DEVELOPMENT OF THE DESIGN TO FABRICATION INFORMATION DELIVERY MANUAL (IDM) FOR MODEL-BASED INFORMATION EXCHANGE

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BIOGRAPHY

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SUMMARY

For the bridge industry to capitalize on BIM for the design, construction, and management of bridge projects, a standardized scheme and method of publishing and exchanges the data needs to be developed and adopted. As the National BIM Standard and the industry foundation classes (IFC) provide the standards and methods for information exchanges for the building domain, so too must one be developed for bridges. In order adopt a neutral format like IFC, the bridge industry must first develop standardized exchange requirements. The Design to Fabrication IDM encompasses the process and workflows that detailers and fabricators need in order to receive the model-based information required to conduct their business processes. Significantly, the success of the IDM will drive the creation and utilization of the neutral exchange standard that can be adopted in end user software. This exchange standard will enable fabricators and detailers to automatically import electronic based information directly into their in-house software, drastically removing the need for manual data input. Additionally, the Design to Fabrication IDM is one of the first developments to utilize the National BIM standard in the transportation industry, and the results of this project would significantly provide the best practices and guidance for future developments.

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Introduction

Building Information Modeling (BIM) for bridges will be integral to the management of bridge projects in the future. State Departments of Transportation (DOTs) and other owners are beginning to see the potential asset management advantages to using BIM. There have been many successful use cases of BIM in the transportation industry, and there are many untapped advantages yet to be achieved (1). BIM is not just a strong visual 3D picture of a structure that one can fly through and use for marketing purposes. Rather, BIM encompasses the information that describes a structure, from conception through operation, and into service. Although being able to use information in a standalone fashion, such as a visual 3D picture, can be useful, much greater potential exists through interoperability; i.e, linking such information to other areas, such as designers to fabricators to contractors to maintenance/asset management tools.

A standard scheme and method of publishing and exchanging data must be developed and adopted in order for the bridge industry to capitalize on interoperability to enhance asset management systems. As the National BIM Standard and the industry foundation classes (IFC) provide the standards and methods for information exchanges for the building domain, so too must standards and methods be developed for the bridge domain. Like IFC, such standards and methods must be neutral (rather than proprietary) to facilitate use by all parties in the domain.

To establish a neutral format like IFC, the bridge industry must first develop standardized exchange requirements. The information that makes up an exchange is known as an information delivery model (IDM). The Design to Fabrication IDM is one of the first developments to utilize the U.S. National BIM standard in the transportation industry. The results of this project of creating this IDM will provide the best practices and guidance for future developments. Hence the development of the Design to Fabrication IDM is a significant first step towards both developing neutral information exchanges and future IDMs for the bridge domain.

This article discusses the initial development of the Design to Fabrication IDM. This IDM encompasses the processes, workflows, and data requirements that designers and fabricators need to facilitate information exchange by data (i.e. BIM) instead of paper (or e-files) for the activities they need to perform. Put another way, the IDM will define the information model (BIM) needed for design data to be conveyed directly to the fabricator. Then, using a neutral format (e.g., IFC), fabricators and detailers will be able to import electronic based design information directly into their in-house software, removing the need for time consuming and error-prone manual data input. The Design to Fabrication IDM will provide the guidance, requirements, and tools needed to enable interoperable data exchange while providing the end users the confidence that the information they receive is accurate, sufficient, and reliable.

Information Delivery Manual (IDM) Development Overview

The U.S. National BIM Standard follows a four phased “Interoperaperable Exchange Development and Use” process to produce BIM specification and implementation standards. Figure 1 illustrates the elements and relationships of the high-level view of the four main phases: program, design, construct, and deploy (2). This image has been modified to show which experts are needed for the various phases. The industry domain experts are key for identifying the information requirements that need to be implemented in software, while the software experts implement those requirements into the exchange standards and software.

The purpose of the first phase, *program*, is to develop a consensus on a business use case for the target industry process needed to adopt a neutral exchange standard. The main questions asked include: *What is the purpose and scope of the process needed to be defined? Who are the process participants*? *What information needs to be exchanged? Which points and in what format are the information exchanged?* The answers to these questions, in addition to other important reference information, are captured in the integrated reference document called the information delivery manual (IDM). The IDM is the main documentation that is created by the industry domain experts to be used by both the software experts to develop the IFC exchanges and the end users to utilize the IFC compatible software. ISO 29481-1:2016(E) (3) provides a methodology and recommendations for general IDM development.

The goal of the IDM is to document all of the information and data requirements needed to produce one or more model view definitions (MVD). An MVD is the subset of IFC schema needed to satisfy the exchange requirements described in the IDM. An MVD is the specific IFC coding that will be directly implemented into software. In other words, the IDM (produced by the industry domain experts) explains to the software and IFC experts what information is needed to perform tasks, and the MVD (written by the software experts) is the technical file that will to be implemented into the software programs. For example, if a fabricator needs material properties for a specific exchange, the IDM would list the specific information in laymen's terms (member type, length, size, etc.), and the MVD provides the corresponding IFC coding needed to satisfy the exchange of information (IfcElement, IfcLengthMeasure, etc.). The MVD would then be incorporated into the software that the fabricators use.

Some basic considerations apply for creating an effective IDM. First, assumptions must be made to specify the scope of the use case to minimize ambiguity and ensure that the real-world use cases are accurately represented. There cannot be multiple variations within one IDM, so specifics are necessary. For example, the IDM for design build projects would be different from the IDM of design-bid-build projects. Although the scope and size vary, IDMs must have a minimum of one point of information exchange where two distinct software applications transfer information (e.g., sender and a receiver). Finally, an IDM must be developed using functions, concepts, and terminology that are common in the industry so that it can be expanded and reused to assist the development of other industry-defined information exchanges.

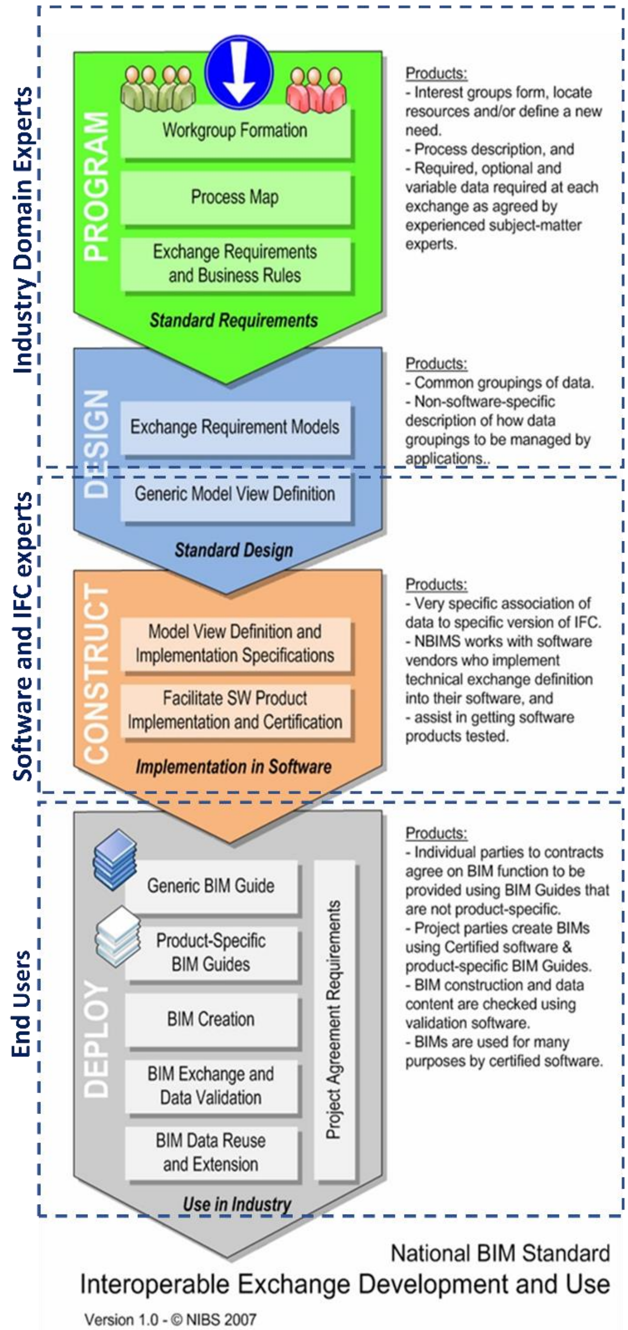

Figure 1: Modified National BIM Standard Development and Use Diagram

The first step in the program phase is the working group formation. This a collaboration of subject matter experts (SMEs) that facilitate the creation the specific IDM. This group must be composed of industry domain experts who have the knowledge and forethought about the specific business processes and use cases needed to effectively define the IDM. Next, the business process is graphically mapped out using standard Business Process Modeling Notation (BPMN) templates (4), called a process map. The process map identifies the content and boundaries of the specific business process, including who is involved (actors), where information is created or used (activities), when the activities happen as it pertains to the lifecycle of the project (phases), how information is passed (flows) and the points of information exchange (exchange models) (See Figure 3). Process maps also display the logical sequence of the activities and information exchanges. Details about each activity are written in a narrative form to provide more information. After the process map has been developed and the points of information exchanges have been identified, the final step is to define the specific exchange requirements (ER) of each point of information exchange. An exchange requirement defines and documents the information between two or more actors to be exchanged in support of a that business use case requirement. An ER identifies what information is needed, where the information is sent from and received by, and the level of detail of the information.

Steel Bridge Fabrication Working Group Formation

The joint effort between the American Association of State Highway and Transportation Officials (AASHTO) and the National Steel Bridge Alliance (NSBA) has been developing the first IDM in the bridge domain. The AASHTO/NSBA Steel Bridge Collaboration created task group (TG15) to focus on Data Modeling for Interoperability. This group built a dataset library and develop the first high-level process map of the bridge life cycle. Then, as a pilot study, a joint erection/data modeling subcommittee (TG10/TG15) worked with erection engineers to establish an Information Delivery Manual (IDM) for steel bridge erection engineering. Because this was the first development of a bridge related IDM, the task force also established a model for the process of creating bridge IDMs. Several lessons learned where identified, including detailed assumption and standardized formats, which enable future work to be completed quicker and more purposefully. Recently, to assist in the Transportation Pool Fund project “Building Information Modeling (BIM) for Bridges and Structures” (5), the AASHTO/NSBA Steel Bridge Collaboration created another joint task group, TG1/TG15, Data Modeling for Interoperability and Detailing, to supply the data requirements needed for the development of the Design to Fabrication model view definition (MVD). The MVD is the subset if IFC entities needed to data required by the fabricator and detailer to complete their scope of work to fabricate the structural steel.

Design to Fabrication Process

The creation of the Design to Fabrication IDM was motivated by the emerging Building Information Modeling (BIM) for Bridges and Structures. One of the main driving questions of developing neutral exchanges is: *what fabrication processes can benefit from BIM?* For example, the Design to Fabrication information exchange provides an excellent opportunity for benefits to owner, designers, and fabricators. In the traditional approach, 2D drawings (plan sets) are manually marked up by fabricators to elicit the data needed for fabrication, and this data is manually inputted into the in-house CNC machine software, used for the creation into the shop drawings, and used for the creation of the bill of materials (Figure 2). In this case, much of the data is transferred manually, which is time consuming and error prone. Therefore, the main question to ask is: *how can these manual processes be automated?*

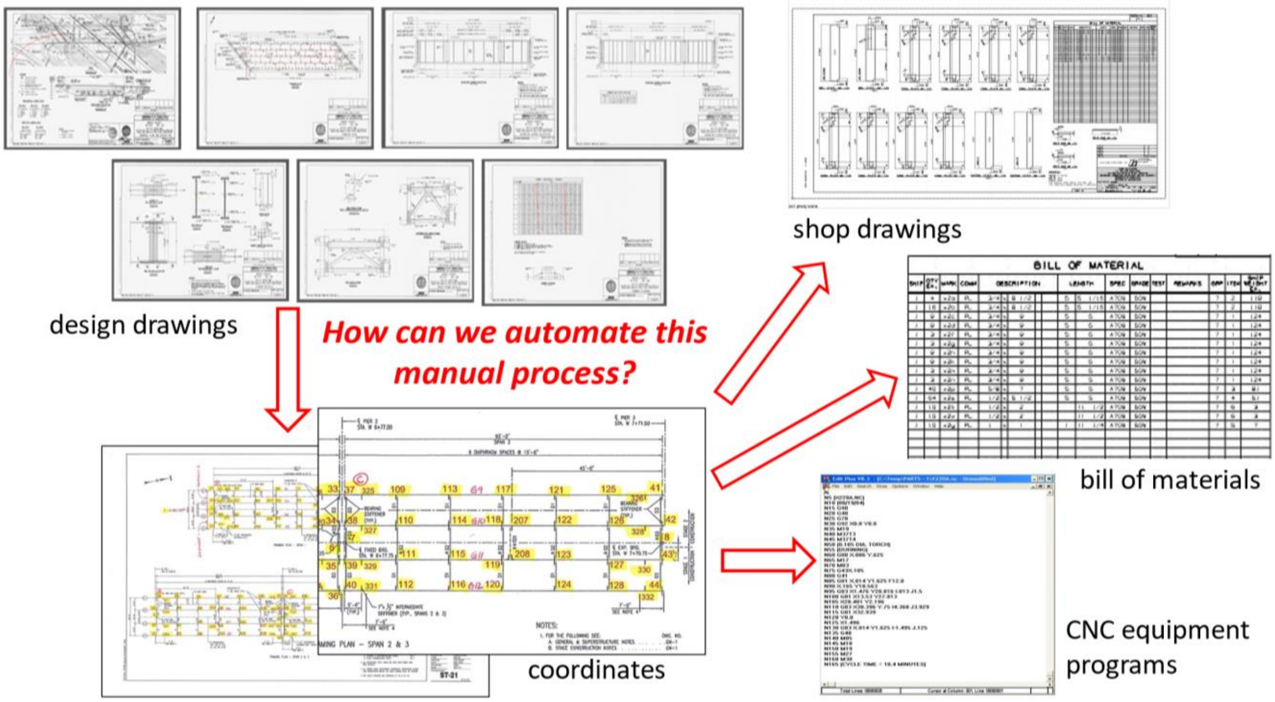

Figure 2: Traditional 2D Design and Mark-up for Detailing and Fabrication

The use of BIM to drive electronic exchange will bypass 2D drawings. Rather, the bridge design will be passed to the fabricator/detailer software to create the geometry needed to produce shop drawings and code for fabrication CNC software. The benefit of BIM-based model is that it will eliminate the manual transfer of original design data. Further, if any design changes are needed, the data model can simply be edited by the designer and passed electronically to the fabricator instead of the designer having to redraw designs and fabricators needed remark up 2D prints and manually input data.

Although this is one a major use case, there are many other use cases that could be explored. Additionally, in preparation for the adoption of IFC in the transportation industry, it is imperative to begin the process of the IDM creation for design to fabrication to expedite the IFC development process Therefore, the scope of the Design to Fabrication IDM is to contain the entire fabrication and detailing throughout the project life cycle.

There are a few major assumptions made to define the scope of the Design to Fabrication IDM. The first assumption is that the bridge project delivery would be design-bid-build (other delivery methods will require alternate IDMs that address needs that are specific to such methods). The second major assumption is that the bridge type will be a typical steel girder bridge. Other bridges, like steel arch bridges and trusses, will be addressed in the future. The third assumption is that the actors will be broken down into roles, even if the same entity can perform multiple roles (e.g. fabricator performing in-house detailing). These distinctions are important since the business processes vary differently based on project type and delivery, and defining the assumptions upfront ensures the consistent and focused development process.

Figure 3 displays a portion of the Design to Fabrication process map that was developed by the working group. Since the scope of the IDM pertains to all activities that produce the information needed for steel bridge detailing and fabrication, any activities that produce data that is critical for fabrication need to be identified. Likewise, any activity that is not related to data needed for fabrication are excluded.

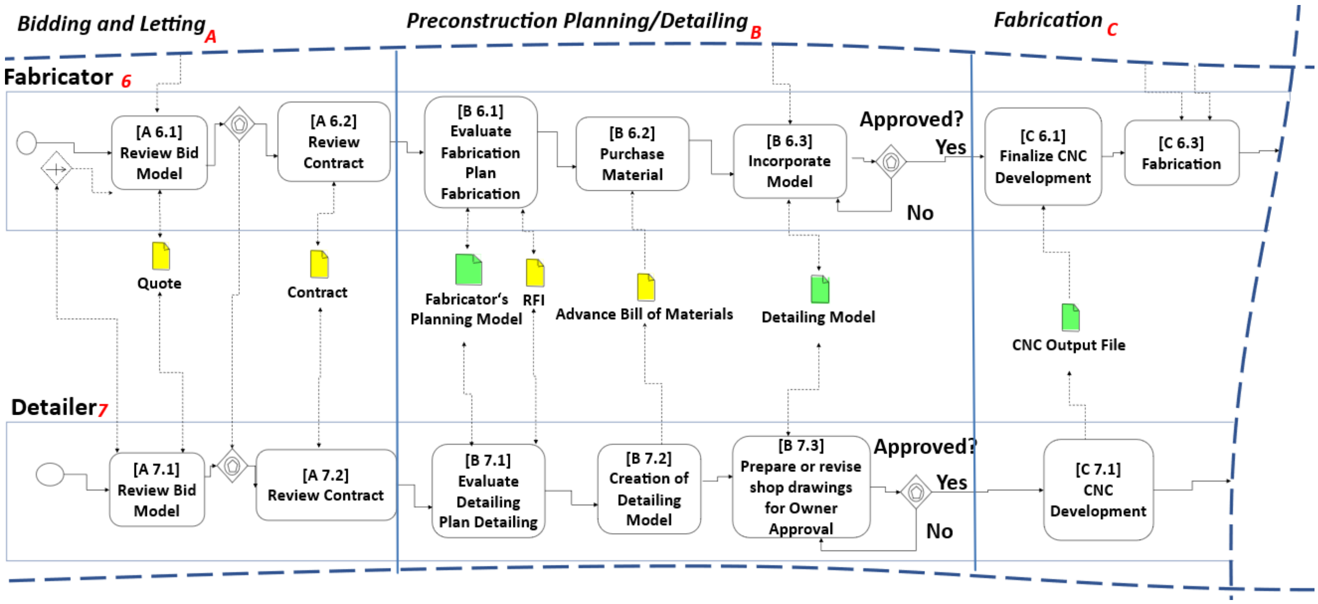

Figure 3: Portion of the Design to Fabrication Process Map

The activities cover the following project lifecycle phases:

- bidding and letting
- preconstruction planning/detailing
- fabrication
- construction

The disciplines (actors) that are involved include:

- structural engineer (owner's agent)
- general contractor
- fabricator
- detailer
- vendor

Overall, 31 activities have defined, which results in 12 points of model-based information exchanges and multiple points of non-model based exchanges. Model-based exchanges (also referred to as exchange models) are the information exchanges that will be developed into IFC and require data exchange requirements and business rules. Non-model-based exchanges are information exchanges between actors that are neither expected to nor are currently in the scope of being imported into software (e.g. pdfs, email, etc.). The following exchange models (EMs) have been identified:

1. Bid Model
2. Bid
3. Contractor's Planning Model
4. Fabricator's Planning Model
5. Final Contractor's Model
6. Detailing Model
7. Fabricator Model
8. CNC Output File
9. Final Fabricator Model
10. Fabrication As-Built
11. Detailing As-Built
12. Final As-Built

Exchange Requirements

As every exchange model is different with varying needs (level of development, data types, etc.), Exchange Requirements (ER) are used to specify data requirements needed for a specific point of information exchange (i.e. Exchange Model). Since each actor receiving the model requires their own subset of data from the model, each actor may have their own ER associated with that Exchange Model (EM).

The information that is defined in an ER is listed in a user-friendly form, such as a spreadsheet or table. A well designed and comprehensive list is important to guarantee that all the possible information is listed. This research utilizes a spreadsheet of bridge software terms called the BrIM Data Dictionary. The BrIM DD was developed by the preliminary work seeking information exchange standard for bridges (6,7). This dictionary is overseen and updated by AASHTO/NSBA Task Group 15.

Information Groups	Information Items	Attribute Sets	Attributes	Approved
Bridge superstructure	Steel girder properties	Steel girder properties	Steel girder cross section at start of span	M
			Steel girder cross section at end of span	M
			Web variation type	M
			Steel girder cross section area	M
			Web depth	M
			Girder shipping mark	O
		Steel girder material	Steel girder material designation	M
		Top flange properties	Top flange plate thickness	M
			Top flange plate width	M
			Top flange plate length	M
			Top flange plate material	M
			Top flange piece mark	M
			Top flange set-back dimension	M
			Top flange CVN testing indicator	O
			Top flange Fracture Critical Material indicator	O
			Specification	M
			Weld size	M
		Bottom flange properties	Bottom flange plate thickness	M
			Bottom flange plate width	M
			Bottom flange plate length	M
			Bottom flange plate material	M
			Bottom flange piece mark	M
			Bottom flange set-back dimension	M
			Bottom flange CVN testing indicator	O

Figure 4: Portion of the BrIM Dictionary and Exchange Requirements

When defining the exchange requirements, the main question asked is: *Do I need this to perform my task?* The current method for validating is using Excel and assigning an "M" (mandatory), "O" (optional), or "N" (not required) to each data cell. The purpose of the assignment is to let the software experts know what data is needed to be included in the MVD. Since each receiver has different data requirements, it important for software functionality of the application. Figure 4 displays and example of the exchange requires in Excel.

In addition to identifying the data requirements, various constraints need to be assigned to specify the usage and details of each data requirement, this include the data type (e.g., text string, integer, float, etc.), context of usage, rules, conditions, and restriction. Information constraints are important to explain and demonstrate how each data requirement is to be used so it can be properly encoded into software.

The data requirements and constraints that are identified for each EMs are next preliminary mapped to the target model view and assembled in a set of data model diagram called the Exchange Requirements Model (ERM). ERMs are visual representations of the exchange requirements in a diagram to show how the data requirements relate in the broader scope. ERMs of a given process map are integrated to form a generic, high level model view definition (MVD). The MVD is referred to as "generic" because is not currently defined in a specify technical solution (e.g., IFC) that can be supported by software applications. Finally, the IDM is complete and can be handed over to the software experts to be this mapped to the appropriate neutral schema, in which this case is the Industry Foundation Classes (IFC) schema.

Conclusion

Collectively known as building information modeling (BIM) for bridges, the definition, exchange, and storage of bridge information by data instead of traditional plan sets offer extraordinary benefits in efficiency, cost savings, and time savings to bridge design, construction, and maintenance. As AASHTO has now adopted the industry foundation classes (IFC) schema as the standard for electronic exchange of BIM for bridges and structures (8), the next phase of the transition to BIM is the population of bridge IFC with the exchange requirements (ER) of the various stakeholders (or actors) in the bridge community. In support of the TPF-5(372) project (5), a task group of the AASHTO/NSBA Steel Bridge Collaboration is defining the Information Delivery Manual (IDM) needed for the Design to Fabrication information exchange. The progress and status of the IDM can be found on the AASHTO/NSBA collaboration meetings site (9), while the MVD and TPF-5(372) progress and can be found on the the project team site (10). The creation of the MVD will both facilitate data exchange instead of 2D plan exchange between designers and fabricator and also establish a path that can be followed for the development of MVDs for other exchanges. Thus, this is a crucial and pioneering step along the journey to BIM for bridges.

Acknowledgements

The authors would like to thank the following individuals from the AASHTO/NSBA Steel Bridge Collaboration that provided substantial volunteer contributions in the creation of the IDM:

Vin Bartucca, Joe Brenner, Colby Christensen, Brad Dillman, John Gast, Randy Harrison, Hanjin Hu
Bill Lally, Rob McKenna, David Stoddard, Eric Stone, Jason Stith, Jon Stratton, Steve Waldon, and Gary Wisch.

The authors would also like to thank the TPF-5(372) sponsors and project consultant team:

Iowa DOT, HDR, Fair Cape Consulting, University of Florida, AEC3, FHWA, AASHTO T-19, and the state DOT sponsors.

References

1. Costin, A., Adibfar, A., Hu, H., and Chen, S. Building Information Modeling (BIM) for Transportation Infrastructure - Literature Review, Applications, Challenges, and Recommendations. *Automation in Construction*, 94: 257-281, 2018. https://doi.org/10.1016/j.autcon.2018.07.001.
2. National Institute of Building Sciences (NIBS). *United States National Building Information Modeling Standard Version 1—Part 1: Overview, Principles, and Methodologies.* The Northern American Chapter of buildingSMART International (bSI), 2007.
3. ISO 29481-1:2016(E). "Building information models - Information delivery manual - Part 1: Methodology and format." 2nd edition, Vernier, Geneva, Switzerland, 2016.
4. Object Management Group (OMG). "Business Process Model and Notation (BPMN). www.bpmn.org. Accessed June. 29, 2019.
5. Transportation Pooled Fund Program. "Building Information Modeling (BIM) for Bridges and Structures." TPF-5(372), https://www.pooledfund.org/details/solicitation/1450. Accessed November. 29, 2019.
6. Chen, S. S., Hu, H., Ali, N., and Srikonda, R. Information Delivery Manual Elements for Highway Bridge Interoperable Data Protocols. The State University of New York at Buffalo, Buffalo, NY. 2013.
7. Hu, H. (2014). Development of Interoperable Data Protocol for Integrated Bridge Project Delivery. Ph.D. diss., University at Buffalo, Buffalo, NY. 2014
8. AASHTO Board of Directors, "Adoption of Industry Foundation Classes (IFC) Schema as the Standard Data Schema for the Exchange of Electronic Engineering Data." Administrative Resolution AR-1-19, 2019, https://highways.transportation.org/wp-content/uploads/sites/46/2019/10/Administrative-Resolution-AR-1-19-Adoption-of-Industry-Foundation-Classes-IFC-Schema-as-the-Standard-Data-Schema-for-the-Exchange-of-Electronic-Engineering-Data.pdf, Accessed October 19, 2019.
9. American Institute of Steel Construction (AISC). AASHTO/NSBA Collaboration, 2020. https://www.aisc.org/nsba/design-and-estimation-resources/aashto-nsba-collaboration/. Accessed January. 2, 2020.
10. TPF-5(372) BIM for Bridges and Structures. 2020, https://www.bimforbridgesus.com/. Accessed January. 2, 2020.