soon as possible. From an industry standpoint (bidders/offerors), it is helpful to provide signposting in the RFP, such as referencing a section with a number to furnish the details, or explicitly outlining all the requirements in the same sentence for clarity and time efficiency, rather than requiring back-and-forth navigation through the documents. This structure would help the industry save time by consolidating all necessary details related to a requirement, eliminating ambiguity, and ensuring compliance with all requirements.

4.1.4.2 Process Framework for BEP Implementation

USACE's BEP implementation process relied on collaboration with industry partners to develop strategic guidelines, engage in in-depth discussions on required information, and establish consensus between internal and external stakeholders during the development of the BEP document. This section outlines the USACE's process framework for implementing the NBIMS-US V4 BEP, which construction organizations can use as a basis for their own implementation. The USACE engaged with the industry partners through the USACE/Industry BIM Consortium. The consortium established strategic guidelines that these documents should be mutually beneficial for all stakeholders, and that there should be no duplicate content in the RFP to minimize the effort required for bidders/offerors.

NBIMS-US V4 is designed to accommodate the diverse roles within the construction industry, allowing each organization to implement the standard according to its specific needs. The BEP is also designed with the same idea for the construction industry, serving

various organizations, including owners, designers, consultants, and contractors. The different roles of organizations determine their specific requirements, and the standard can be implemented according to their needs. Organizations must be aware of the file format while revising and implementing NBIMS-US V4 BEP. One of the biggest implementation challenges was the file format difference between the USACE PxP (a Microsoft Word document) and the NBIMS-US V4 BEP (a Microsoft Excel spreadsheet).

The USACE and USACE/Industry BIM Consortium developed this approach during the transition from USACE PxP to NBIMS-US V4 BEP.

Based on the agreed strategic guidelines, the consortium reviewed the NBIMS-US V4 BEP template (MS Excel spreadsheet) overall, went through all the tabs of the BEP template, and the major tables of the required information that the USACE, as an owner organization, might need before getting into the information details column by column.

Implementing a new standard is an iterative process, so utilizing these techniques would provide clarity, reflection, and discussion time for stakeholders regarding the content of the template as the standard is implemented. One method for developing consensus among stakeholders during the transition and implementation of NBIMS-US V4 BEP could be to utilize color coding to add or remove items from the NBIMS-US V4 BEP template, rather than deleting items during the initial review. Another method is to strike off the information that stakeholders intend to remove. USACE initially adopted striking off the information but later switched to color coding for better readability and clarity.

The meeting leader ensured that all columns in the NBIMS-US V4 BEP template (MS Excel spreadsheet) were unhidden before stakeholders proceeded with the discussion.

A drop-down function in the spreadsheet was added to incorporate more information in a cell, allowing users to pick and choose rather than entering full text or text spread across different cells of the spreadsheet. Having information in the drop-down format would keep the sheet concise, rather than having mistyped information.

It is recommended to go in-depth with the language if needed, such as instructions at the end of the revision process.

The table of contents of the NBIMS-US V4 BEP template was updated after changes were made in the working file and incorporated, resulting in an accurate Table of Contents.

A separate checklist was developed to ensure that its content and language matched the NBIMS-US V4 BEP. Numbers were associated with the tabs at the bottom of the NBIMS-US

V4 BEP tabs for better communication. These numbers help refer to the accurate tab and section numbers in the checklist to avoid confusion.

The checklist was incorporated into the BEP (MS Excel spreadsheet) and automated to fill in the checklist by linking it to the respective sections of the BEP template. This automation allows the information to be filled in once in the relevant sections of the BEP, and it will automatically populate the checklist.

The key takeaways from the above process framework are that owner organizations need to collaborate with industry stakeholders to review, revise, or develop new BEPs from scratch using NBIMS-US V4, taking into account their own specific needs. They should create a process and logistics in collaboration with stakeholders and establish consensus between internal and external stakeholders regarding the information in their BEP.

4.1.4.3 BEP Template Modifications

The USACE and USACE/Industry BIM Consortium introduced several adjustments to the NBIMS-US V4 BEP template, including sections such as deliverables, tab numbering, language instruction, reference numbers (e.g., transmittal numbers and project numbers), and the removal of certain elements (e.g., cover pages and project certifications). This section enlists the changes below.

The USACE PxP document had 'letters' attributed to the sections of the document, such as L and M. However, the NBIMS-US V4 BEP template has different tabs in the spreadsheet, and there are no numbers or letters associated with them. Assigning numbers to the tabs of the NBIMS-US V4 BEP template, i.e., Cover, Summary, Roles, and Goals, would be a more effective way to work with the sheet. It will facilitate effective communication among stakeholders by referencing the accurate tab number and section numbers in the checklist, thereby avoiding misunderstandings and confusion.

USACE also crosswalked its PxP checklist with the NBIMS-US V4 BEP and aligned it with the particular tabs of the BEP MS Excel spreadsheet and tables by inserting 'section numbers' in the checklist corresponding with the pertinent tabs and tables numbers in the BEP.

A 'Deliverables' tab was added along with the Information Exchange (IE) tab, as there is a significant amount of information in the IE that needs to be furnished, and bidders/offerors may not be well-versed initially in providing all the required information. Deliverables are for the owners, and IE is not a deliverable but an exchange of information among the project team. This tab will help the USACE, as an owner organization, with the deliverables of projects.

The USACE believed that there was a need for more instructions in certain sections. Some additional language was added in the BEP template, such as in the 'Goals' tab under the 'Project Goals' section and the 'Intro' tab under the 'Introduction' section, from their PxP document. The instructions were borrowed from the PxP document and inserted into the NBIMS-US V4 BEP template in red to differentiate them during implementation. The instructions were added to help bidders/offerors, as they may not be well-versed with the NBIMS-US V4 BEP. If an organization lacks a developed language, discussions among stakeholders can be held to determine where more instructions are needed. Once those are identified, language from existing documents can be transferred if it already exists, or new language can be written. Afterwards, the language should be scrutinized to be agreed upon with industry partners, as the essence is that these documents must be mutually agreed upon and beneficial.

In the NBIMS-US V4 BEP template, in the Reference Info tab, there is no 'transmittal number' or 'project number'. The USACE has two different numbers when it comes to projects: (1) the transmittal number and (2) the project number (PN), which were in their PxP checklist as well. The transmittal number is used for design-build projects and new construction projects and is utilized for external coordination purposes. Although the project number is sometimes applicable and sometimes not, it is typically used for internal coordination purposes. For instance, a bidder submits a proposal with a transmittal number. It would be reviewed, and if approved with some suggested changes, a new version of the proposal would be submitted with the same transmittal number but following a version number, such as 1, 2, or 3, as a suffix. Therefore, the transmittal number is crucial for the USACE's working practices, and it must be incorporated into the NBIMS-US V4 BEP template in the Reference Info tab under 'Project Reference Information'. Additionally, selecting the position of the transmittal number on the list is crucial, as it is one of the primary tracking numbers for USACE when working with external partners. In the case of Project Number, the short form is PN (which shouldn't be confused with Project Name, as it could also be PN, but that is not what the USACE intended the acronym PN to represent). The project name is sometimes used and sometimes not, typically for internal USACE purposes rather than external use.

In the NBIMS-US V4 BEP template, the Reference Info tab under Project Reference Information 'project owner' is mentioned, but 'facility owner' is not mentioned. The Facility Owner is added in the Reference Info tab under Project Reference Information and is aligned with the BEP checklist. The USACE used 'Facility Owner' in their BEP checklist, as USACE is not the owner of the facility. The Air Force and/or Army might own the facility, and

the USACE delivers projects to the end users. So there is a difference between the project owner and the facility owner.

The USACE also removed specific details from the NBIMS-US V4 BEP template to meet their particular needs. The cover page of the template wasn't needed. Project Certifications Information was removed, as LEED certification is not mandatory for each project, as per current practices. Additionally, the color of the tables in the NBIMS-US V4 BEP template has also changed from Green to Red, as the template is now adopted for the USACE rather than the original NIBS BEP template.

Reflecting on this case study, owner organizations can tailor the template to their specific needs, depending on their market, project types, and role in a project. The USACE added and removed information from the NBIMS-US V4 BEP template at the request of the owner organization, with the consensus of both internal and external stakeholders. This collaboration supported the USACE team in producing a general USACE project BEP template for submission to higher management for final approval.

4.1.4.4 PxP to BEP Checklist Alignment

The USACE had a separate PxP checklist to streamline the process of RFP submission review. During the implementation process of NBIMS-US V4 BEP, the USACE PxP checklist was transformed into the BEP checklist by aligning with their NBIMS BEP template language. The USACE crosswalked its existing PxP checklist with its new NBIMS BEP template and aligned it with the particular tabs of the BEP Excel spreadsheet and tables by inserting 'section numbers' in the checklist corresponding with the pertinent tabs and tables numbers in its NBIMS BEP template.

4.1.5 Lessons Learned from Implementation

This section presents the key lessons learned from the USACE case study during the implementation of the NBIMS-US V4 BEP.

There should be a balance between the standard NBIMS-US V4 template and the adopted organizational BEP template, tailored to each organization's specific needs. The idea behind the NBIMS-US V4 BEP template is to provide a broadly applicable version for the industry, and each owner should tailor it to their specific requirements, such as developing a subset of the template to meet their needs. However, one of the primary objectives of the standard is to maintain consistency in the names of its content and templates, as the standard aims to standardize the industry. So owners should minimize the customization where they can.

There was a significant misunderstanding about whether this transition would create a compliance-based BEP or a collaborative BEP process that brings project teams together to work collaboratively. The NBIMS BEP is intended to be a collaborative document, as viewed by NIBS; however, organizations may have a compliance-based approach to BEP deliverables. It is advised to keep that in perspective and strive to make BEP a collaborative working document and process.

USACE staff reflected on the value of having BEP as a spreadsheet and determined that a spreadsheet is preferable to using file formats in PDF or MS Word. As more projects are completed, such as 10-20 projects, the data can be combined and analyzed for further insights. Based on those insights, USACE can make some decisions for future projects.

Ensure that if a separate checklist is developed, it is aligned with the BEP template in terms of numbering associated with the tabs and tables within those tabs.

"Copyright-All Rights Reserved" notes can be updated, such as being 'adopted' from the NBIMS, as USACE or any other organization makes changes to the file to adapt to their needs. This point could be discussed with USACE's legal team when adopting and adapting the NBIMS BEP template to meet USACE's specific needs.

In summary, owner organizations can tailor the NBIMS-US V4 to their needs, ensuring that it maintains standard content and terminology. They should also consider the BEP as a collaborative working document with stakeholders.

4.1.6 Feedback About NBIMS-US V4

This section presents the feedback provided by the USACE and the USACE/Industry BIM Consortium regarding the NBIMS V4 during its implementation. These will be helpful in future development of the standards, guidelines, and resources.

NBIMS-US V4 template documents could be made web-based for more collaborative implementation among stakeholders.

Adding numbering to the tabs of the NBIMS-US V4 BEP template (MS Excel spreadsheet), such as "Cover," "Summary," "Roles," and "Goals," would be an effective way to interact with the sheet and communicate information among project stakeholders with proper signposting, thereby eliminating confusion and ambiguity.

4.2 MassPort (Owner) NBIMS-US V4 Use Case

4.2.1 Executive Summary

This use case describes the implementation of NBIMS-US V4 by a public owner organization. MassPort is primarily involved in infrastructure and capital improvement projects, and owns facilities like international and local airports, sea ports, and a freight movement terminal. MassPort implemented the NBIMS-US V4 to standardize its operations and make them more comprehensive but retained its own terminology. MassPort suggested that organizations should adopt NBIMS-US V4 because it is practical, but tailor it to have maximum value for their needs. One of the main pieces of feedback was that the standard templates, like the BEP template, can be improved by making them simpler for wider adoption.

4.2.2 Organizational Overview

MassPort is an owner organization that moves people and products. MassPort owns infrastructure facilities, including international and local airports/fields, a cruise port, and a cargo container terminal. MassPort is involved in two primary markets, transportation (airports and seaports specifically) and real estate.

4.2.3 Project BIM Requirements

4.2.3.1 Implementation Process

MassPort crosswalked its established organizational BIM requirements against two standards and incorporated necessary improvements using NBIMS-US V4. MassPort already had existing Project BIM Requirements documents, so an initial gap analysis was conducted using NBIMS-US V4 and ISO 19650 to identify discrepancies and gaps for improvement. One of the key focuses of this gap analysis was to examine the BIM requirements that are either working or not working for their projects. They sought to document those portions of their requirements that were not working by defining the specific issues and developing recommendations as to how they could be solved. This involved defining requirements more clearly and/or adding additional requirements for greater clarity. The issues in the internal project BIM requirements were addressed using language from the PBR of NBIMS-US V4.

This case study recommended that owner organizations collaborate with the industry partners and project stakeholders while developing and implementing the PBR. The owner organization enhanced its PBR by clarifying requirements and processes through collaboration with industry stakeholders, including designers and the construction team, as

the USACE collaborated with its industry partner through the BIM Consortium. MassPort believed that ideally, everyone involved in the project should be included during the transition to and adoption of new BIM standards. Involvement also depends on the specific BIM uses; nevertheless, all project delivery teams, including their BIM teams, should be involved in the process. Facility operators are also important stakeholders, as they will utilize the asset information for the facility's operations after the project's completion.

4.2.3.2 Lessons Learned

Owner organizations can incorporate information from the NBIMS-US V4 PBR into their project BIM requirements but should be aware of the capabilities of the project delivery teams and the associated costs of the BIM requirements. Developing a modularized NBIMS V4 standard facilitates easier adoption. Although some owner organizations might have already developed internal PBRs, there is a wealth of valuable information in the NBIMS PBR V4 that owners can incorporate into their existing BIM requirements documents. One of the barriers that owners should be aware of while developing PBRs is the in-house capability of the project delivery team and the required complexity of work requested by the owner for the successful delivery of project deliverables; otherwise, it would result in a mismatch between expectation and reality. It is recommended that owners also be aware of the costs associated with the PBRs, which can be a barrier to meeting the project deliverables' requirements.

Owners should have early and consistent involvement with the project delivery team to ensure the achievement of requirements and desired outcomes. Early involvement by owners with project delivery teams ensures the delivery of accurate results. This can be done by conducting an early meeting with the project delivery team to clearly outline and discuss the project requirements and expectations. These meetings could be aligned with milestones, even before those milestones are achieved, to ensure that the correct deliverables are being delivered rather than having a reactive approach to an unforeseen condition or unrealistic deliverable.

Infrastructure projects require BIM, but effective implementation requires standardized workflows. It is clear that infrastructure projects should use BIM, as not using BIM would be more costly. However, the key consideration is how to effectively specify the use of BIM. One of the best ways to utilize BIM is to standardize workflows using BIM standards. It is recommended that owners provide the standard and sample documentation, along with the project requirements and the core requirements, to the project delivery team. MassPort found that NBIMS V4 PBR is a useful and practical tool for standardizing documentation or enhancing existing documentation. Thus, MassPort believes in the

practicality of NBIMS V4 PBR, but owners need to provide resources and guidelines to the project team.

4.2.3.3 Feedback

Specific language based on projects and organizations could be incorporated in the next version. One improvement for further versions of NBIMS could be to develop and customize the language according to the types of projects and organizations. For instance, public agencies and private property developers are distinct entities, and the way contractors perceive BIM requirements differs between public and private owners.

4.2.4 BIM Execution Planning (BEP)

4.2.4.1 Implementation Process

Massport needed standardization for their projects and NBIMS-US V4 also supported the BEP standards development. This owner organization utilized various versions of BEP, both internally developed and adopted from external organizations, including designers and general contractors, because their internal BEP didn't comprehensively cover some areas. This necessitates the adoption of a BEP standard that can be used across all projects. MassPort conducted a gap analysis of their standard with NBIMS-US V4 and ISO 19650. Massport uses the NBIMS-US V4 BEP template as a starting point and tailors it to their specific needs to make its BIMxP template. The template was tailored in areas such as the connection between BIM and Lean processes, LOD specifications, and Massport's critical asset information requirements. But Massport uses BIMxP terminology rather than BEP. Nevertheless, the owner organization carefully considered embedding flexibility and scalability in their BEP depending on the project. Their template is designed to accommodate some customization based on the project's size, making it comprehensive while avoiding overkill, taking into account the project's scale and nature. Thus, Massport implemented the NBIMS-US V4 BEP template in a way that embedded flexibility and scalability into their template, according to the nature and size of their projects.

A framework for roles and responsibilities was developed with the right person in mind for the right job. Massport defined the roles and responsibilities of project teams to implement BIM in their projects and documented this framework in their BIMxP to ensure clarity of roles and responsibilities. For instance, if a project needs site logistics modelling, then the engineering and design firm would be the best party to be responsible for developing 4D models. Another example is that a general contractor would be responsible for creating shop drawings by collecting all the models from specialty subcontractors. The focus role

and responsibilities are based on the best fit among the project stakeholders to accomplish the work.

Massport also defined roles and responsibilities for developing and maintaining the BEP. The owner organization also added another layer of roles and responsibilities for developing and maintaining the BIMxP document, which is a contractually required BIM deliverable. MassPort contractually obligated the designer team to develop BIMxP during the design phase, and the general contractor would be responsible for developing and maintaining the BIMxP during the construction phase. The project delivery team would continue to submit the latest and updated BIMxP to the owner as a deliverable at each milestone. Therefore, having such contractual outlining of roles and responsibilities to deliver updated BEP as a deliverable at each milestone can be beneficial for projects.

4.2.4.2 Lessons Learned

Based on this Massport case study, it is recommended to simplify the BEP template to maximize its value for your organization. One of the lessons learned from implementing NBIMS-US V4 BEP is that organizations need to simplify the BEP template in a way that provides the greatest value for their organization. This depends on the type of organization, its role in a project, the types of projects, and the nature of the market of operations. Accordingly, different organizations have varying needs, and the implementation of NBIMS-US V4 BEP should be done in a manner that brings the most value to each organization.

BEP is a live and collaborative document throughout the project life cycle. It is not created at the start of the project and remains the same until the project's completion. The respondent stated: "*BIMxP as a live document. So, it's not something that you create once and then keep at the end of the project. It's a live document that you have to keep up-to-date. You need to get back to that at each phase, right at each milestone.*" As a live document, it will be updated at each milestone. The respondent also mentioned that "*It should reflect the way that you dynamically and collaboratively implement being in your projects. That's the purpose of the document, and so it should be treated that way.*" Therefore, it is a dynamic document that will be collaboratively updated and implemented in projects.

4.2.4.3 Feedback

The BEP should incorporate flexibility while also simplifying the template to promote greater adoption. For instance, the deliverables of a project depend on the scope of work and the project's size, so they cannot be a fixed list of required deliverables. Additionally, the number of milestones organizations want to have differs from project to project. These

aspects should be addressed in the BEP template to showcase the bare minimum requirements, while also allowing for customization according to the project's specific needs.

4.2.5 BIM Use Definitions (BUD)

4.2.5.1 Implementation Process

Massport indirectly utilized the NBIMS V4 BIM Use Definition module and tailored it according to their understanding and needs. While adopting the NBIMS-US V4 BUD module, they reduced the number of BIM uses from 16 to 10, and categorized them based on perspective and priorities as an owner organization. Additionally, the organization used different names for the BIM uses, claiming that the NBIMS-US V4 BUD module deviates from the traditional terminology used in the US construction industry. Nevertheless, Massport acknowledged that these terminologies in the NBIMS-US V4 might be adopted to create consistency in the industry. MassPort reviewed the module but wanted to keep it simple, as compared to the differentiation made in the BIM Use and BIM Use Cases, so that even non-technical users can easily understand them. Despite understanding that BIM uses are the goals an organization wants to achieve, and BIM use cases are the specific technical processes selected to achieve those BIM goals, Massport did not make this distinction. Rather, based on their understanding and for simplicity, they prepared a list of 10 BIM uses that are applicable to them. A separate comprehensive section in their BIM Standard document (Appendix-A: BIM Uses) outlines details about BIM uses, requirements, and how to implement them. Therefore, Massport reviewed the NBIMS-US V4 BUD module, simplified it, and tailored the module to meet their specific needs.

4.2.5.2 Lessons Learned

One of the key lessons learned from the BUD module is to identify and quantify the value created by using BIM uses, rather than utilizing it solely for the sake of technology implementation.

The owner emphasized that the NBIMS V4 BUD module is a good source for creating or adopting BIM uses. There is no need to be too prescriptive while defining BIM uses. The project delivery team can fill in the technical details.

4.2.5.3 Feedback

The module is good as it is, but there were discussions to provide supplemental documentation that provides technical requirements. Examples of what can be included in the supplemental documentation would be: "*Technical instruction in terms of what are the specific requirements for implementing each of the BIM use that is identified in the NBIMS? What*

are the roles and responsibilities? What would be the expected outcome? How to standardize the deliverables for each of those BIM uses? What are the context or considerations for implementing each of those beam uses? What are the potential constraints and challenges based on the, you know, current market capabilities?" Nevertheless, it was recognized that providing such information covering all types of organizations and projects would not be an easy task.

4.2.6 Construction Operations Building Information Exchange (COBie)

Massport required asset data delivery but did not make COBie mandatory. As stated, *"I think COBie is too complicated as a data schema for collecting and delivering asset information.*" It was recommended that organizations distinguish between BIM data and asset data, identifying specific data requirements for BIM implementation and treating asset data as a subset of BIM data. The organization has an internal mechanism for collecting asset data that prescribes the asset data requirements but has not made it mandatory to use the COBie approach, as tools and emerging technologies may be a better, more efficient way to do so. An internal data collection mechanism defines types, attributes, and a specific format for the data, rather than mandating a specific scheme, such as COBie, for collecting and organizing it. Thus, the concept of COBie is embedded, but the means and methods differ from the COBie approach, as it is regarded as complicated.

4.3 Autodesk Consulting NBIMS-US V4 Implementation Use Case

4.3.1 Executive Summary

This use case is about Autodesk Consulting, which supports the Architecture, Engineering, and Construction (AEC) industries in implementing BIM technologies and standards. Implementation of BIM standards depends on the role of organizations in projects and the project's intended outcomes. Autodesk Consulting found that NBIMS-US V4 is a comprehensive standard with a wealth of information; however, the information needs to be simplified in a manner that allows owners to implement the standard without requiring technical assistance. There is also room for improvement in the clarity of information when transitioning from one stage to another in the project. More awareness is required about the significance of COBie before it can be implemented, as it is challenging and complex. There is an opportunity to incorporate more BIM uses, particularly in emerging technologies such as AI. All in all, the NBIMS-US V4 could be simplified, and that would drive the adoption of the standard.

4.3.2 Organizational Overview

Autodesk is a large software company, providing software products like Revit for the architecture, engineering, and construction industries. Autodesk has a large market share with 3D model tools like Revit in the US, which is a crucial technology for BIM. Autodesk Consulting offers services to support AEC organizations in developing and implementing BIM standards, ensuring standardized BIM processes and compliance with the standard requirements.

4.3.3 Project BIM Requirements (PBR) Module

4.3.3.1 Implementation Process

The implementation process and stakeholder involvement vary project-to-project. The implementation process of PBR depends on three key considerations: what is the role of Autodesk Consulting in the project, what are the project's end goals, and what are the most important considerations regarding facilities and operations. These three things will govern the implementation process. In terms of key internal stakeholders involved in defining the PBR, these may include delivery managers, project managers, and sales representatives, particularly if the project is related to the commercial side of the business. So, the

involvement of stakeholders in a project and the outcomes to be achieved play a significant role in the implementation of PBR.

4.3.3.2 Lessons Learned

The most important lesson learned related to PBR is to define the flow of information. There is a reason why BIM is often referred to as a verb: Building Information Modeling. Organizations must determine how project information is created, how it will be shared with project stakeholders, and the purpose of sharing that information. Also, in what format will the information be shared, such as models, a database, drawings, sheets, or other forms of documentation? These are essential considerations to be included in the PBR.

4.3.3.3 Feedback

PBR and NBIMS V4 overall need to be simplified so that owners can employ them with minimal or no technical knowledge. Typically, these requirements are fulfilled with the assistance of architects and/or consultants. The PBR modules could be simplified based on the number of roles to define stakeholders, information flow during different stages of the project, and the type of deliverables to produce and share with the relevant stakeholders at various stages of the project. An example of simplifying roles in the PBR is to have fewer roles, as ISO 19650 only has three roles: an appointing party, a lead appointed party, and an appointed party. Most of the roles can be mapped out with these three roles. This simplification would make it easy for organizations to implement the standard, which in turn drives the adoption of the modules.

4.3.4 BIM Execution Planning (BEP) Module

4.3.4.1 Implementation Process

Autodesk Consulting collaborates with various clients to support the implementation of BIM standards and recommends a three-step process for implementing the BEP. To begin with, it is essential to define BIM uses for the project that depend on the scope of work. Afterwards, a RACI matrix (Responsible, Accountable, Consulted, Informed) should be developed that is pertinent to the required BIM uses for the project. Once those are outlined, a timeline for completing tasks, such as the ISO 19650 master information delivery plan, can be developed. According to Autodesk Consulting, the process of BEP implementation must include these steps.

As a consulting organization, defining roles and responsibilities when working with clients depends on the client organization's role in the project and the project's stages. For example, the roles and responsibilities of architects and engineering organizations differ

even at the design stage, and these responsibilities also change depending on the project's stages. When the project enters the pre-construction stage, we need to have more collaboration with construction stakeholders. So, the expertise required from an organization in different stages of a project would be different.

4.3.4.2 Lessons Learned

Owners should implement NBIMS V4 to control all aspects of their projects. As stated, "The national BIM standards represent a way to keep every single aspect of the project under control...the implications of cost and execution are enormous...at the end of the day, the owner is going to pay for those delays, for those changes, for those updates." Standards support the structuring of BIM usage for projects, and without standards, the implications of cost and execution would be enormous, including change orders and additions. As a result, ultimately, the owners would suffer and bear the financial impact of those changes and delays. Thus, standards help the owner organizations to have control over their projects.

4.3.4.3 Feedback

The BEP module could include guidelines, rather than just defining what needs to be done. The BEP could also provide guidance on what constitutes a good approach to developing a BEP from the perspectives of owners, designers, and contractors. As stated: "*And in terms of the execution planning, more than defining what needs to be done, maybe provide a guide of how to develop your own BIM execution plan with a very good approach in like what is important to have in a BIM execution plan, what is the from an owner's perspective, what is the interest, the main interest from a designer's perspective? What is the most important things to consider from a builder or a contractor perspective?*" These guidelines would be helpful for Autodesk Consulting in developing BEPs.

Facilities and operations are critical, as many owners must operate the asset after the project's completion. Therefore, what is essential for them should be included in the BEP. As mentioned, *"What is the important things that you need to consider, and at the end of the day, from a facilities and operations what is important to be considered?"* Although some information is available in the BEP, it is not structured by roles, different stages of the project, or the essential considerations in terms of BIM requirements for a particular project stage. As explained: "*So those things are, in my opinion, there, but not like this, like I mentioned, not in a way that everything is perfectly structured by role by the different break stages, and I think that is important. The break stages are defined, yes, but not specifically what is important to consider on the BIM execution side of the stages, if I can say so."* The NBIMS V4 BEP can be further improved in terms of clarity regarding stages, deliverables,

expectations, and criteria for a particular stage of a project, as well as asset management data.

NBIMS-US V4 BEP should be simplified, as it currently contains extensive information. A comparative analysis between ISO 19650 and NBIMS BEP revealed that ISO 19650 is clear about transitioning information from different stages of the project, including the design stage, construction, and asset information. The NBIMS V4 BEP also has that information, but it is too extensive. Also, the BEP should be simplified so that organizations, particularly in the US, can avoid spending multiple hours on the template, allowing them to focus on project tasks. It was expressed as: "*So it could be a very good way to simplify that adoption and understanding, and particularly in the US that people does not want to spend hours and hours. Because those hours are hours that you can dedicate to, you know, charge it to a project and make money out of it. So I think that if we can simplify that, it will increase that option drastically.*" This simplification and clarity regarding the transition of information from different stages of the project in the BEP would help increase adoption.

4.3.5 BIM Use Definitions (BUD) Module

4.3.5.1 Implementation Process

The implementation process of BIM uses and definitions depend on the owner's requirements. Owner organizations define the scope of work and the outcome that they want to achieve from the project. Based on these owner requirements, project teams would define BIM uses so that the desired outcomes and scope of work can be accomplished. For instance, the owner may want to coordinate everything before construction and extract quantities of all the materials from the model. Therefore, those BIM tools would be adopted that can achieve coordination and quantity takeoff from the model. Thus, the implementation of BIM depends on the owner's requirements, which vary based on the project.

4.3.5.2 Lesson Learned

Define BIM uses earlier in the BEP and develop clear definitions about the benefits and implications of BIM uses in terms of time and cost. The biggest lesson learned about the BUD is to define the BIM uses at the beginning. Definitions for BIM uses can be established based on the benefits to the project and the project team, as well as the impacts of implementing these uses. There is always some processing required for the BIM uses to produce the necessary data or utilize the model, which consumes time and, in turn, cost, and should be clearly outlined for the BIM uses.

4.3.5.3 Feedback

NBIMS should consider data automation and AI for predictive analysis based on the data. These are emerging technologies that must be regarded as essential for the future NBIMS BIM uses. It was explained that "*the point is the use of data plus AI will change the way that we manage projects, and I think that the national BIM standards need to have that mindset, in a sense of how we are going to use the available technology and the future technology on behalf of the construction industry? We cannot be unaware of those things, right? This is happening, and we must consider the use of these improvements.*" Therefore, the NBIMS should consider incorporating BIM uses for emerging technologies.

4.3.6 COBie Module

4.3.6.1 Implementation Process

Although COBie is valuable for the end users and owners, it is very challenging and complex. Even in the European market, where COBie standards are widely recognized, the concept of COBie is complicated. Creating awareness about the importance of COBie among project stakeholders is crucial, so that they understand why we should adopt the COBie standard, their roles, and what is expected of them. Additionally, establish relationships between asset criteria and equipment criteria, as well as a mechanism for tracking and automating COBie. It was recommended that academia-industry research be conducted to identify best practices for COBie. Thus, developing stakeholders' understanding of roles and responsibilities for COBie is crucial for its implementation.

4.3.6.2 Lesson Learned

The biggest lesson learned about COBie is that we need to create awareness and training about this standard, as there is a lack of understanding about it, and different stakeholders hold varying perspectives. The awareness should be presented in a manner that makes stakeholders understand the significance of the standard for their respective roles, such as owners, designers, contractors, facilities, operations, and quality management.

4.3.6.3 Feedback

The benefits of COBie can be highlighted to owner organizations so that they utilize this standard.

4.4 Digital Building Services (Consultancy) NBIMS-US V4 Implementation Use Case

4.4.1 Executive Summary

This use case illustrates the operation of a small consultancy firm collaborating with organizations to implement NBIMS-US V4. Digital Building Services (DBS) works with owner organizations to support them in implementing the standard. DBS believes that there is a significant gap in awareness regarding the NBIMS-US V4 standard and its potential. More awareness should be created about the potential of the standard and its tools, such as BEP, including definitions, roles, and responsibilities. Additionally, having online accessibility to develop a BEP with ease would improve the adaptability of the module.

4.4.2 Organizational Overview

DBS is a consulting firm that offers services in laser scanning, Virtual Design and Construction (VDC), and Building Information Modeling (BIM). DBS is primarily focused on providing services to the aviation industry, but also renders services to academic institutions and luxury hotels.

4.4.3 Project BIM Requirements (PBR) Module

4.4.3.1 Implementation Process

DBS uses the BEP process to define the project BIM requirements. As this consultancy organization is a small business, only two personnel are involved in developing the project BIM requirements and/or BIM requirements for projects.

4.4.3.2 Lessons Learned

There is a lack of awareness among owners about NBIMS V4. Owners are not fully aware of the NBIMS, its functionality, and its assistance capabilities, so they do not adopt this standard and tailor it to their needs. Some owner organizations involved in national infrastructure, such as airports, are committed to BIM in the long term. But other airport owner organizations did not reference NBIMS for the project. "*We just had a proposal come in for BIM services for an airport, and you know we're going through it, and there isn't a single requirement to NBIMS anywhere. And this is for somebody to basically oversee the digital twin of the airport. Basically, they don't say that, but that seems to be where they're going with this. And there's no reference to NBIMS at all. And this is a major International Airport. Like, yes, during my proposal, I'm absolutely going to suggest that we use this, but like, they don't seem to even*

know that that's a thing." There is a need to develop awareness among owners to enable them to implement the standard.

4.4.3.3 Feedback

Early involvement of facilities management in the PBR is recommended. It is suggested to involve facility maintenance personnel earlier in the process, as they are the primary users of the data and will utilize it on a day-to-day basis.

4.4.4 BIM Execution Planning (BEP) Module

4.4.4.1 Implementation Process

The DBS implemented the NBIMS-US V4 BEP module for an owner organization by crosswalking the BEP template with the owner's organizational BEP. While developing a BEP for a large owner organization, DBS crosswalked its organizational BEP with the NBIMS V4 BEP template to identify gaps and subsequently enhance the existing documents. For instance, BIM goals were not included in the given documents and were incorporated from the BEP template. Some project-specific information was also added to the document, such as the sheet naming convention, which was not included in the NBIMS-US V4 BEP. After a few iterations with the client, the document was finalized. Although the client was a large owner organization with an understanding of the NBIMS-US V4, it lacked the necessary human resources to perform the crosswalk and produce its project-specific BEP. Accordingly, if the owner organizations have already existing BIM documents, they can crosswalk them with the NBIMS-US V4 to align them with the standard.

Standard predefined terms were used for roles and responsibilities from the NBIMS-US V4 BEP template, along with some details about each role. Typical responsibilities of a BIM manager include overseeing all team members to ensure they meet the project's technical requirements. In the case of the BIM coordinator role, the position involves more technical details on a day-to-day basis, such as clash detection and model verification. BIM engineers/modelers are personnel who develop models within individual organizations. It was noted that documenting the workflows in the BEP can require significant effort and should be used strategically.

4.4.4.2 Lessons Learned

Organizations should utilize the BEP tools and make use of the level of detail they provide, but keep the BEP document concise. A significant amount of detailed information is involved in BEP, and owner organizations can significantly benefit from this level of detail. Organizations can utilize the available tools in the BEP, including BIM goals and the model matrix, which is underutilized. BIM goals will help DBS think through what it really wants to

achieve in projects. Nonetheless, the BEP should be condensed and brief. The length of the BEP is essential, as people tend to avoid going through longer BEP documents. The industry can benefit from the tools and details that the BEP can offer to organizations, but keeping the documentation concise would make it more readable.

4.4.4.3 Feedback

The NBIMS-US V4 BEP module, in its current form, can be daunting for beginner users, as it presents an overwhelming amount of information. According to the respondent, "*It's a bit daunting the way it is right now, if you are not familiar with it, because there's so much information. That it's kind of like overwhelming to some people, I think.*"

There could be a user-friendly approach to ease the adoption of the BEP. Having an online, user-friendly, and interactive survey that requires inserting information piece by piece to move forward and build the complete BEP, with minimal effort, would encourage owners, designers, and contractors' organizations to adopt the NBIMS-US V4 BEP, even at the early stages of the project. This online version and tools would ease filling and provide greater accessibility for organizations.

4.4.5 BIM Use Definitions (BUD) Module

4.4.5.1 Implementation Process

Implementation of BUD involves selecting and choosing from the NBIMS-US V4 BUD module based on the provided services. DBS adopted BIM Use Cases from the NBIMS V4 BUD module rather than developing internally. The selection process primarily involved picking and choosing from the standards applicable to the nature of services DBS provides to its clients.

4.4.5.2 Lessons Learned

Various stakeholders involved in a project may interpret the BIM Uses differently, so the same statements about BIM use may have distinct meanings for them. For instance, on a hospital renovation project, the architect and engineering organizations had to phase out the work. However, the architect's phased approach differed from that of the engineering, which caused significant disruption for the remainder of the project and ultimately extended its completion time. Consequently, BIM uses should be tailored to make them specific to a role in the project.

4.4.5.3 Feedback

The standard can include role-based definitions. One improvement that can be made to the NBIMS-US V4 BUD module is to define uses according to the specific roles within the

project team, such as owner, designer, and contractor. As stated: "*Maybe kind of like a bit, almost like a definition as it relates to an owner, a definition as it relates to a designer, a definition as it relates to a contractor.*" These definitions may provide deeper insights into the roles and responsibilities of the project stakeholders.

4.4.6 COBie Module

COBie is beneficial for owner organizations, but it has developed a negative perception and is overwhelming. DBS does not use COBie V3. Nevertheless, the respondent had personal experience with COBie and thought that it is beneficial and should be made a mandatory requirement by the owners. But it has attracted a negative perception; therefore, the name should be changed to give it a fresh chance. Additionally, it is complex and overwhelming for many organizations to begin with, so they often prefer not to deal with it. Sharing personal experience of COBie usage on a project, an online searchable database made working with COBie and asset data much better and efficient. The standard should be simplified and rebranded to facilitate greater ease of adoption through an online, searchable database.

4.5 WSP (A/E Designer) NBIMS-US V4 Implementation Use Case

4.5.1 Executive Summary

This NBIMS-US V4 use case is particularly related to the Federal unit of WSP, which is an Architecture and Engineering (A/E) consulting organization. The implementation of the standard depends on the client's requirements as WSP is a service provider organization. Nonetheless, they have internally adopted the standard for standardized and effective design delivery to their clients. One of the key lessons learned from the implementation of the standard is to showcase the value of using the modules of the standard for the project stakeholders like owner, designer and general contractor. This would help organizations to buy in and adopt the standard. In the case of feedback, WSP suggested being aware of the future trends like AI technology, AI-generated data and models, digital twins and the emerging and dynamic policy landscape. More BIM uses should be developed to cater for future technologies. Particularly embedding digital twin starting from PBR to COBie for support organizations that want to employ the emerging technology for future use.

4.5.2 Organizational Overview

WSP is one of the world's leading professional services firms, uniting its engineering, advisory and science-based expertise to shape communities to advance humanity. From local beginnings to a globe-spanning presence today, WSP operates in more than 50 countries and employs approximately 75,000 professionals. WSP in the U.S. 's team of 19,600 professionals pioneer solutions and deliver innovative projects across the transportation, infrastructure, environment, building, energy, water, and mining and metals sectors.

4.5.3 Project BIM Requirements (PBR) Module

4.5.3.1 Implementation Process

WSP works with the client's Project BIM Requirements. Clients may base their requirements on internal or external BIM standards. The participant stated that: "*Our organization's process of developing project BIM requirements is directly aligned to whatever the client is and whatever the client's requirements are.*" The process was further explained: "*Yes, we have a process. It is per client, per region, and it is highly project specific, and it's part of my team's job...we need to be very savvy on where it came from, why it's there, and does it have value?*" The implementation process of PBR is highly dependent on clients' needs and

requirements, as well as their specific region, and is tailored specifically to each project. WSP also examines the sources of the client's requirements and the value those requirements would bring to the project.

WSP has an internal need to standardize project BIM requirements across their firm, ensuring its design teams deliver effectively. As explained, "*We have to have BIM standards and guidelines to assure that our design teams are delivering effectively. So, there's an internal need.*" The internal adoption process depends on the NBIMS-US V4, which also enables WSP to meet the client's project BIM requirements. The team carefully reviews owner-added project BIM requirements that are not based on NBIMS-US V4 to determine whether these additions result from the project type, the client's region of operation, or selective adoption of NBIMS-US V4.

The key internal stakeholders at WSP involved in the project's BIM requirements are the project managers and design managers, to ensure that these requirements are defined and aligned with the project's objective. Facility managers, quality control, program coordinators, and IT, digital, and tech support teams are also stakeholders in the project.

4.5.3.2 Lessons Learned

The key takeaway in terms of lessons learned is to define and communicate the value that stakeholders can derive by implementing NBIMS-US V4 PBR. For instance, WSP identified value in terms of risk management, addressing conflicts in projects, and the speed of delivery. This value proposition for stakeholders would facilitate the adoption of the NBIMS-US V4 standard.

4.5.3.3 Feedback

Industry stakeholders require clearer guidance on how to effectively implement this standard. Providing an example such as the USACE implementation, as a member of the USACE/Industry BIM Consortium, the respondent stated that the USACE already had its general specifications, which they tweaked in consideration of NBIMS-US V4. This process involved a tedious effort with the help of industry and academic stakeholders, leveraging the USACE/Industry BIM Consortium. However, most owners don't have those consortia and resources, and they struggle to incorporate these specifications into their contracts; so there is a need for more guidance on how to implement NBIMS-US V4.

The standard could outline for the owner organizations the amount of work required and the cost necessary to keep the assets operational. This information should be detailed rather than high-level, enabling the owners to understand data management and governance and what value these data provide to their organization and the project team.

Another aspect is that NBIMS-US V4 can create value for owner organizations, considering space planning and associated costs, particularly in view of the future of hybrid working. Also, how NBIMS-US V4 can improve project delivery and quality for retrofit and tenant improvement projects. It is recommended that the standard define how NBIMS-US V4 supports the delivery of digital models to facilitate digital twins, thereby enhancing scenario planning and simulation for owner organizations. And, define how NBIMS-US V4 ensures that models can be archived and used by owner organizations for a future record of site conditions. Lastly, define how NBIMS-US V4 can reduce risks and costs during the construction phase of projects.

4.5.4 BIM Execution Planning (BEP) Module

4.5.4.1 Implementation Process

WSP receives a contract and a statement of work, and BIM standards are typically specified within it. Clients may have internal and/or external BIM standards based on NBIMS-US V4 or other standards. WSP develops the BEP according to the client's requirements. However, if owners don't reference any BIM standards or are open to adopting a BIM standard, WSP suggests that the NBIMS-US V4 is a good starting point for BIM-based project delivery. Defining roles, responsibilities, and workflow depends on the client's requirements, the specific nature of the project, the asset being built, and the project's location globally.

4.5.4.2 Lessons Learned

Owners' adoption of NBIMS-US V4 largely depends on the type of asset. So, it is beneficial to understand the audience of the standard and their end-use cases, as well as data utilization, since these differ significantly depending on the facility. For example, a dam differs from a manufacturing facility. Knowing the source of documentation and processes in the client's requirements is important; as noted, "*Knowing where a lot of their documentation and process comes from is very valuable*". It helps in understanding the chain of command and information flow of the government agencies we work with, as mentioned: "*So just lessons learned is the chain of command, the information flow across all of these different government agencies.*" Thus, having that background information and particular needs of the clients helps better understand the project and subsequently the implementation of the standard.

4.5.4.3 Feedback

Standard developers should keep in view emerging technologies, such as AI and digital twins, as well as legal obligations, including data governance and security policy. Considering AI-generated models and content, owners and project teams need to define

who would be responsible and liable for its quality control, and associated liabilities and legal issues. The standard needs to develop BEP with the end use cases in mind such as an intent to use the models and data for a digital twin in the future. Project teams need to identify data governance issues in different regions, which are a growing legal obligation in certain parts of the world, such as Europe. The standard should address these emerging trends that how project teams plan, where data will be hosted and how they will work with it.

4.5.5 BIM Use Definition (BUD) Module

4.5.5.1 Implementation Process

WSP uses the BIM use cases as a reference and selects specific uses according to the needs of the owner organization. In their working practice, the selection of the BIM uses are directly related to planning, budgeting, and also the amount of effort required in terms of working hours for a project.

4.5.5.2 Lesson Learned

BIM uses should be directly related to the contracted scope of work and are defined by project participants with insights into the type of project, contract, the project team, and stakeholders, as well as how those BIM uses will bring value to the project stakeholders, particularly the owner, designer, and contractor. Additionally, owners need to consider the BIM uses in terms of the project type, scope of work, and associated budget. Defining BIM uses in that manner is crucial to ensure that the project team is not overpromising and underdelivering the project.

4.5.5.3 Feedback

The standard should look into the emerging trend and incorporate them as BIM uses. For instance, a BIM use that outlines a mechanism to help the owner organization track the latest updates and changes incorporated into archived models, and keeping asset information up-to-date for future uses. Another consideration is how owner organizations, particularly their facilities management teams, can utilize digital twins or building management systems for enhanced building operations. Lastly, NBIMS uses cases for model usage in terms of future scoping and capital planning for retrofit projects. These BIM uses would support owners to use the data as digital products that are up-to-date and reliable for future usage.

4.5.6 COBie Module

4.5.6.1 Implementation Process

COBie is more related to the general contractor and requires intense effort. WSP is an A/E design firm, and it's only involved in fewer than 25% of design-build projects. Their work and requirements are relatively light for as-built and record modeling and data, as the designer firm doesn't have manufacturing warranties and can't sole-source items when working with public agencies. The type of project, project delivery, and teaming arrangement will impact the COBie plans and delivery. So, COBie data collection and quality control is a more intensive effort by the general contractors.

4.5.6.2 Lessons Learned

COBie can be a solution to gather data for facility management and operations. The commissioning phases of a building, from contractors to facility management, are a challenging process, and they often lack the necessary data to perform their day-to-day facility operations. Additionally, they need to plug the data into a facility management software. Therefore, COBie can be a solution that supports facility management teams in gathering the necessary data to operate buildings effectively.

4.5.6.3 Feedback

In the wake of emerging technologies like digital twin, there is a need to define how COBie could be utilized by organizations that want to employ digital twin technologies.

4.6 Design-Build Organization NBIMS-US V4 Implementation Use Case

4.6.1 Executive Summary

This use case outlines the implementation process of NBIMS-US V4 by a large Design-Build (DB) firm who chose to remain anonymous. As this DB firm provides services to owner organizations, they must adopt the owners' BIM requirements as specified in the RFP and contractual agreement. Nevertheless, this DB firm has internal working practices to follow the NBIMS-US V4 standard, which is referenced in the BEP. Additionally, the DB firm implemented NBIMS-US V4 to standardize its working practices across all markets in which it is involved. The standard implementation would provide the DB firm and project stakeholders with a common language and understanding regardless of the markets and projects involved. This use case explains the implementation of NBIMS-US V4 in two different units of this DB firm, specifically those involved in design and transportation.

4.6.2 Organizational Overview

This DB firm delivers multi-billion-dollar projects across various markets, including buildings, industrial, marine, mining, power, and transportation. This DB firm offers multiple services, including engineering, construction, and technical services. Furthermore, this DB firm is ranked as a top firm by ENR.

The following sections provide module-based information on the implementation process, lessons learned during implementation, and feedback for improvement of the NBIMS-US V4. These sections are related to two different units within the DB firm: transportation and design. Notably, neither unit currently implements COBie V3. In the next section, we first address the Transportation Unit, and then the design unit.

4.6.3 Transportation Unit Project BIM Requirements (PBR) Module

4.6.3.1 Implementation Process

There is a growing trend of digital delivery requirements from the Departments of Transportation (DOTs), but some DOTs have more stringent BIM requirements than others. Consequently, the owner's requirements govern the RFP proposal; nonetheless, this DB firm maintains an internal minimum core competency for NBIMS-US V4 implementation on all projects.

The RFP from clients stipulates the implementation of project BIM requirements. The main internal stakeholders in defining project BIM requirements are the design management team and the digital delivery team. The latter team relied on the design management team to determine the project requirements, and both teams collaborated to understand the meaning of the RFP's language. However, internally, this unit of the DB organization has minimum requirements that they typically implement on any project, such as model federation, quantity takeoff, clash detection, and data organization. Regardless of the RFP requirements, the core competencies will be incorporated into all projects, as that is how the DB organization wants to operate our models and business. Thus, although the DB organization provides services to the owner organization and develops the RFP proposal based on the owner's RFP, the DB firm maintains minimum internal project BIM requirements across all projects, in accordance with NBIMS-US V4.

4.6.3.2 Lessons Learned

There should be clear expectations from owners and constant communication about the BIM standard among project stakeholders. Owners should clearly and specifically communicate their expectations regarding BIM requirements, rather than providing

overarching guidelines, as these requirements will be priced from the services provider's standpoint. The respondent stated, "*...need to be a little bit more clear and defined...So I think it's just more about communication and what do you want from it. And what do you need from us to get you there*?" Regular communication should be maintained about the BIM standard so that stakeholders are aware of the source of detailed information. Hence, clarity and effective communication about PBR among project stakeholders are key lessons learned from the implementation process of NBIMS-US V4 in the transportation market.

4.6.3.3 Feedback

Enhance accessibility and searchability to improve usability within the industry. The PBR module contains a substantial amount of information. The format of the module is good, but a web-based approach would be better, with some keyword-searchable options to help users navigate the module effectively.

4.6.4 Transportation Unit BIM Execution Planning (BEP) Module

4.6.4.1 Implementation Process

The BEP implementation process of the DB firm is based on NBIMS roles, responsibilities, and workflows involving all project stakeholders. Initially, the DB firm developed the BEP in accordance with the owners' RFP specifications. It is then ensured that the information in the BEP is aligned with the NBIMS-US V4. The BEP undergoes regular review to add and remove information, as the BEP is considered a live document in its line of work. Typically, the DB firm can version the BEP 8-12 times, depending on the project's nature. For instance, water market projects often require numerous revisions, whereas marine projects, such as fish passage, typically do not. All internal and external project participants are involved in the development of the BEP, and the document contains all the information related to BIM in the project. The DB firm adopts NBIMS V4-based roles, their definitions, and associated responsibilities. Nevertheless, the duties may have additional requirements based on the internal organization's needs, the project role, and the workflows. The DB firm conducts extensive workflow analysis, for instance, on how to utilize BIM for a specific use case. There is a collaborative effort going on with stakeholders of a project based on regularly scheduled model task force meetings that are also defined in the BEP. These kick-offs, along with regular meetings, showcase the progress of the models and design to project stakeholders. Consequently, the BEP document should be collaboratively developed as a live document by project stakeholders throughout the project, with regular meetings to discuss progress and updates.

4.6.4.2 Lessons Learned

The industry should implement BEP for standardized operations, particularly in large organizations, to align with the future projections of digital innovation. The industry should adopt NBIMS-US V4 BEP to standardize across the industry and avoid unique one-off developments. One of the major takeaways for large organizations that span different districts is that standard implementation is beneficial across the industry, regardless of the market and project they are involved in. Implementation of standards is necessary for aligning with future digital innovation. We are already in a digital age, and markets, such as those for buildings, water, and power, have been facilitated by digital technology. The transportation market is also catching up with this digital transformation and is significantly ahead of where it was. Without implementing BIM standards, organizations would be left behind. Therefore, the industry should standardize BIM implementation by utilizing the NBIMS-US V4 BEP module, tailored to their specific needs, to align with future projections.

4.6.5 Transportation Unit BIM Use Definition Module

4.6.5.1 Implementation Process

The DB firm has a collaborative BUD implementation process and believes that using standardized BIM uses improves clarity. BIM managers select specific BIM uses for a project. Initially, various BIM uses are added to the BEP, and then, through a collaborative review process among project-related disciplines, the team adds or removes these uses as needed. Standardizing the names of BIM uses and defining them clearly helps alleviate confusion. For example, capture conditions can be referred to as reality capture, existing conditions, or LIDAR; however, having a standard term and its definition reduces ambiguity. Accordingly, standardization of BIM uses will provide clarity about the name and definition of BIM uses among project stakeholders, allowing them to be applied to various markets and projects.

4.6.5.2 Lessons Learned

The industry can utilize defined and fine-tuned BUDs available in the NBIMS-US V4 BUD module. It is a valuable resource for understanding BIM uses, and organizations can benefit from learning about them rather than creating their own definitions that differ from those of stakeholders.

4.6.5.3 Feedback

More BIM use cases may be added to the module to cater to the future needs of the industry.

4.6.6 Design Unit Project BIM Requirements (PBR) Module

4.6.6.1 Implementation Process

The implementation of BIM depends not only on the owner's contractual requirements but also on the value that it would bring to a project. As this DB firm undertakes design-build projects, the design unit works closely with the construction unit; however, there is ultimately an owner of the project who directs the work. Once the design unit has determined the scope of work and identified its role in the project, the DB firm establishes internal BIM standards as the minimum requirements for implementing the project's BIM requirements, in addition to the owners' requirements. The digital delivery team is the primary internal stakeholder, along with the design manager. Additionally, the project control team is a key stakeholder, as they review the specification that the DB firm is contractually obligated to provide to the client for a specific project. There might be projects that do not require BIM requirements contractually. The DB firm is not obligated to use BIM, as there is no contractual requirement that serves as a guiding force; however, it also does not mean that the DB firm will not utilize BIM. The utilization of BIM depends on the nature of the project. For example, if a project involves complex utility work but the scope of work does not require BIM, the DB firm will still use BIM, as it will bring value to the project. Thus, the design unit must follow both the firm's minimum internal project BIM requirements and the owners' project BIM requirements.

4.6.6.2 Lessons Learned

DB organizations should understand the owners' requirements through an outcome-based BIM approach. The implementation of the standard should focus on outcomes rather than outputs. The purpose of utilizing BIM should be to reduce the pain points for owner organizations, so that is the outcome the owner wants to achieve. As mentioned, "*So the outcome is I want to decrease X by 20%. BIM is the mechanism to do it. NBIMS[-US] version 4 is the implementation to help get there.*" Therefore, it is crucial to understand the client's actual requirements and the goals they aim to achieve.

There can be a gap between the leadership's vision and the digital delivery team's vision. There can be gaps and misalignment between the leadership and the digital delivery team in foreseeing the team's ability to add value to a project, as well as the hours required to deliver that value. Also, there is a need to be technology agnostic. For instance, BIM is not synonymous with Revit; one can use Revit, but it does not necessarily mean that BIM is equivalent to Revit. The DB firm seeks to use the technology that best suits the DB firm's needs to add value to the project.

The industry should understand its requirements and undertake outcome-based BIM implementation. Additionally, developing a shared vision between leadership and the digital delivery team would be beneficial for the DB firm BIM implementation.

4.6.6.3 Feedback

Currently, in the NBIMS-US V4, there is a gap between vertical and horizontal construction, as the standard is more focused on vertical occupied space construction. There is an opportunity for development in civil works and localization of the standard to the US market. For example, building a mall, a skyscraper, or a stadium is essentially the same, differing only in scale and scope. And all these are occupied vertical spaces, but it would be difficult to use for vertical construction of unoccupied spaces, such as a power plant. The process piping, outputs, and outcomes of a power plant differ significantly from those of a typical occupied vertical construction. Additionally, horizontal construction, such as dam and road construction, is quite different. The respondent explained, "*The project BIM standard requirements and version four, in general, is geared toward buildings and structures. So in civil, there are structures like dams and other things, but roadway design is very, very different. So I think there's an opportunity there. I think there's also a way to expand it for civil…The BIM standard is built for vertical construction of occupied space. It is not very easily usable in horizontal construction of non-occupied space or vertical construction of non-occupied space…As an example, I'm not sure I could use NBIMS[-US] version 4 on a power plant because there's not a lot of, you know, the process piping is very, very different. The outcomes are different, the outputs are different. Methodology is different.*"

Furthermore, there should be localization of international standards according to the US-based construction industry. It was stated that "*a US localization of ISO 19650, because no United States-based company wants to use a UK-based standard that doesn't make any sense for them"*. Hence, there is an opportunity to develop the standard for other markets, such as transportation, energy, and civil works, and tailor it towards the US construction industry.

4.6.7 BIM Execution Planning (BEP) Module

4.6.7.1 Implementation Process

The digital delivery team of the design unit is responsible for developing the BEP by working with internal and external stakeholders and presenting the outcomes based on the client's scope of work. Implementation of a standard depends on the client. If the client has a standard, then the DB firm has to adjust to it; otherwise, they will use NBIMS-US V4 for the project. But regardless of the BIM requirements for the project, it is the digital

delivery team's responsibility to collaborate with all internal and external stakeholders. The team should consider various aspects of work, including BIM, CAD, construction documents, IT, and production. The digital delivery team collaborates with these groups to capture outcomes so that they can be incorporated into the BEP.

4.6.7.2 Lessons Learned

One of the challenges to digital delivery teams is to exhibit the value of BIM to non-BIM leadership. This value proposition helps them understand the time incurred and charges allocated by the digital delivery team in the budget. The use of BIM is insurance for a better product, which is a physical asset, and a better project with lower costs, fewer change orders, and a faster time to market. The respondent stated, "*Make sure that your non-BIM leadership understands the value of what you're doing.*"

The owner must standardize their bidding process using the NBIMS-US V4 BEP template. This standardization would make it cost- and time-effective for owners to process bids, marking down the differences and differentiators to award bids. This will make the bidding process more efficient and effective, ultimately leading to better products overall.

4.6.7.3 Feedback

Automating the development of BEPs, such as a plug-and-play approach, would make it much easier for project stakeholders to quickly develop the BEP and encourage the industry to adopt the NBIMS-US V4.

4.6.8 BIM Use Definitions (BUD) Module

4.6.8.1 Implementation Process

The implementation of BIM uses depend on the scope of work provided by owners. During project initialization, the design unit reviews the scope of work and determines which BIM uses are required to achieve the work. Those BIM uses from the NBIMS-US V4 BUD module are included in the BEP. The DB firm has internal, ready-to-use standard templates, such as process maps or standard operating procedures, for the selected BIM uses.

4.6.8.2 Lessons Learned

BIM uses should be embedded into all processes that project teams undertake. Organizations should integrate BIM use into their design and construction processes. There should be a standard of care to ensure that models are embedded into each discipline and production structure, connected to output and outcomes, rather than just creating the model for the sake of model creation. Owners should have an outcome-based BIM use adoption mechanism. The adoption of BIM uses depend on the outcomes that owners

want to achieve, such as decreasing capital expenditure costs of capital projects. There must be metrics attached to it to measure what is successful and what is not. Thus, the industry must associate BIM uses with the outcomes they want to achieve and evaluate whether the implemented BIM uses help them achieve their desired outcomes.

4.6.8.3 Feedback

There is a significant gap in education regarding the practice of making process maps related to BIM use. Many organizations struggle to develop process maps for BIM use due to a lack of available information. The industry, like bidders, can establish means and methods for BIM use, but they want to know the scope and deliverables required for BIM use, for instance, authoring temporary work. Therefore, there is a need to provide more guidelines and education about the scope and deliverables to the industry for the BUD module, the NBIMS-US standards, and the process as a whole.

4.6.9 COBie Module

The DB firm's design unit does not implement COBie V3 at present. COBie, in the current form, is very confusing. It should be re-evaluated from the commissioning and turnover standpoint to define what operations and maintenance staff need. At its core, it is an information exchange, but for some there is a presumption that no data needs to be entered into the model to complete a spreadsheet. Additionally, the data can be hosted separately and does not need to be in the federated model; it can have a pointer that connects databases. Thus, the DB firm understands the concept of COBie but disagrees with the means and methods for implementing it.

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