The United States National Building Information Modeling Standard: The First Decade

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Abstract

This case study examines the process, development, and challenges faced by the leadership of the United States Building Information Modeling Standard® (NBIMS-US™) over its first decade. While it began as a purely aspirational document, NBIMS-US-based deliverables are now required in contracts in many countries. Drawing from internal working documents, published consensus documents, and personal interviews, the paper presents a first-hand account of the development of NBIMS-US and identifies the strengths and weaknesses of the resulting products. Lessons-learned identified in this paper may be of interest to those participating in the ongoing development of the US standard, and those developing, or aspiring to create, national BIM standards in their own countries.

Keywords: Building Information Modeling, BIM, Standard, NBIMS, STEP, PDES, IFC, IDM, MVD

1 Objective

The objective of this paper is to outline the purpose, process, and content of the first decade of the United States National Building Information Model Standard® (NBIMS-US™) for others to use as a baseline for comparison. The approach taken in this paper was to abstract and summarize the communications, working documents, publications, and communication of those directly engaged in the development of NBIMS-US. Interviews with NBIMS-US leadership were also conducted. Their comments were included throughout this paper without attribution, at their request.

The next several sections of the paper describe the historical context that lead to the NBIMS-US. Later sections discuss each of the three versions published to date. The paper concludes with recommendations for those creating their own national or regional standards.

2 Introduction

The first pen-based drawing system was developed at the start of the computer age (Southerland 1963). The "Sketchpad" system allowed its user to draw line-segments that snapped-to end points and to draw circles and regular shapes by identifying the center and radii. The data developed in Sketchpad was used as direct input to structural analysis software. By the end of the 1960's Computer Aided Drafting (CAD) systems began to be sold commercially. Within a decade these in-house systems had been commercialized as mainframe hardware gave way to minicomputers and engineering workstations. In 1979, the need for users of these systems to be able to share their designs across a product's life-cycle led several Unites States manufacturers to join with the US National Bureau of Standards (now the National Institute of Standards and Technology) to begin working on an Initial Graphics Exchange Specification (IGES) (Harrison 1989). Among its goals, IGES aimed to create a loss-less exchange of project designs in both two- and three-dimensional representations from design to production, and operation; and to ensure that replacement parts and instructions were also delivered.

While a design goal of the IGES project was the development of a clear and testable standard, as the requirement to support multiple applications grew, so did the ambiguity and complexity of the IGES specification (Harrison 1989). Those changes directly lead to difficulty of vendors to consistently map their internal data representations to those of IGES. In addition, IGES participants quickly understood that both the geometric representation and the phased delivery of design, construction, and operational product information were required. With the internal development of the "Standard for the Exchange of Product model data" (STEP) by the International Standards Organization in 1983, attention in the US turned to the Product Data Exchange Specification (PDES) (Smith 1991). PDES' goal was to define "the geometry, topology, relationships, tolerances, attributes and features necessary to completely define a component part or an assembly of parts for the purposes of design, analysis, manufacture, inspection and product support."

With such a wide mandate and variety of design and manufacturing software all tailored for specific domains, it is no wonder that these efforts were not successful. Interviews with former colleagues who participated in PDES committees describe how disagreements over terminology between building and naval architects resulted in members of the building design community leaving PDES. To respond to the specific needs of building information exchange, a group of twelve US based companies created, in 1994, the International Alliance for Interoperability (IAI); what would later become buildingSMART international (Laasko 2012). In 2013, the schema for life-cycle building information exchange, built atop of STEP was published as the "Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries" (ISO 16739).

Rather than creating conformance standard such as those developed based on years of CADD use, standards for building information models developed in IFC should be considered an "anticipatory" since the development of the standard has largely been driven by a perceived need not a funded requirement (Laasko 2012). An example of the result of that perspective can be seen in the "Coordination" Model View Definition (MVD). The need for the Coordination View has largely been overtaken by direct integration of proprietary formats by the software vendors themselves. Given that fact, the business case justifying the creation of the most important MVD published by buildingSMART international has been largely overcome by events. Those applications that have used IFC as the basis for their standards, both internationally and within the US appear to be driven by national governmental owners facing pressure to increase planning accuracy and decrease costs.

In parallel with the general effort to create a holistic building data model, a discipline-specific standard was also developed as a separate project. From 1987 to 1999, a STEP-based data model for steel structures was developed (Eureka 2016). Called the CIMsteel Integration Standards (CIS) it included both the detailed modeling of structural steel components and detailed specifications of requirements at each stage of the design and construction process. By focusing on a single building system, CIS identified actionable business process improvement possible through open information exchange. Although CIS/2 (the second version of the CIS standard) appeared superior to broader efforts, failure to maintain an ongoing, independent testing regime lead local variations that effectively created proprietary extensions of what was to have been a commonly adopted open standard. Another pressing problem to the CIS community was the inability of their discipline-specific standard to interoperate with other sectors of the construction industry.

3 From to CADD to BIM

As with most new technologies, individual governmental agencies struggled with the transition from paper to electronic drawings. The original contracts allowed government-wide purchase of CADD tools specified IGES formats. As use of these tools became more widely understood, the needs of those designing ships, airframes, infrastructure, and buildings became more apparent, each governmental agency began creating customized guidelines and requirements. A multi-agency CAD hardware and software contract (CAD2) was developed by the US Navy with support from the Army and Air Force. The half-billion dollar facilities portion of this contract was called "Facilities CAD2." Realizing the additional cost of individual requirements, military agencies organized through the U.S. Army, Corps of Engineers CADD Center in Vicksburg, MS to try to standardize these requirements. Unable to create sufficient critical-mass, a small, government-focused not-for-profit organization, the National Institute of Building Sciences, began to develop an extensive United States National CADD Standard®. This standard is now in its sixth version as CAD continues to be broadly used.

Despite this progress, it was also clear that standards aimed at capturing e-documents alone were not actually improving the productivity or competitiveness of the US construction industry. The US National Academy of Engineers identified information loss as a major barrier to productivity improvement in the construction industry as early as 1980 (NRC 1983). Unfortunately, it would be an additional 20 years before something would be done to energize the country to move toward a solution. The 2004 NIST report entitled "Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry," (Gallaher 2004) reenergized the discussion by outlining best and emerging practices that began to move away from e-document exchange to information exchange. Unfortunately, the priories of the U.S. Department of Commerce required NIST to return to their support of product manufacturers. As a result, there was no follow-up by NIST to support the construction industry.

Efforts by US Federal government agencies were also underway to try to solve recurring problems by applying new BIM technologies. The General Services Administration (GSA), was found to be leasing billions of dollars of unrented space, and had project cost overruns that required additional Congressional appropriation. With the assumption that better information management might impact the underlying organizational problems leading to their difficulties, GSA published a "BIM Guide for Spatial Program Validation" (GSA 2006). While less publicized, the US Army, under its Military Construction Transformation program, also began, in 2006, to transform its set of standard designs from CAD to BIM. Goal of this effort was to decrease the time from project start to facility handover. As with the application of CADD, decades before, rather than work toward the adoption of consensus standards, each agency has developed its own standards within their own echo-chambers.

Once again, NIBS stepped in to try to coordinate these efforts, as they had with the National CADD standard. NIBS was host to local chapters of IAI (and later buildingSMART alliance), and formed a committee to develop what would become NBIMS-US. The next sections of the paper describe NIBS-based efforts.

4 NBIMS-US Version 1

Unlike CAD, whose standard had developed from the best-practices across an industry, no standards of practice for BIM had been established in 2004. As a result, NBIMS-US V1 was seen as a roadmap for adoption of BIM technology. NBIMS-US V1 was to be published in two parts. Part 1 entitled "Overview, Principals, and Methodology" (bSa 2007).

NBIMS-US V1, Part 1 had two contributions to the discussion of BIM in the US. The first contribution was to define BIM as "a digital representation of the physical and functional characteristics of a facility." Given this information, each stakeholder in a building project could access their discipline's information over the life of a project. Rather than adopt a proprietary approach, such access would only be possible using "open standards for interoperability."

After seeing the 30-year prior history of unusable building standards under STEP, IGES and PDES, Version1 participants wanted to create standards that would be used, not simply published. As a result, the second contribution of NBIMS-US V1 was to establish a four-part methodology to guide the development of later technical standards. The first of the four parts was to establish working groups targeting specific interoperability problems. The most important work product to be produced in this stage was a business process model that clearly defined the problem to be solved. Next, was the identification of the information content in the exchanges of information shown in the process model. With this came the specific set of information to be delivered. Third, was the application of that information within commercial software. Software testing was also covered in this third section. Fourth, was the development of user implementation resources.

When published, NBIMS-US V1 contained a total of 183 pages. These pages were organized into roughly five sections, as shown in Figure 1. The largest section of the standard was the section related to Technical Standards, however, that section did not actually contain any technical standards, only a single vendor-developed suggested methodology applied to support the somewhat unique requirements of a single US government agency.

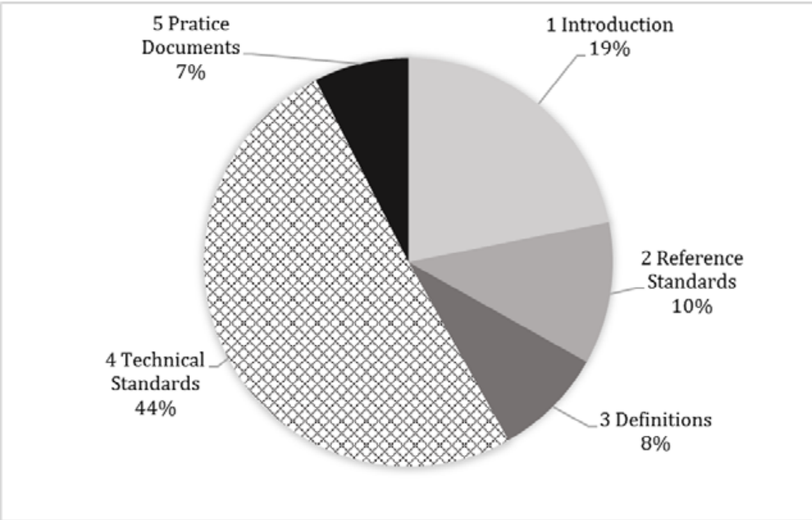

Figure 1 NBIMS-US V1, P1 Sections

Following the publication of NBIMS-US V1, Part 1 efforts began on Part 2. Part 2 was to contain specific standards and standard testing methods. Part 2 was, however, never completed. The organizing committee was unable to reach consensus as different constituents directed their efforts to competing proprietary approaches. Rather than force a resolution based on the open standard mandate identified in Part 1, multiple ideas for how to proceed with Part 2 were allowed to directly compete in the interest of holding volunteers together. Each idea promoted its own answer to one basic question, “What is the correct basis for a standard?”

Reflecting the anticipatory nature of the NBIMS-US effort, the resolution of similar topics was also taking place within the buildingSMART international organization. The development process to be used for IFC-based information exchange standards was given the acronym - Information Delivery Manual (IDM). Rather than being something new, IDM was the name given to one way to organize professional software engineering projects. Within the IDM, the subset of the IFC schema capturing process-specific information was named the Model View Definition (MVD). Through the IDM-MVD process, multiple open data standards could be implemented by applying common functional parts.

Outside the buildingSMART community, the wider adoption of proprietary BIM technologies was taking place (McGraw Hill 2007). For designers, the motivation of using 3-D design software was the reduction of drafting costs and better visualization. For builders, the motivation was an improvement shop drawing coordination made possible by adding the vertical dimension, and associated volumetric shapes, to 2-D drawings. A follow-up report in 2009 indicated that BIM technology was used in almost 50% of companies (McGraw Hill 2009). It is interesting to note that this report did not define what “using BIM” meant. As long as someone, somewhere in a large company had, at least on one project, purchased a copy of “BIM software”, the company could be considered to have “used BIM.”

5 NBIMS-US Version 2

NBIMS-US V1, P1 had been created by those with history within the standards development or IAI/buildingSMART communities. V1, P1 was widely acknowledged to be a “philosophy document.” Some participants indicated that the document had “no appeal to construction companies." Instead, industry participants wanted "something measurable." Given the anticipatory nature of NBIMS-US V1, P1 and the failure to complete P2, such critiques were expected.

The first challenge of the NBIMS-US V2 organizing committee was to reconvene the volunteer group that had been largely scattered following disagreements concerning NBIMS V1, Part 2. A renewed effort was also placed on establishing rules of governance so that matters of process could no longer be continuously questioned by those interested in moving a specific discussion in one direction or another. In some areas, committee co-chairs were introduced to ensure that multiple points of view would be respected. Given a more directed effort, persons delaying committee activities could be directly identified, resulting in the withdrawal of some volunteers' effort.

Yet there was still not a demand for collaboration in the industry, which was at the heart of the purpose of the standard. Therefore, NBIMS-US V2 continued to be seen as an "anticipatory" standard by those involved. The complete set of NBIMS-US V2 reference standards, technical standards, and practice documents were, simply a catalog of work done by others. The inclusion of the full text of reference standards created and maintained by organizations other than NIBS was a clear example of the aggregated nature of NBIMS-US V2. With regard to the technical standards included in NBIMS-US V2, all technical standard ballot submissions were required to complete a questionnaire that allowed information existing sources to be referenced within the publication.

When published, NBIMS-US V2 contained a total of 677 pages (bSa 2012). These pages were organized into roughly five sections as shown in Figure 2. The largest section of the standard was the section related to Reference Standards where classification tables (provided by a single association) were reproduced in their entirety. On the positive side, V2 did contain actual technical standards. Much of the content of the technical standards simply copied the proprietary specifications produced for the US General Services administration. The exception was the inclusion of the first consensus-driven standard for information exchange, Construction Operations Building information exchange (COBie).

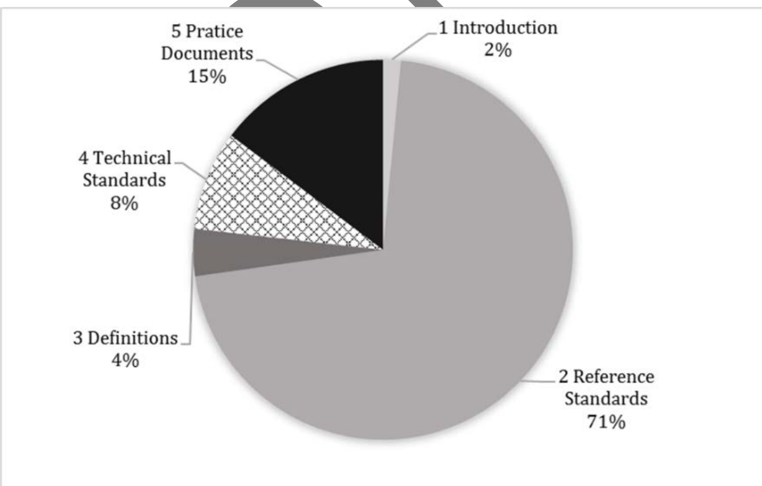

Figure 2 NBIMS-US V2 Sections

While pressure was applied by some committee members and leadership, neither the technical standards nor practice document committees achieved the goal of providing consistent, measureable standards. The technical standards committee did not require the IDM/MVD process since the development of content predated the development IDM/MVD. Also, some content contained sponsor's proprietary requirements.

On the process-standard side, subcommittee members were under great pressure not to require ISO 9000 Quality Management standards as the basis for balloted submissions since none of the prior aggregated materials were developed in accordance with international quality management standards.

The lack of clarity as to the governing rules aimed at supporting the widest possible industry inclusion resulted in two problems for NBIMS-US V2 during the balloting period. One problem arose due to language in the governing rules allowing ballots to be submitted that simply identified problem areas to be solved without providing any solutions at all, open-source or otherwise. These “blue sky ballots” were aimed at increasing industry participation, but were not required to explicitly quantify their problem statements or even identify affected business processes, as defined in the technical standard methodology of NBIMS-US V1, P1. In the end, following many long committee hours, these blue-sky ballots were not included in the publication. Neither were these ideas acted upon after NBIMS-US V2 was published, since those submitting these ideas did not have organized teams ready to define their requirements and fund the needed software engineering.

The goal of casting the widest possible net for content also introduced a procedural “loop hole” for those with proprietary specifications attempting to by-pass any technical review whatsoever. The normal process required the technical subcommittee to review and recommend forward any technical standard. The committee’s review was to check that the ballot author’s documented a proper requirements analysis and software engineering process. The committee only considered ballots whose data schema had been mapped to the underlying IFC model. This was a critical requirement to ensure that the various subsets of technical information in NBIMS-US might be able to work together. The loop hole allowed any submitter of any ballot to resubmit that ballot, independent of subcommittee recommendation, by direct appeal to the members at large. This loop hole was exercised by one firm whose proprietary data format was submitted without any requirements analysis, software engineering documentation, or IFC mapping. After several months of intensive discussion, this proprietary format was withdrawn by its author.

The final difficultly with NBIMS-US V2 occurred after balloting was complete. The production of the actual standard documentation took over a year to complete. This was due, in-part, to the lack of funding for technical editing and document production. When finally published, technical standards included in NBIMS-US V2 contained referenced information on a myriad of private and government websites containing the original source documents. Problems with the reliability of information on these sites would be directly addressed in NBIMS-US V3.

6 NBIMS-US Version 3

The Chair of the third version of NBIMS-US began by looking to correct problems that occurred in the steel industry’s STEP-based CIS/2 standard. As noted in the introduction what began as a process-based open standard for the delivery of steel design, fabrication, and erection drawings had become a set of proprietary add-ons that actually increased barriers to using the resulting information. Key to NBIMS-US V3 was the understanding that an effective standard must take into account testing, enforcement, and version control.

Despite the increasing awareness of the need to have a sound basis for process and technical standards, a significant problem with the development of NBIMS-US V3 was the pressure by all parties who provided previously included referenced content that did not conform to such a basis. To continue to contribute to this volunteer-driven effort, these authors, required their previous, non-conforming, content to be included. Practically, what that meant was that anything included in NBIMS-US V2 was required to be automatically included in V3. Although NBIMS-US V2 “practice standards” were known not to be definitive, not prescriptive, and not documented according to ISO 9001 standards, they were passed forward in V3. Over the objection of many in the leadership, technical standards referenced in NBIMS-US V1 using inadequate methodologies and containing proprietary client requirements were also passed forward in V3. The only notification that this inadequate content was passed forward was an asterisk in the table of contents.

Much of the information in NBIMS-US V3 was recognized, even at that time, as a “hodge podge” of different, and possibly even conflicting or outdated, and proprietary information with limited use in practice. Since there were no provisions to remove outdated or incomplete content in the rules of governance, intense pressure by individual authors, and NIBS stated organizational need for increases in perceived growth and inclusion, this “dubious” information incorrectly remained within NBIMS-US V3.

Despite the lack of movement on practice and legacy “standards,” progress was made in NBIMS-US V3. The first area of progress was creating a set of consensus requirements for the development of technical standards. When compiled, these requirements created an outline for technical and reference standards that demonstrated a life-cycle view of the standards process. This outline also provided the detailed criteria to be used when voting on each element of the ballot. Training was provided to ensure that those voting might have a common understanding of associated rubrics. National experts on the technical committee conducted extensive training to allow allowed practitioners to more fully understand the details of the standard and the standards process.

For the first time, NBIMS-US V3 technical standards could be considered as being more than a list of what others had done. Starting from ensuring representative stakeholder participation, business case definition, requirements analysis (i.e. IDM), software engineering (i.e. MVD), and moving to testing, training and version control, the main focus of NBIMS-US V3 was how can the standards be used and maintained. Critical to this effort was the understanding that piece-meal, unit testing of software exports is insufficient. Unit testing is important for software engineering, of course, but must be put in the context of realistically scaled contractual deliverables to become adopted in practice. Only by providing full context-based testing using whole simulated buildings can it be proven that information in models matches that provided on contract drawings.

NBIMS-US V3 technical standards also were developed with a life-cycle view in mind. Each of the “information exchange” standards in V3 identifies relevant life-cycle phase(s) that consume or produce defined building assets and performance information. For example, the Construction-Operations Building information exchange (COBie), containing significant updates from NBIMS-US V2, documented how requirements for classes of building assets were outlined during building programming, defined during the design phase, fulfilled during construction, and delivered with the keys to the building.

Ensuring efficient use of natural resources was the driver behind the development of brand new standards for heating, ventilating, and air conditioning systems (HVACie), electrical systems (Sparkie), and water systems (WSie). While these coordinated standards may be used to replace current design and fabrication drawings, the ultimate value of these standards is expected to be the development of supervised machine learning systems for building automation systems [East 2015].

Along with the technical standards, another significant contribution of NBIMS-US V3 was its glossary. Including a definition for every major term introduced in the technical standards has proven invaluable in the resolution of disputes regarding the meaning and application of the standard.

What became clear to the leadership of NBIMS-US V3, is that the groups who added the greatest contribution to NBIMS-US V3 were those who clearly defined, consensus-based objectives and processes. Having clearly defined objectives ensured that anyone doing work in that area could align their efforts with the consensus objectives. Doing so ensured that when conflicts arose there was a way to resolve, and move past, those conflicts. At least at the working-committee level, this kept every meeting from being a re-adjudication of previous decisions, as had been the case in both NBIMS V1 and V2.

NBIMS-US V3 was organized into roughly five sections. For the first time, the largest section of the standard was the section containing Technical Standards. The second largest section included, once again, the verbatim inclusion of classification systems developed by outside organizations. Practice documents continued to include the laundry list of aggregated information submitted by any party with the interest to submit a document. In one case the document included was originally created a decade before the standard’s publication date. While the overall size of this publication is large, it is provided in individual PDF chapters for ease of use.

At the conclusion of NBIMS-US V3 there were several points left unresolved. These points remain unresolved to this date. The first is how work done at the national US level is coordinated within the country and with international participants. That problem has been compounded by the splintering of building information committees and standards in the United States. The second is to determine the extent to which standard production cycles should more closely match the speed of emerging technologies. When published NBIMS-US V3 contained a total of 2167 pages organized into 50 separate files (bSa 2015) as shown in Figure 3.

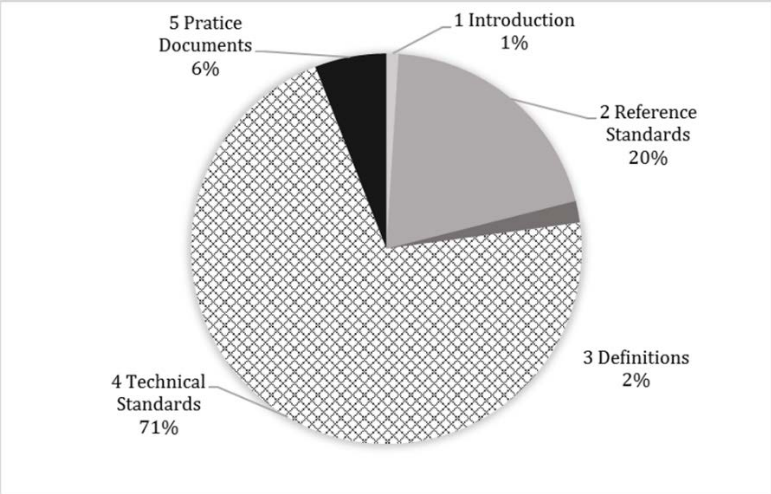

Figure 3 NBIMS-US V3 Sections

7 Conclusions and Recommendations

Ten years after the start of the US National BIM Standard effort, the key question that has yet to be clearly defined for most NBIMS-US participants is, “What is a standard?” While the NBIMS-US V3 Technical specifications have offered a clear, consensus-based answer to that question, many others will, given past history, press for inclusion of non-technical information into a “standard’. Future NBIMS-US versions must explicitly address this question with respect to the “hodge podge” of practice guides if the standard is to remain relevant. Recommendations for separating “publications” and “guidelines” from the actual technical standards, and for providing clear standards-based requirements for such documents must also be adopted moving forward.

As we move from an “anticipatory” standard to one which has been, at least in part, adopted and used in many countries, the balance between all-inclusive rules of governance aimed at growing an organization, and concrete rules required to define measurable standards have to be adjusted. To move forward, an increasing emphasis on testability and independent testing of all standards, versus the inclusion of non-working or out-of-date information, should be acknowledged and explicitly including in rules of governance before beginning work on any contents.

It has been said that a standard is not a standard unless there are objective tests to determine if the standard has, or has not, been met. As a result, explicit testing requirements for each expected deliverable against a technical standard must be included in the standard. This has been well demonstrated by the information exchange standards included in NBIMS-US V3. Implementation of test algorithms for such criteria should be accomplished using open-source software against common test files. Open-source software testing is needed to ensure transparency of testing and to fully evaluate and document multiple possible implementation assumptions and decisions. Common test files are also required to ensure transparency to be able to objectively compare software-specific examples. Given the time and effort that has gone into these test files, those in other countries may be able to reduce their efforts by reusing such information.

Process-based “standards” must be forced into future NBIMS-US documents, the documentation of such processes must also comply with standard ISO-9001 documentation requirements. To provide a defensible business case for these processes, business process simulations must also be included allow users of NBIMS-US to determine the applicability of that process to their current practice. With such documentation those adopting business-process standards would, at least, be able to judge their performance against the benefit posited by the authors. Here the business process simulations documented directly in the NBIMS-U V3 can provide a useful starting point.

Once the definition, criteria, and process for standards development have been defined, NBIMS-US, and other national standards bodies, must adopt common “rules-of-order” for all committees. In the history of NBIMS-US there has never been any training in the standards-development process. In the next NBIMS-US, norms for the management of committees, ballots, and voting must be established and used by all subcommittees to defend the claim of “standard.” These rules-of-order should be developed by the NBIMS-US organizing committee before standing up any working committees. Once completed, all officers and committee chairs should be required to attend a course, let by the organizing committee, covering standard rules-of-order and the needed committee documentation demonstrating the consensus process.

Early on, the volunteer participants who lead NBIMS-US efforts spent as little as 15 hours per week. By the end of the process, many of those serving in leadership positions were spending full-time to complete the work of their committees and coordinate their efforts with others. Two factors that contributed to these problems. First was the resolution of issues that should have been addressed by the rules of governance, but were not. Second, resolved issues were re-adjudicated due to the interest in maintaining volunteer participation. These problems occurred either because the rules were incomplete, or that the rules were not followed. While issues will inevitably arise, proper prior planning of appropriate national BIM standard content, processes, and training, should allow the Chair and committee members to reduce the time needed to organize and execute their effort and eliminate time spent re-hashing once-resolved issues.

While sponsors have supported the effort to date, these efforts have been largely underfunded. The results to date demonstrate that fact. If NBIMS-US is to grow, then potential users need to fund the effort. Several types of funding are needed. The first type is stakeholder funding to solve specific problems through Better Information Management (BIM). The second type of funding ensures that such standards are independently tested, applied, and maintained over time. The third type of funding creates the national dialog and consensus around these standards that changes industry-processes and, ultimately, contracts and performance.

The growing international adoption of the NBIMS-US COBie standard, demonstrates what can occur when adequate funding is provided to: (1) develop a technical standard that solves a specific information exchange problem, (2) freely provide testing tools and capabilities to anyone using the standard, and (3) document the use of the standard in performance-based contracts. Efforts accomplished by US-based trade associations demonstrate that paying for a technical specification alone will not result software implementation and, ultimately, industry use.

In the wider industry as a whole, there are multiple ongoing efforts toward the development of BIM “standards.” Creating, updating, and promoting these necessarily incomplete, duplicative, and often inconsistent guides and requirements costs far more than what is needed to develop well-formed, technically consistent, discipline-specific, information exchange solutions. It is the authors’ hope that lessons-learned from the first decade of NBIMS-US development will provide a firm foundation for those solving these problems in the decades to come.

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