# DEVELOPING A ROADMAP FOR BIM IN MASONRY: A NATIONAL INITIATIVE IN THE UNITED STATES

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## ABSTRACT

Building Information Modeling (BIM) provides a unifying framework for building design, analysis, and construction. The BIM model provides a digital representation of the building, so that the modeling and analysis tools used by architects, engineers, constructors, managers and owners can read from and write to the same information source. Over the last 20 years, the development of material-specific BIM tools has been led by the structural steel and precast-concrete industries, and recent efforts are advancing the state of the art in cast-in-place concrete. This paper reports on a national initiative in the United States to develop BIM requirements for masonry. The National Building Information Modeling for Masonry Initiative (BIM-M) is developing a roadmap for BIM development in five key areas: architectural parametric modeling, structural modeling and analysis, masonry construction activities, construction management, and masonry materials provision. The paper introduces the overall initiative, provides background on the development of the BIM-M roadmap, which has just recently been released, and highlights key aspects of each area of BIM for masonry.

**KEYWORDS:** building information modeling, BIM

## INTRODUCTION

BIM is an acronym that stands for an object, a "building information model" and also a process for creating and using that object "building information modeling". According to the National Institute for Building Sciences, a building information model "*is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward.*"[1, 2] In this context, the proposed parallel definition for masonry BIM is *a digital representation of the physical and functional characteristics of masonry materials and systems*.

This paper introduces an initiative by the North American masonry industry to bring masonry materials and systems into BIM. Through a process of precedent research, stakeholder input, building case studies and software evaluation, the effort is defining the requirements for masonry BIM. The initiative is sponsored by the International Union of Bricklayers and Allied Craftworkers (IUBAC), the Mason Contractors Association of America (MCAA), the International Masonry Institute (IMI), the National Concrete Masonry Association (NCMA), the Western States Clay Products Association (WSCPA) and The Masonry Society (TMS) and is being overseen by the Digital Building Laboratory at the Georgia Institute of Technology. The initiative is focusing on both aspects of BIM, the development of the digital representation of masonry units, products and buildings; and on the development of the business processes and workflows that will implement masonry BIM.

**DEVELOPMENT OF BIM**

The term BIM arose in or around the year 2000, but the fundamental work supporting the development of building product models and the use of information technology in the AEC industry has been ongoing since the mid 1980's [3]. It is beyond the scope of this work to track the historical development of BIM, but a number of important efforts that will impact the development of masonry BIM are described here. The International Alliance for Interoperability (IAI) formed in 1994 to bring information technology to the construction industry. The IAI promulgated open standards for building data models, and introduced a data standard known as Industry Foundation Classes (or IFCs) in 1996 and 1997 [4, 5]. The IAI is now known as buildingSMART and is represented in the United States by the buildingSMARTalliance (under the auspices of the National Institute of Building Sciences) and in Canada as buildingSMARTCanada (under the auspices of the Institute for BIM in Canada or IBC).

In the commercial software world, the transition from the creation of 2-D "flat" CAD drawings to the creation of full 3-D computer models took place first in the mechanical engineering, automotive, and aerospace industries with the development of parametric modeling software such as Pro/E (Parametric Technology Corporation) and CATIA (Daussault Systems). In parametric modeling systems, both the geometry of the objects, and the relationships of the objects to one another are captured. In parametric CAD systems, the concept of pre-defined, permutable parametric objects (i.e., classes, families) allow for the rapid creation of design geometry. These objects are linked to data that describe non-geometric aspects of the objects, for example material properties, supplier information, and specifications. The linking of geometric- and non-geometric data allows the parametric modeling software to integrate with engineering and manufacturing analysis applications such as quantity estimating and finite element analysis.

The Architecture, Engineering, and Construction (AEC) industry followed these precedents with the inclusion of 3-D aspects in CAD programs such as AutoCad (AutoDesk) and Microstation (Bentley), but these platforms did not support the data structures necessary for BIM. Current BIM software such as Revit (AutoDesk), BentleyBIM (Bentley), Digital Project (Gehry Technologies), and Tekla Structures (Tekla) support to varying degrees the parametric geometry and meta-data requirements necessary to create and share BIM models. All of these software have internal, proprietary data structures, and thus the sharing of information between BIM platforms and specialized software used in engineering analysis and construction management is limited. The OpenBIM concept being promoted by buildingSMART is pushing the industry to a more widespread use of IFCs, in support of better interoperability between BIM applications [6].

In addition to BIM software, much work has gone into understanding BIM processes, that is, the means through which the BIM software and data models will be used in practice by a wide range of stakeholders in the AEC industry. When a given building project is under design, a design-phase or BIM authoring tool is of primary interest, and the focus is on design activities by the architect and engineering consultants: structural, mechanical, electrical etc. The American Institute of Architects (AIA) has developed a guide for implementing BIM in the design phase, and determining the level of detail to be included in the final BIM deliverable [7]. In the construction phase, a more detailed BIM model may be generated to take the place of traditional shop drawings or to drive fabrication processes. In addition, this construction-phase BIM model can be used by the general and sub-contractors for cost estimating, project scheduling, clash detection, etc. The BIM Project Execution Guide describes procedures for implementing BIM during the construction phase of a project [8]. A comprehensive report by McGraw Hill captured the value of BIM to stakeholders throughout the process, from design through construction, and provided a business case for BIM implementation in the AEC industry [9].

## RELATED EFFORTS IN NON-MASONRY CONSTRUCTION SYSTEMS

One of the first efforts to develop digital data for a construction material system took place in the structural steel industry, beginning in the early 1990's. The CIS (CIMSteel Integration Standard) project from the Steel Construction Institute of the United Kingdom formed the basis for the American Institute of Steel Construction (AISC) computer database of structural steel shapes that is in use today [10]. Eastman and colleagues showed how the use of the structural steel data model could be integrated into BIM platforms and processes [11]. The efforts in bringing structural steel into BIM have been highly successful and the steel detailing software used for shop drawing production in the steel industry today rely on the construction of full 3-D parametric BIM models of structural steel in buildings. Work on the automation of design and detailing processes in structural steel is ongoing, with a focus on the transition of computer representations of steel elements and connections into IFCs [12].

Another important example for masonry BIM is the 10-year effort sponsored by the Precast Concrete Consortium / Precast/Prestressed Concrete Institute (PCI) and the Charles Pankow Foundation, to develop BIM requirements for load-bearing precast concrete buildings and for precast concrete cladding on non-precast buildings. These efforts were led by Chuck Eastman at Georgia Tech. The precast concrete BIM effort included an initial planning effort and roadmap, first published in 2003 [13]. As the work progressed, the research team led an industry-wide effort to develop parametric models for precast concrete elements [14], and to implement these elements in commercial BIM software (Tekla Structures and StructureWorks). More recent work is developing requirements for exchanges between design-level BIM authoring software, structural analysis, and construction and fabrication modeling software [15]. Real-time exchanges of BIM information among various software platforms were recently demonstrated at the US national PCI Convention in October 2012.

## TECHNICAL CHALLENGES OF MASONRY BIM

The structural steel and precast concrete examples provide powerful guidance for the process that should be followed in the development of masonry BIM. The technical challenges to developing masonry BIM will however be different than those faced by the steel and precast industries. Because BIM is a digital representation of design and construction, and because masonry is a significantly different construction system relative to structural steel and precast concrete, it follows that many of the data requirements for masonry BIM will be unique. In the section below, specific challenges to the underlying information technology for masonry BIM are highlighted. These are examples only will be greatly expanded upon and will form the basis for the masonry BIM specification, to be developed in the next phase of this research.

*Multitude and complexity of masonry types:* Both concrete and clay masonry units are available in a wide range of sizes, many with complex geometry. Though there are common sizes and configurations of clay and concrete masonry units available [16, 17], there is also an extended range of masonry units that are frequently used that have not been standardized [18]. And, in many instances, such as in the cut and cast stone industries, the masonry units may be made custom for the specific job. The use of custom units occurs often in brick masonry. As an example, in Frank Lloyd Wright's Johnson Wax Building, over 200 curved brick types were used [19]. In a more recent example by architects Mack Scogin and Merrill Elam, a family of custom bricks was developed for the new Yale Health Services Building [20].

*Lack of a digital standard for representation of masonry units:* The wide range of standard units must be instantiated in a computer data structure that is standardized across the masonry industry. This data structure must be capable of representing geometric attributes of the masonry, as well as meta-data regarding the strength and other non-geometric attributes. To facilitate photorealistic rendering of masonry construction using these units, the data structure should also include bitmaps that can be applied to the surface during rendering. An interface to this data structure, which will allow for the creation of custom units, must also be developed.

*Requirements for modulation and aggregation of individual units into assemblies:* Currently, it is simply not computationally practical (or even possible) for masonry BIM software to track individual masonry units in an entire building. Therefore the masonry BIM data structure must include the definition of wall types, and means to map these wall types onto regular and irregular regions on wall surfaces. The walls must be represented in at least three different modes: regions without populated masonry units (wireframe), regions with masonry units as 2-D polygons, and full 3-D photorealistic rending with masonry units modeled as solids. In addition, the wall definition must include the propagation of masonry units in various bonding pattern with modular coordination of masonry veneer and backup systems. The current version of Revit (AutoDesk) provides some aspects of this envisioned functionality.

*Structural and construction definitions or viewpoints of masonry walls:* Current BIM authoring tools do not differentiate between load-bearing and non loading-bearing masonry walls, and thus the transfer of architectural wall definitions to the structural engineer, and the subsequent analyses of these walls for gravity and lateral forces is not facilitated as it should be in a BIM-driven process. This functionality does exist in other material systems. In addition, the BIM data structures do not support walls being subdivided into meaningful production increments (such as the work of one masonry crew on a wall for a day or a week) so it is difficult to use the construction BIM model as a planning resource for masonry. To support alternative views of a given object, by extracting that information necessary from the given user's viewpoint, is known as a Model View Definition or MVD. As part of the masonry BIM initiative, these MVDs will be developed, along the lines of those developed for the precast concrete industry [21].

## EARLY DEVELOPMENT EFFORTS IN MASONRY BIM

Though there has been no previous coordinated industry-wide effort to bring masonry into BIM, there are a number of research and software implementation efforts that are related to and support the new industry-wide masonry BIM effort. These efforts can be categorized into one of the following areas:

1. Efforts to embed masonry objects in current BIM platforms.
2. Integration of masonry into BIM-related AEC software.
3. Parametric modeling of masonry systems and buildings.
4. Data structures for representing masonry in BIM platforms.

Most of the major suppliers of brick in the United States have developed masonry families[1] for their brick, which can be imported into the Revit BIM application. This allows for Revit to display the proper brick coursing and to roughly estimate the number of bricks that are contained within a given rectangular region containing this brick. At this time however, the brick families do not contain any detailing information, no coursework coordination between brick and backup systems, etc.

In the structural domain, the masonry industry in North America supported an effort to integrate structural masonry materials into structural analysis software (Bentley Ram) [22] supporting earlier work by Biggs on hybrid steel/masonry structures [23]. Whiting et al. have developed structural modeling techniques for complex masonry structures, and briefly describe the representational requirements to transfer architectural information for complex load bearing structures into structural analysis programs [24]. Gentry et al. have also described a process by which structural analysis can be tied to architectural parametric modeling [25].

Recent work by Cavieres et al. have introduced the potential for embedding masonry as fully parametric objects in a BIM system [26]. An experimental prototype of this software was developed using Generative Components and Microstation (Bentley). The software was demonstrated at the NCMA Annual meeting in 2010, and a group of apprentice masons constructed a wall with information extracted from the BIM model [27]. Along similar lines, Monteiro et al. discuss data structures for representation of masonry patterns within BIM systems [28]. The authors discuss rules for horizontal and vertical propagation of masonry, and the relationship between the propagated wall masonry elements and other building elements such as floor plates and pilasters. The modularity of masonry is discussed, along the lines of the now withdrawn ASTM standard on block/brick masonry modularity [29]. Nawari proposed an initial view of the way that masonry walls might be represented in IFCs [30].

## MASONRY BIM FROM THE STAKEHOLDERS VIEWPOINT

The national initiative began with an initial survey and follow-on symposium at Georgia Tech, held in September 2012, to gather input from stakeholder groups. Around 50 stakeholders from the AEC industry and from the masonry industry sponsors met for two days in general sessions and separately in five workgroups to provide input to the project team. These stakeholder workgroups were focused on the specific viewpoints of material suppliers, architects, structural engineers, general contractors, and masonry contractors. Key aspects of masonry BIM as voiced by each workgroup are shown in Figure 1 and discussed in brief in the text below. In some instances the aspect expresses a desire that a given stakeholder group perceives as a benefit from

[1] A family is a pre-defined arrangement of elements in a parametric model. The family includes rules that allow the family to adapt to specific dimensional requirements when it is applied to a given building. In the context of Revit and masonry, it includes masonry units represented as surface of rectangles in a given bonding pattern.

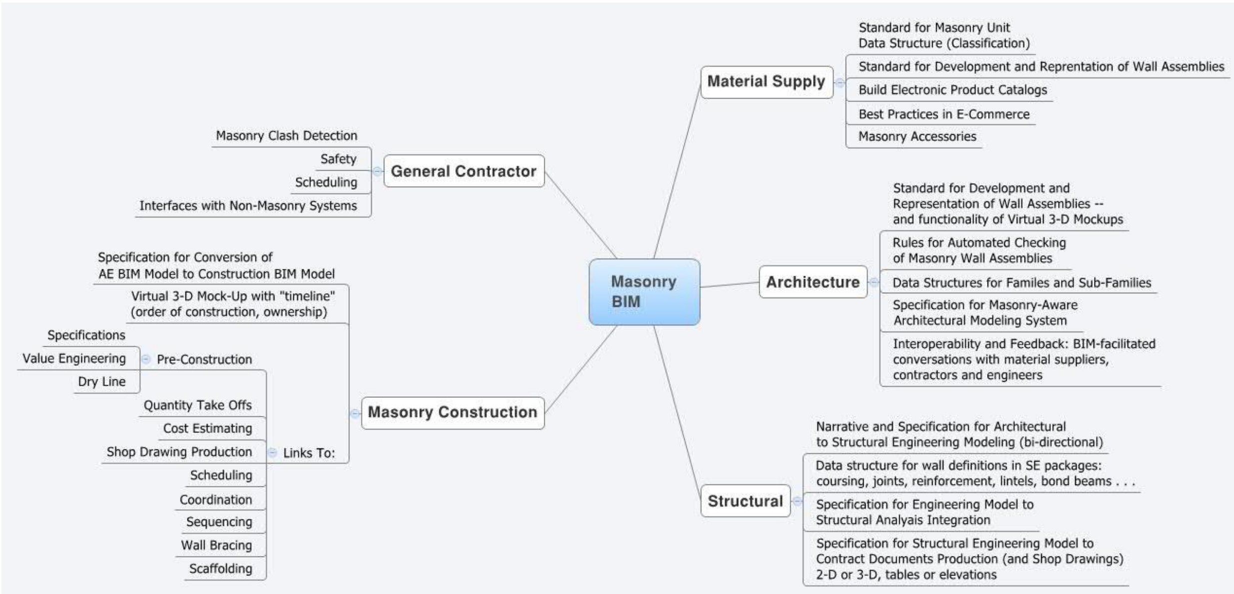


**Figure 1: Key Aspects of Masonry BIM by Stakeholder Group**

a BIM-enabled masonry industry. In other instances, the aspect represents a contribution that the given stakeholder group must make in order to enable masonry BIM. The viewpoints are described as a broad narrative at this point, but as they are refined they will speak directly to the model view definitions (MVDs), BIM workflows, and data requirements for each masonry BIM viewpoint.

## MATERIAL SUPPLIER VIEWPOINT

The masonry material supplier desires a closer connection to the clients that specify (architects and engineers) and purchase (building owners) their products. In order to achieve masonry BIM, the suppliers will be required to collaborate in and contribute to the development of a common electronic data structure for masonry units. They will need to support the development of electronic versions of the technical notes and industry-standard details that are currently in widespread use by masonry designers. The material suppliers stand to benefit from tighter integration of BIM and the masonry supply chain. This may allow for better prediction of masonry unit consumption, and the integration of e-commerce concepts through which masonry contractors can automate the ordering and delivery of masonry units and accessories.

## ARCHITECTURE VIEWPOINT

The architect desires tools to quickly map masonry units and systems onto building forms, and to be able to manipulate these forms without having to re-generate the masonry. Architects want BIM systems to recognize the module on which a given masonry system acts and to guide in the dimensioning of walls and the placement of openings to conform to the masonry system. They want access to preliminary takeoffs and cost-estimates to understand the practical implications of their design decisions. Architects are concerned with building enclosure and waterproofing, and desire that details regarding masonry reinforcing, support, ties, and sealing are included in the BIM families published by the masonry industry for their materials and systems. For novel and

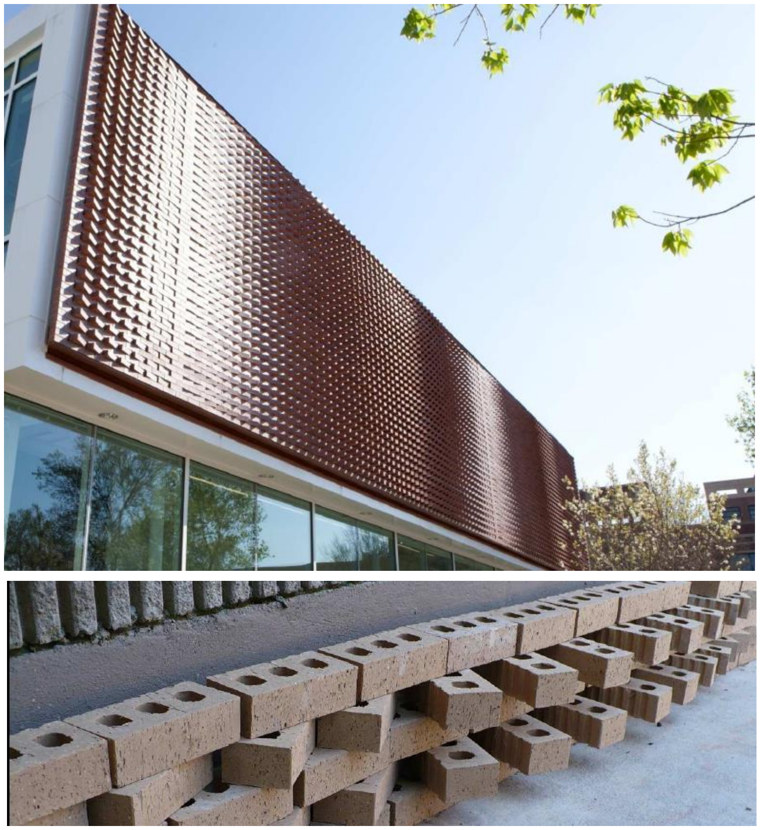

**Figure 2: Parametric modeling requirements for complex masonry walls: Southern Polytechnic State University, Design Studio II, Marietta, Georgia by Cooper Carry Architects.**

complex buildings, architects wants a BIM system that supports flexible parametric modeling that allow for representing novel forms of masonry (Figure 2).

## STRUCTURAL ENGINEER VIEWPOINT

The structural engineer desires to closer integration with the digital tools that architects use, including the ability to share digital information bi-directionally with architects using BIM tools.[2] The structural engineer needs to identify walls that are load-bearing and non load-bearing, and to further identify walls that are acting as part of the lateral load resisting system. The structural engineer desires to have these wall identification steps operate within BIM, to preserve the dialog with the architect during early stage structural design. In addition, structural BIM should be linked with structural analysis software, to provide feedback on the efficacy of structural configurations [31]. Finally, as designs mature, the structural engineer needs to have

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[2] A uni-directional information flow in BIM indicates that the downstream user can convert and use information provided by the upstream user, but is not able to return updated information to the originator within the BIM process. Bi-directional information flows imply that the two users can collaborate within the BIM process. In masonry, collaboration between the architect and engineer is of critical importance, due to the nature of load-bearing masonry.

BIM-enabled tools for generating reinforcing plans for reinforced masonry walls, as well as coordinating masonry details in the structural BIM model.

## GENERAL CONTRACTOR VIEWPOINT

Sophisticated general contractors (GCs) are pushing their subcontractors to embrace BIM technology. In many cases, general contractors are creating complex models 3-D models of masonry buildings, in the absence of masonry contractors' ability to do so (see example from Mortenson Construction, Figure 3). Contractors desire to have masonry construction fully embedded in BIM, so that BIM tools for interference checking, 4-D simulation, and project scheduling can interact with masonry in a reliable manner.

## MASONRY CONTRACTOR VIEWPOINT

Of all of the stakeholder groups, only the mason contractor (and the staff and masons he employs) are dependent on masonry as their livelihood. And so from this point of view, the mason contractor stands to gain the most from masonry BIM. The processes involved in planning, procuring, scheduling and executing masonry construction will all benefit from working from a rich (masonry aware) and common (available to all applications) knowledge repository. In the surveys completed as part of this research, both general and masonry contractors identified project scheduling and clash detection as two of the highest priorities for masonry BIM. In addition to these two activities, mason contractors identified quantity take-off, cost estimating, scaffolding design, and wall bracing design as high priorities for masonry BIM. Masonry contractors will have to support the BIM development by providing access to their internal processes and ways of doing business. When masonry BIM becomes a reality, contractors will have to commit to educating their staffs and implementing BIM workflows.

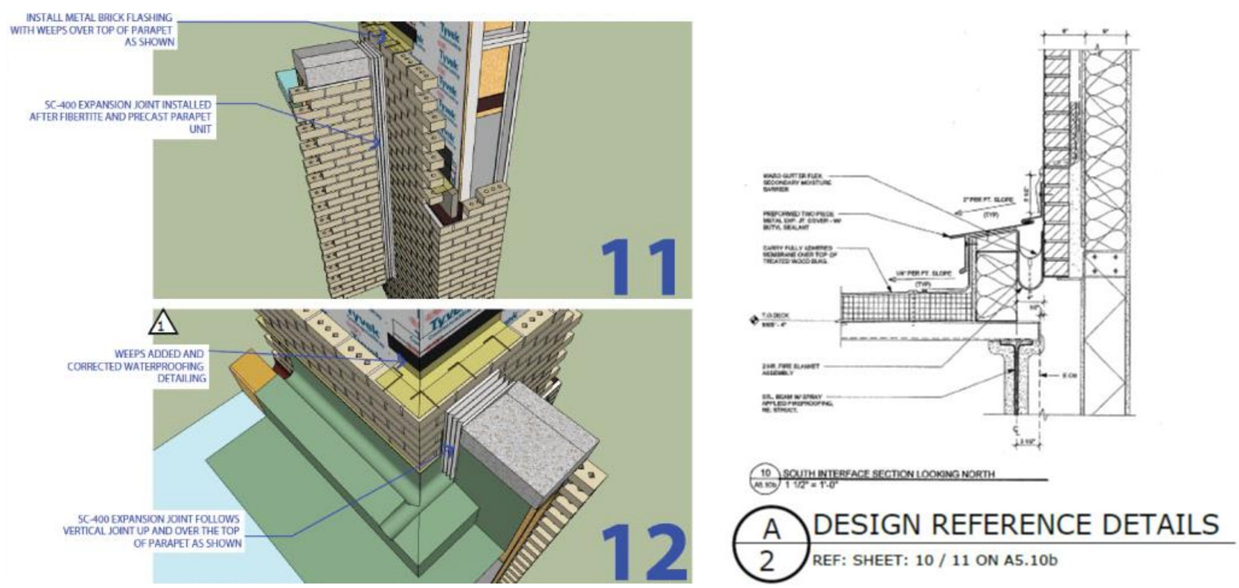

**Figure 3: 3-D Virtual Mockups of Masonry Construction (courtesy Mortenson Contruction)**

## INSTITUTIONAL CHALLENGES TO MASONRY BIM

In addition to the technical challenges enumerated previously, the BIM-M initiative faces a number of institutional challenges beyond those faced by the precast concrete and structural steel industries. First, the stakeholders in the masonry industry are represented by a diverse set of institutions representing various and, in some matters, divergent interests. As a material system, masonry is a much more diverse and ubiquitous material as compared to steel and precast. Masonry encompasses many precursor material types (clay, concrete, natural stone, cast stone) and is widely used in both residential and commercial construction. Fortunately, the masonry industry recognizes that a commitment to BIM is important for all facets of the industry, and the initiative has garnered wide support from industry partners.

## SUMMARY

BIM is an object, a building information model, as well as a process for creating and deploying that model. The National Building Information Modeling for Masonry Initiative (BIM-M) has developed a roadmap for BIM development in five key areas: architectural parametric modeling, structural modeling and analysis, masonry construction activities, construction management, and masonry materials.[3] The roadmap follows examples set by the structural steel and precast-concrete industries. The major challenges to masonry BIM revolve around the complex and diverse nature of masonry, and the need to represent masonry construction in BIM systems in both compact (for computational efficiency) and highly detailed (to support virtual construction) manner to fulfill various stakeholder requirements. The masonry industry is clearly more diverse and diffuse than the precast concrete and structural steel industries, with a wider range of stakeholder groups. Success for the initiative will depend to a great degree on the willingness of the stakeholders to seek and support a common vision for masonry BIM.


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[3] The BIM-M roadmap can be downloaded from: http://www.ncma.org/foundation/programs/Lists/Funded%20Grants%20and%20Scholarships/Attachments/102/BIM-M%20Roadmap%20for%20Distribution%2031%20January%202013.pdf

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