BIM FOR BRIDGES AND STRUCTURES

TPF-5(372)

Investigation and Exploration

Task 1 Report
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BIM FOR BRIDGES AND STRUCTURES
TPF-5(372)

Table of Contents

Chapter 1 – Introduction 1
Purpose 1
Chapter 2 – Comparable Efforts 2
General Standards 3
National Information Exchange Model (NIEM) 3
buildingSMART Data Dictionary 5
ISO 19650 Building Information Modeling 5
IFC4 Precast 6
National Building Information Modeling Standard-United States® Version 3 7
Common Data Exchange 8
CSI Project Dynamo 9
Transportation Standards 9
Model Inventory of Roadway Elements 9
IFC-Alignment & IFC Infra Overall Architecture 10
IFC Road 11
AASHTOWare Data Integration Framework 12
Bridge Standards 13
IFC Bridge 13
National Bridge Inventory 14
Manual for Bridge Element Inspection 14
Bridge Information Modeling Data Dictionary 15
Project Delivery Workflow and National Library 16
Summary 17
Chapter 3 – Compendium of Terms 19
Terminology Identification 20
Terminology Aggregation 20
Recommendations 21
Future Goals 21
References 22

List of Figures

Figure 1: The path for terminology from identification to IDM. 1
Figure 2: Options for Resolution 2
Figure 3: Options for Scale 2
Figure 4: Options for lifecycle Phases 3
Figure 5: Options for level of Coordination 3
Figure 6: Characteristics for NIEM 4
Figure 7: Characteristics for bSDD 5
Figure 8: Characteristics for ISO 19650 6
Figure 9: Characteristics for IFC4 Precast 7
Figure 10: Characteristics for NBIMS-US™ V3 8
Figure 11: Characteristics for CDX 8
Figure 12: Characteristics for CSI Project Dynamo 9
Figure 13: Characteristics for MIRE 10
Figure 14: Characteristics for IFC-Alignment & IFC Infra Overall Architecture 11
Figure 15: Characteristics for IFC Road 12
Figure 16: Characteristics for the AASHTOWare Data Integration Framework 13
Figure 17: Characteristics for IFC Bridge 13
Figure 18: Characteristics for the NBI 14
Figure 19: Characteristics for the Manual for Bridge Element Inspection 15
Figure 20: Characteristics for BrIM Data Dictionary 16
Figure 21: Characteristics for the PDW&NL project 16
Figure 22 : Structure of an Data Dictionary (Adapted from Costin, 2016) 19

List of Tables

Table 1: General Standards Summary 17
Table 2: Transportation Standards Summary 18
Table 3: Bridge Standards Summary 18

List of Abbreviations

AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway Transportation Officials
BIM	Building Information Modeling
BME	Bridge Management Elements
BrIM	Bridge Information Modeling
bSDD	buildingSMART Data Dictionary
bSI	buildingSMART International
CDX	Common Data Exchange
COBS	Committee on Bridges and Structures
CSI	Construction Specifications Institute
ERM	Exchange Requirements Mode
FDE	Fundamental Data Elements
FHWA	Federal Highway Administration
GUID	Globally Unique Identifier
IDM	Information Delivery Manual
IFC	Industry Foundation Classes
ISO	International Organization for Standardization
KCJIS	Kansas Criminal Justice Information System
MAP-21	Moving Ahead for Progress in the 21st Century
MIRE	Model Inventory of Roadway Elements
MVD	Model View Definition
NBE	National Bridge Element
NBI	National Bridge Inventory
NBIMS-US™	National Building Information Modeling Standard – United States
NIEM	National Information Exchange Model
NSBA	National Steel Bridge Alliance
OGC	Open Geospatial Consortium
SCOA	Special Committee on AASHTOWare
TPF	Transportation Pooled Fund
XML	eXtensible Markup Language

Chapter 1 – Introduction

The report documents the outcome of research to find comparative implementation efforts of common data standards and makes terminology recommendations for Building Information Modeling (BIM) for Bridges and Structures. The goal of the first task is to document and report on comparable industry efforts that require a shared vocabulary and definition of terms. The goal of the second task is to create a reference document of standardized terminology and definitions for BIM for Bridges and Structures. These topics are covered in Chapters 2 and 3, respectively.

Purpose

Business processes in transportation are increasingly being digitized and automated; there is an ongoing need to standardize digital information exchanges. These information exchanges happen both within an agency and with external public agencies at the local, state, and national level. To execute an information exchange, the data fields in a source database must be matched to the data fields in a target database. Data dictionaries that use standardized terminology and data definitions that include the format, resolution, and accuracy of the data make it easier to execute both planned and *ad hoc* information exchanges.

The first task identified potential targets for digitally exchanging information from BIM for Bridges and Structures. The second task created a compendium of standard terminology that will be used to build a data dictionary for BIM for Bridges and Structures. Figure 1 shows the steps from identifying terminology to producing an Information Delivery Manual (IDM). This report describes the first two steps. Steps three and four are part of the TPF-5(372) project Task 4: Industry Foundation Classes (IFC) Development and Verification. Task 4 includes additional steps to create the IDM.

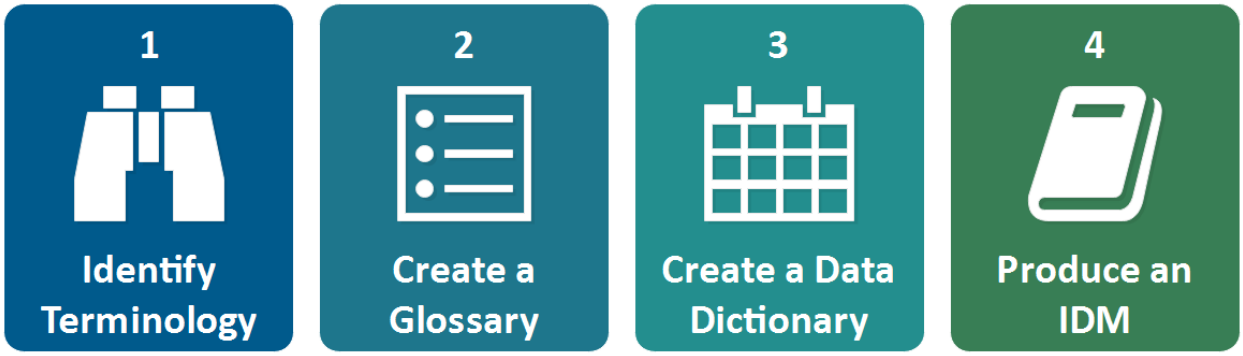

Figure 1: The path for terminology from identification to IDM.

A secondary purpose of the standardized terminology is to support stakeholder engagement and outreach activities. The compendium of terminology will serve as a reference for consistent messaging and as a glossary of terms for stakeholders.

Chapter 2 – Comparable Efforts

This section summarizes comparable implementation efforts for creating common data standards. The identified efforts share vocabulary and definitions of terms with BIM for Bridges and Structures. Each effort was described in terms of its purpose, governance, relationship to bridges and structures, and types of exchanges of BIM for bridges and structures information. Each comparative effort was also assessed in four qualitative categories:

- **Resolution**: Describes the level of detail at which bridges and structures are represented; i.e., is the bridge described as a single entity (*low*), as general systems (*medium*) or in detail (*high*). These options are presented in Figure 2.
- **Scale**: Describes whether the standard applies at the *local*, *national*, or *international* level. These options are presented in Figure 3.
- **Phase**: Describes the phase in the lifecycle of bridges and structures at which the standard applies; i.e. whether it describes bridge information during *design*, *construction* (including fabrication), operations, or *maintenance*. These options are presented in Figure 4.
- **Coordination**: Describes whether the BIM for Bridges and Structures project should *monitor* the standard, *align* to the standard, *collaborate* with the standard's governing body, or *inform* the governors as part of the stakeholder engagement and outreach activities. These options are presented in Figure 5.

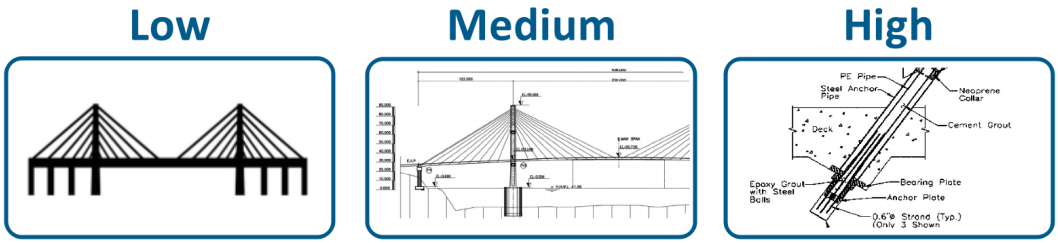

Figure 2: Options for Resolution

Figure 3: Options for Scale

Figure 4: Options for lifecycle Phases

Figure 5: Options for level of Coordination

The standards are grouped by domain, from general, multi-industry standards to transportation standards and standards that are focused specifically on bridges and structures.

General Standards

This section summarizes standards for information exchanges with a broad purview.

National Information Exchange Model (NIEM)

The National Information Exchange Model (NIEM) is a data model made up of core elements (the NIEM Core) with definitions that are universal (e.g. person, location, activity) and elements defined by communities. It is an XML-based information exchange framework. The NIEM model establishes the rules and methods for using the model and a standardized information exchange development lifecycle. (National Information Exchange Model, 2019) There are 14 communities within NIEM and more are likely to be added in the future. The communities include Surface Transportation, Infrastructure Protection, and Emergency Management. NIEM is developed for the U.S. by U.S. government agencies, but it is used by public and private organizations in the U.S. and internationally.

Purpose

NIEM facilitates inter-agency coordination and data sharing. NIEM was initially designed for the law enforcement and homeland security communities. The Kansas Bureau of Investigation and the Kansas Department of Transportation used NIEM to create the Kansas Criminal Justice Information System (KCJIS). KCJIS enables various state and local agencies to submit and store disposition reports (relating to criminal driving violations) in one electronic repository. (National Information Exchange Model, 2015)

Governing Body

NIEM is governed by committees operating in four areas:

- An **Executive Steering Council**, which makes organizational decisions about membership, funding needs, program direction, technical direction, and staffing.
- A **Management Office**, which manages daily operations, markets the standard, coordinates with stakeholders and other information-sharing initiatives, and provides oversight to the working groups and committees.
- A **Business Architecture Committee**, which establishes the business architecture and requirements, manages the NIEM Core, and regulates how the NIEM domains are added and how they coordinate.
- A **Technical Architecture Committee**, which establishes the technical architecture, manages technical specification documents, and develops the NIEM Core and related processes for developing data definitions and information exchange specifications.

Role of Bridges

"BridgeStructure" is a facility type defined in the Surface Transportation domain, one of 14 NIEM domains. The "BridgeStructure" facility type refers to bridge, underpass, overpass, or tunnel structures and can be linked to the National Bridge Inventory (NBI). The information connected to the "BridgeStructure" facility type is aggregate; examples are contact information, capacity, location (which could be an address or a geospatial coordinate), and a facility diagram that is an image.

The Surface Transportation domain includes limited, aggregate information about the highway transportation system. There are federal identifiers, such as the National Highway System (NHS) route code, Average Annual Daily Traffic (AADT), functional class, access control and operation information (one-way or two-way operations) and limited geometric information such as width and slope.

Exchange Types

The Surface Transportation domain is intended for transportation regulators, operators, and users, including law enforcement and emergency management partners. Exchanges would occur during operations and maintenance phases, such as when an incident occurs or a structure is closed or significantly modified.

Summary

NIEM is a low-resolution standard with a national scale. It applies during the operations phase of a bridge. The TPF-5(372) project should monitor the NIEM standard for any efforts to expand the scope of the Surface Transportation domain to define bridges in more detail. NIEM does not currently break a bridge down into components. Figure 6 summarizes the characteristics of NIEM.

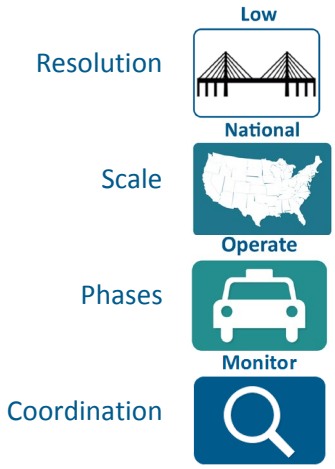

Figure 6: Characteristics for NIEM

buildingSMART Data Dictionary

The buildingSMART Data Dictionary (bSDD) is one of the services that buildingSMART International (bSI) provides to support the implementation of bSI standards, such as IFC. The bSDD is a shared library of building and construction industry objects and their attributes, which is organized using a standard ontology (ISO 12006-3). (buildingSMART International, 2019) The bSDD is intended to serve as the highest level of knowledge representation and developers can continue to add more detail to it. The bSDD includes over 200,000 "concepts" with over 800,000 "names" (drawing from multiple languages) and over 800,000 "relationships" between them. (buildingSMART International, 2019)

Purpose

The bSDD is a tool that enables members of the global building and construction industry to share product information. The bSDD is a tool for content owners to align their data to the IFC standard and to produce an IDM. (buildingSMART International, 2019)

Governing Body

bSI owns the copyright to the bSDD, but it is a user service that is implemented by users; local chapters play a key role in delivering the service.

Role of Bridges

There is space in the bSDD specifically for bridge property sets. Bridges and their sub-components are subjects in the bSDD. For example, a Bridge is a subject with properties of location, position, and point. It has many subtypes, including arch bridge and truss bridge. Bridge subjects are part of a larger object group that includes road, tramway, street, and railroad subtypes.

Exchange Types

The bSDD is a tool for creating IDMs and thus it serves all exchanges in the bridge asset lifecycle.

Summary

The bSDD is a high-resolution standard with an international scale. It applies during all phases of the bridge lifecycle. The standard developed by the TPF-5(372) project should align to the bSDD standard and could potentially add to it. Figure 7 summarizes the characteristics of the bSDD.

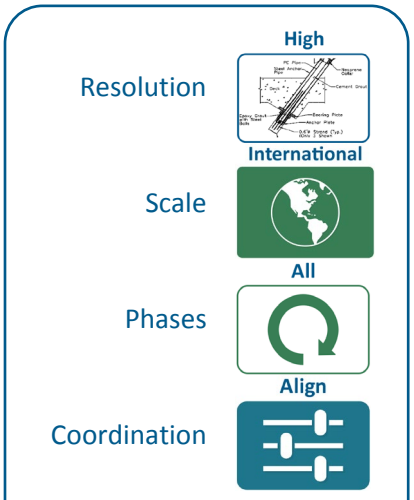

Figure 7: Characteristics for bSDD

ISO 19650 Building Information Modeling

The International Organization for Standardization (ISO) standard for Building Information Modeling (BIM), ISO 19650, evolved from the United Kingdom 1192 series of publicly available specifications for BIM Level 2. The ISO 19650 is an international standard for managing information about built assets (including buildings and civil works) using BIM over the asset lifecycle. The standard is officially called *"Organization and digitization of information about buildings and civil engineering works, including*

building information modelling -- Information management uses building information modelling." Two standards in the series have been published to date:

- BS EN ISO 19650-1, which covers concepts and principles, (International Organization for Standardization, 2018) and
- BS EN ISO 19650-2, which covers the delivery phase of the assets. (International Organization for Standardization, 2018)

Purpose

The ISO 19650 standard establishes the foundation of business processes for information management (ISO 19650-1) and specific requirements for the information (ISO 19650-2) to be used with BIM.

Governing Body

The standard was developed by Technical Committee ISO/TC 59, *Buildings and civil engineering works*, SC 13, *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)* and is maintained by the ISO.

Role of Bridges

Bridges are one of the built assets—along with roads, buildings, etc.—covered by the standard.

Exchange Types

The standard applies to all phases of the asset lifecycle.

Summary

ISO 19650 is a high-resolution standard with an international scale. It applies during the whole lifecycle of a bridge. The standard and guidelines developed by the TPF-5(372) project should align to the ISO 19650 standard. Figure 8 summarizes the characteristics of ISO 19650.

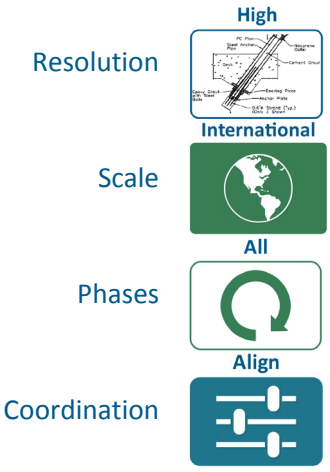

Figure 8: Characteristics for ISO 19650

IFC4 Precast

There is already an IFC standard for the design-to-fabrication exchange for precast architectural elements, which was developed in 2009 by a committee of the Precast/Prestressed Concrete Institute with support from Georgia Tech. (National Institute of Building Sciences, 2009) However, there is not yet an IFC standard for taking shop models to production. This is particularly important for automated fabrication equipment, such as precast manufacturing execution systems (MES) and Production Planning Software (PPS) systems. (buildingSMART Deutschland, 2018)

Purpose

The IFC4 Precast project aims to create an international standard for exchanging data from shop models to MES and PPS systems. Specifically, the project aims to extend the reach of open BIM into precast production, bridge the gap between shop models and MES/PPS systems with a standardized data

exchange based on the IFC standard, and improve data flow across the building asset lifecycle. (buildingSMART Deutschland, 2018)

Governing Body

The buildingSMART German Chapter oversees the execution of the IFC4 Precast project.

Role of Bridges

Precast concrete bridge elements are within the scope of precast elements covered by the standard.

Exchange Types

The standard applies to the fabrication phase only, which is a subset of the construction phase.

Summary

The IFC4 Precast project is a high-resolution standard with an international scale. It applies during the construction phase of a bridge. The standard and guidelines developed by the TPF-5(372) project should align to the IFC4 Precast standard. Figure 8 summarizes the characteristics of the IFC4 Precast project.

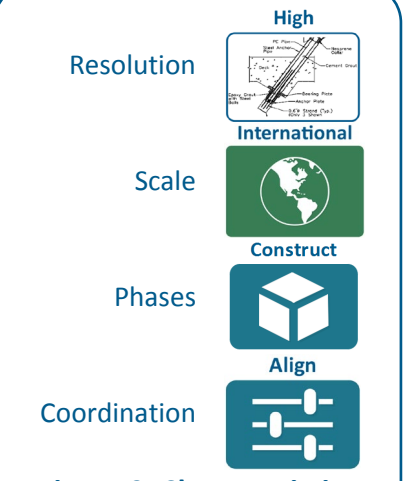

Figure 9: Characteristics for IFC4 Precast

National Building Information Modeling Standard-United States® Version 3

The National Building Information Modeling Standard-United States® version 3 (NBIMS-US™ V3) is an open consensus standard. That is, NBIMS-US™ V3 is a framework for using BIM based on industry-accepted open standards. NBIMS-US™ V3 uses reference standards (such as the ISO 16739 standard for IFC 2x3 and OmniClass™), has a compendium of terms and definitions, uses reference information exchange standards (such as Construction Operations Building information exchange version 2.4), and references practice guidelines such as the U.S. Army Corps of Engineers contract requirements for design-build projects and the BIMForum Level of Development Specification. (National Institute of Building Sciences, 2015)

Purpose

NBIMS-US™ V3 is a curation of notable practices for using BIM that enables owners and practitioners to select the best-available process and open data exchange for using BIM.

Governing Body

The National Institute of Building Sciences (NIBS) governs NBIMS-US™ V3.

Role of Bridges

NBIMS-US™ V3 could be used on bridge construction projects or bridge owners could use NBIMS-US™ V3 to develop their own BIM standard and practice guidelines.

Exchange Types

NBIMS-US™ V3 is primarily for information exchanges during construction project delivery, though it is intended to support BIM uses throughout the asset lifecycle. These include delivering the project specifications (i.e. design-to-construction exchanges) as well as furnishing facility information for asset management (i.e. construction-to-operations exchanges).

Summary

NBIMS-US™ V3 is a high-resolution standard with a national scale. It applies primarily during the design and construction of a bridge. The TPF-5(372) project should align to NBIMS-US™ V3. Figure 10 summarizes the characteristics of NBIMS-US™ V3.

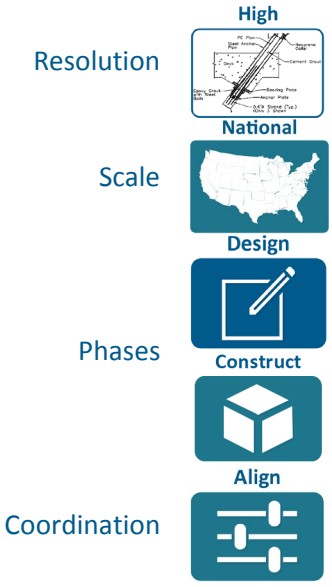

Figure 10: Characteristics for NBIMS-US™ V3

Common Data Exchange

Common Data Exchange (CDX) is a communication framework that is being developed to streamline information management at the construction project level. It promotes open data standards and transparent workflows for data exchange. (Construction Progress Coalition, 2018)

Purpose

CDX enables project stakeholders to identify their data needs, actors, and relevant standards to implement the data exchanges through valid workflows.

Governing Body

The Construction Progress Coalition, a non-profit organization, governs CDX.

Role of Bridges

CDX could be used on bridge construction projects.

Exchange Types

CDX is for information exchanges during construction project delivery. These include delivering the project specifications (i.e. design-to-construction exchanges) and exchanging information througout the project, such as for Requests for Information.

Summary

CDX is a high-resolution standard with a national scale. It applies during the design and construction of a bridge. The TPF-5(372) project should inform Construction Progress Coalition as part of stakeholder engagement and outreach activities. Figure 11 summarizes the characteristics of CDX.

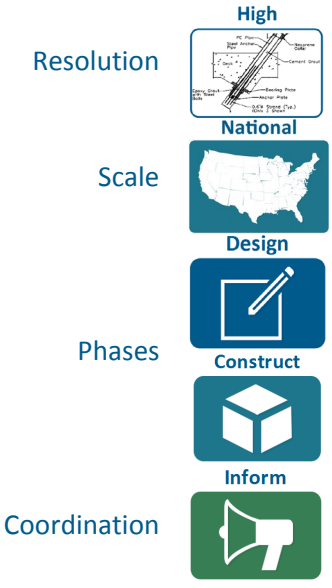

Figure 11: Characteristics for CDX

CSI Project Dynamo

The Construction Specifications Institute (CSI) is a national membership association representing the building construction and materials industry. CSI has a mission to advance building information management, education, and facility performance. CSI's activities include developing and maintaining standards such as MasterFormat®, UniFormat®, and OmniClass®. UniFormat® is widely used to organize BIM objects. CSI Project Dynamo is a pilot program to expand these three CSI standards to improve how they connect BIM objects to specification information. (Construction Specifications Institute, 2018)

Purpose

BIM provdies the physical geometry required for construction, but a lot of construction requirements are provided by specifications. CSI Project Dynamo is a pilot project to better connect the specification information to the physical geometry contained in BIM.

Governing Body

CSI Project Dynamo is a CSI initiative.

Role of Bridges

Bridges and structures are just one of many types of built assets that CSI Project Dynamo would serve.

Exchange Types

CSI Project Dynamo relates to connecting BIM objects to specification information. This is related to the design and construction phases of the lifecycle (including fabrication). These exchanges could be for bidding and estimating bridge projects or for fabricating and constructing bridges.

Summary

CSI Project Dynamo is a high-resolution standard with a national scale. It applies during the design and construction phases of a bridge. The TPF-5(372) project should inform CSI Project Dynamo as part of stakeholder engagement and outreach activities. Figure 12 summarizes the characteristics of CSI Project Dynamo.

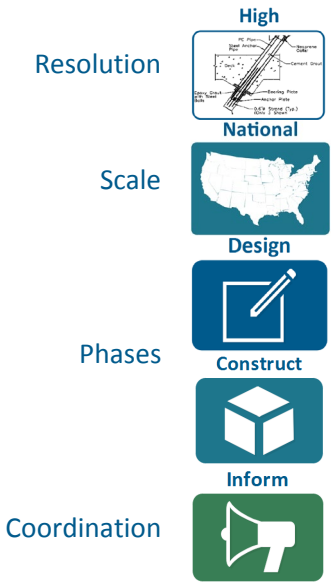

Figure 12: Characteristics for CSI Project Dynamo

Transportation Standards

This section summarizes standards for information exchanges within the transportation industry.

Model Inventory of Roadway Elements

The Model Inventory of Roadway Elements (MIRE) is a framework for roadway inventories. It provides a comprehensive list of data elements and a data dictionary. MIRE is specifically for data-driven safety analysis, but the second version (MIRE 2.0) is consistent with other federal data programs: Highway Performance Monitoring System, Long-Term Pavement Performance program, and the Second Strategic Highway Research Program Roadway Information Database. (Lefler, et al., 2017)

Purpose

Data-driven safety requirements have been part of the federal transportation law since the Moving Ahead for Progress in the 21st Century (MAP-21) Act in 2012. MIRE was created as part of implementing MAP-21. MIRE provides a structure for roadway inventory data that enables roadway owners to use their own inventory data with analysis tools and to comply with requirements for Highway Safety Improvement Program funds.

Governing Body

The Federal Highway Administration (FHWA) safety program office governs MIRE.

Role of Bridges

Part of the process of creating MIRE 2.0 involved reviewing the NBI data dictionary and database. Bridges are not one of the 37 Fundamental Data Elements (FDE) in MIRE. Bridge descriptors are one of several "supplemental databases" identified in the MIRE 2.0 report that agencies could include in their safety analysis, but are not required to by law. Other "supplemental databases" include signs, roadside fixed objects, speed data, and pavement data.

The MIRE elements are grouped into six main sections: Segment, Intersection, Intersection Leg, Interchange/ramp, Horizontal Curve, and Vertical Grade. "Bridge Numbers for Bridges in Segment" is the 109th and last element for Segments. This element is the official bridge number and can be used to link the safety data to the NBI record or to the record in the bridge owner's bridge inventory.

Exchange Types

MIRE is specifically for exchanging safety data. It could be used to locate crash data for bridge assets.

Summary

MIRE is a low-resolution standard with a national scale. It applies during the operations phase of a bridge. The standard developed by the TPF-5(372) project should align to the MIRE standard. This would occur at the highest level, as MIRE does not break a bridge down into components. Figure 13 summarizes the characteristics of MIRE.

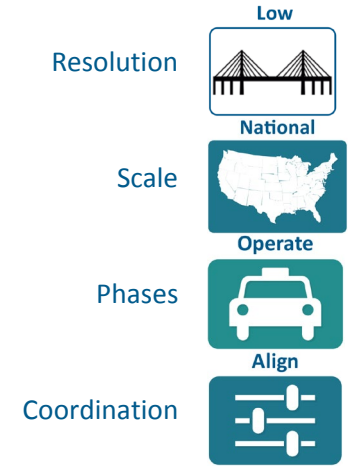

Figure 13: Characteristics for MIRE

IFC-Alignment & IFC Infra Overall Architecture

The IFC-Alignment & IFC Infra Overall Architecture projects provided the foundational, common elements that were required in order to extend the IFC schema to support linear infrastructure assets. The IFC-Alignment project provided the data structures for alignments and alignment-based positioning. The IFC Infra Overall Architecture project provided additional basic data structures and made recommendations for developing extensions for infrastructure assets. The two projects were developed in parallel and in partnership with the Open Geospatial Consortium (OGC) in order to create aligned conceptual models and a common basis for IFC-Infra and InfraGML. (Borrmann, et al., 2017)

Purpose
The IFC-Alignment project and the IFC Infra Overall Architecture project are extensions to the IFC standard to enable its expansion to support road, rail, bridge, and tunnel assets. Both elements were adopted into the IFC standard as part of the IFC 4.1 release.

Governing Body
The IFC Infra Room, a subcommittee of bSI, governs the IFC-Alignment and IFC Infra Overall Architecture standards.

Role of Bridges
The schema extensions provide foundational elements that support bridge geometry and bridge project elements. These are:

- alignment and alignment-based positioning geometry,
- representations for stringlines, cross-sections, surfaces, and solids, and
- terrain objects (as Triangulated Irregular Networks)

Exchange Types
The standard applies to all phases of the asset lifecycle.

Summary
IFC-Alignment and IFC Infra Overall Architecture are high-resolution standards with an international scale. They apply during all phases of the bridge lifecycle. The standard developed by the TPF-5(372) project should align to the IFC-Alignment and IFC Infra Overall Architecture standards. Figure 14 summarizes the characteristics of IFC-Alignment and IFC Infra Overall Architecture.

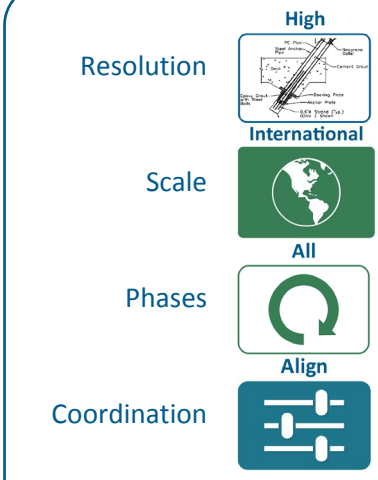

Figure 14: Characteristics for IFC-Alignment & IFC Infra Overall Architecture

IFC Road

IFC Road extends the IFC schema to describe road semantics and geometry. The IFC Road project intends to publish the schema extension as an ISO standard. The project began with leadership from the Korean chapter in 2012 and joined the bSI Infra Room in 2014. The project was delayed to allow the IFC Infra Overall Architecture and IFC-Alignment projects to complete. The Korean chapter continued development, diverging the Korean IFC Road standard from the IFC Road project. The Korean IFC Road standard was adopted by bSI as a bSI SPEC. A bSI SPEC is a publicly accessible specification, which differs from a bSI standard in that it does not need to reach consensus. An organization that is interested in standardizing a practice, without advancing it to a bSI Standard, can publish a bSI SPEC and receive comments. (Moon, et al., 2018)

Purpose
The IFC Road project is an extension to the IFC standard to support road and highway assets.

Governing Body

The IFC Infra Room, a subcommittee of bSI, governs the IFC Road project. The Korean chapter of bSI governs the Korean IFC Road SPEC, which diverged from the international IFC Road project in 2016.

Role of Bridges

The schema extension provides support for the roadway elements that may form part of bridge construction projects.

Exchange Types

The IFC Road standard applies to all phases of the asset lifecycle.

Summary

IFC Road is a high-resolution standard with an international scale. It applies during all phases of the bridge lifecycle. The standard developed by the TPF-5(372) project should align to the IFC Road standard. Figure 15 summarizes the characteristics of IFC Road.

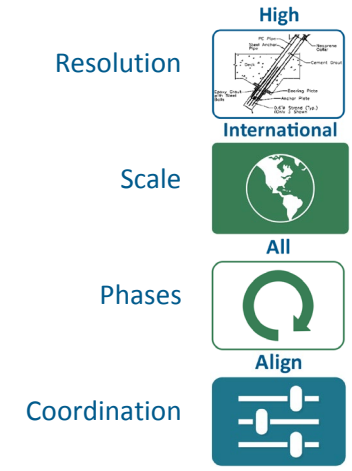

Figure 15: Characteristics for IFC Road

AASHTOWare Data Integration Framework

AASHTOWare products provide critical business systems for many State transportation agencies. Currently, there is no comprehensive AASHTOWare data dictionary and the AASHTOWare products integrate in an *ad hoc* manner with other agency business systems. The AASHTOWare Data Integration Framework is a research project to identify product integration points, develop a data dictionary, and create a process to integrate AASHTOWare with other agency systems. (Edwards, 2018)

Purpose

Increasingly, agencies need the mission-critical business data stored in AASHTOWare product databases to perform analyses. The AASHTOWare Data Integration Framework will create a data dictionary and a path to integrate the business data stored in AASHTOWare with other agency business systems.

Governing Body

AASHTOWare is governed by the American Association of State Highway Transportation Officials (AASHTO) Special Committee on AASHTOWare (SCOA).

Role of Bridges

AASHTOWare Bridge is one of the four main AASHTOWare product groups.

Exchange Types

The AASHTOWare Data Integration Framework seeks to integrate data across all phases of the asset lifecycle. Specifically for bridges, bridge data may be connected to the related data residing in the three other AASHTOWare products groups: Project (construction and materials information), Pavement, and Safety. The AASHTOWare Data Integration Framework (especially through the data dictionary) could connect bridge data to related data residing in non-AASHTOWare agency business systems.

Summary

The AASHTOWare Data Integration Framework is a medium-resolution standard with a national scale. The AASHTOWare Data Integration Framework applies to all phases of the bridge lifecycle. The TPF-5(372) project should collaborate with SCOA. Figure 16 summarizes the characteristics of the AASHTOWare Data Integration Framework.

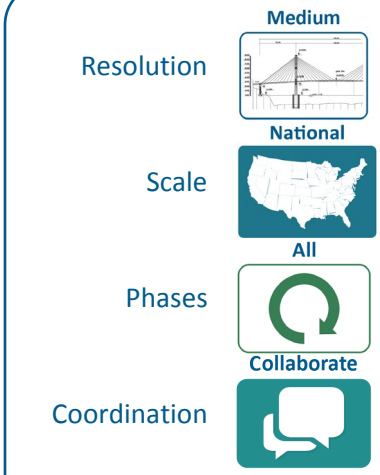

Figure 16: Characteristics for the AASHTOWare Data Integration Framework

Bridge Standards

This section summarizes standards that are focused specifically on bridges.

IFC Bridge

IFC Bridge extends the IFC schema to describe bridge semantics and geometry. The IFC Bridge project is a two-step project to extend the IFC schema to support bridges. The first step is to implement basic "workhorse" bridge support in IFC 4.2 and expand the complexity of bridge elements supported by the IFC standard in the 5.0 release. (Castaing, et al., 2017)

Purpose

The IFC Bridge project is an extension to the IFC standard to support bridge assets.

Governing Body

The IFC Infra Room, a subcommittee of bSI, governs the IFC Bridge project.

Role of Bridges

Bridges are the focal element of this schema extension.

Exchange Types

The standard applies to all exchanges of bridge geometric information. It is currently being developed to support design-to-construction, design-to-fabrication, and construction-to-operations exchanges.

Summary

IFC Bridge is a high-resolution standard with an international scale. It applies during all phases of the bridge lifecycle. The TPF-5(372) project should collaborate with the IFC Bridge project. Figure 17 summarizes the characteristics of IFC Bridge.

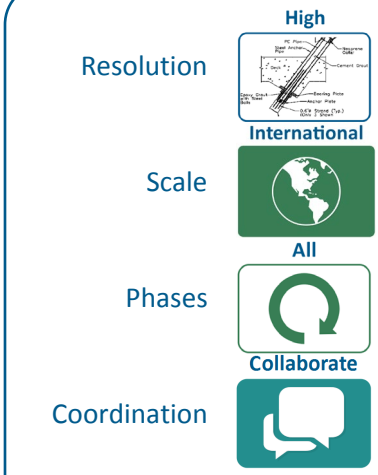

Figure 17: Characteristics for IFC Bridge

National Bridge Inventory

The FHWA is required by 23 U.S.C. 144 to maintain an inventory of all highway bridges on public roads and to classify the bridges by a number of criteria. The inventory is the NBI. Agencies are also required to conduct regular element-level inspections of bridges included in the NBI and submit routine reports to the FHWA.

Purpose

The Specification for NBI Elements provides the framework for collecting and reporting the required data to the FHWA. The AASHTO Manual for Bridge Element Inspection provides further guidance. (Federal Highway Administration, 2014)

Governing Body

The FHWA governs the NBI.

Role of Bridges

Bridges are the focal element of this database.

Figure 18: Characteristics for the NBI

Exchange Types

The standard applies to routine reporting of bridge inventory and element-level condition information.

Summary

The NBI is a medium-resolution standard with a national scale. The NBI applies to the operations and maintenance phases of the bridge lifecycle. The TPF-5(372) project should align to the NBI. Figure 18 summarizes the characteristics of the NBI.

Manual for Bridge Element Inspection

The Manual for Bridge Element Inspection is a manual for bridge owners to guide element-level condition assessments. Element-level bridge assessment became typical in the 1990s and best practices have continued to evolve. The Manual for Bridge Element Inspection provides guidance for two element types: National Bridge Elements (NBEs) and Bridge Management Elements (BMEs).

NBEs are structural elements, such as superstructure and deck, necessary to determine the safety and condition of primary load-carrying members. NBE data is consistent from agency-to-agency and includes the core data reported to the NBI. BMEs are additional elements (such as joints and coatings) that agencies manage as part of their Bridge Management Systems. BMEs may vary from agency-to-agency. The manual also includes Agency Developed Elements, which gives agencies a way to customize their inspection data models.

Purpose
The Manual for Bridge Element Inspection provides a consistent framework for element inspection. The consistent approach to element inspection enables the FHWA to use the NBI to develop national policy and it enables states to share best practices.

Governing Body
The AASHTO Committee on Bridges and Structures (COBS) governs the Manual for Bridge Element Inspection.

Role of Bridges
Bridges are the focal element of this manual.

Exchange Types
The Manual for Bridge Element Inspection is specifically for the collection and sharing of bridge inspection information. It is used to exchange bridge condition information between inspection software and the Bridge Management System or from the Bridge Management System to the NBI.

Figure 19: Characteristics for the Manual for Bridge Element Inspection

Summary
The Manual for Bridge Element Inspection is a medium-resolution standard with a national scale. The Manual for Bridge Element Inspection applies to the operations and maintenance phases of the bridge lifecycle. The TPF-5(372) project should align to the Manual for Bridge Element Inspection. Figure 19 summarizes the characteristics of the NBI.

Bridge Information Modeling Data Dictionary

The Bridge Information Modeling (BrIM)[1] Data Dictionary is a project conducted by the National Steel Bridge Alliance (NSBA) through its Task Group 15: Data Modeling for Interoperability. NSBA previously developed an initial taxonomy of "workhorse" bridge terms. There is a current NSBA project to formalize that taxonomy into a data dictionary. (National Steel Bridge Alliance, 2019)

Purpose
Steel bridge fabricators have a desire to receive digital information to estimate and fabricate bridges.

Governing Body
The NSBA Task Group 15: Data Modeling for Interoperability governs the BrIM Data Dictionary.

Role of Bridges
Bridges are the focal element of this data dictionary.

[1] Bridge Information Modeling (BrIM) is the name of the NSBA project. COBS adopted a resolution to use the term "BIM for Bridges and Structures," which is the preferred term for the TPF-5(372) project.

Exchange Types
The BrIM Data Dictionary is being developed for the exchange from designer to erector. However, a data dictionary is a tool for creating IDMs and thus it serves all exchanges in the bridge asset lifecycle.

Summary
The BrIM Data Dictionary is a high-resolution standard with a national scale. The BrIM Data Dictionary applies primarily to the construction (specifically, fabrication) phase of the bridge lifecycle. The TPF-5(372) project should collaborate with the NSBA Task Group 15. Figure 20 summarizes the characteristics of the BrIM Data Dictionary.

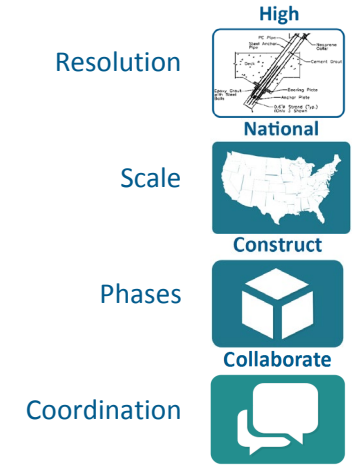

Figure 20: Characteristics for BrIM Data Dictionary

Project Delivery Workflow and National Library

The Project Delivery Workflow and National Library (PDW&NL) research project has two objectives. The first is to study workflows for bridge and roadway project delivery and asset management. The second is to develop a conceptual framework for a national library of BIM-based object definitions and a process to create and maintain the library.

Purpose
The first objective is to create guidelines for incorporating BIM into highway and bridge development and management processes. The second objective is to support crowd sourcing for highway and bridge BIM object definitions, as well as to facilitate digital exchange and digital linking of BIM-based highway and bridge data.

Governing Body
The FHWA oversees the PDW&NL research project.

Role of Bridges
Bridges are one of the two focal elements of this research.

Exchange Types
The PDW&NL project applies to all exchanges of bridge geometric information.

Summary
The PDW&NL project is a high-resolution guide with a national scale. The PDW&NL project applies to all phases of the bridge lifecycle. The TPF-5(372) project should collaborate with the PDW&NL project research team. Figure 21 summarizes the characteristics of the Project Delivery Workflow and National Library research.

Figure 21: Characteristics for the PDW&NL project

Summary

The research identified sixteen comparable efforts, which were grouped by the domain that they serve. Each comparable effort was described qualitatively in terms of its purpose, governaning body, the role of bridges, and the information exchanges that were facilitated. Each comparable effort was also assessed in terms of the resolution, scale, lifecycle phase, and recommended level of coordination with the TPF-5(372) project.

Table 1 summarizes the comprable efforts to create general standards. All the identified efforts continue to evolve. NBIMS-US™ V3 is a standard-of-standards; the standards and guidelines referenced by NBIMS-US™ V3 continue to evolve. NIBS has initiated work to develop NBIMS-US™ V4. The CDX and CSI Project Dynamo efforts are candidates to include in the TPF-5(372) stakeholder outreach.

Table 1: General Standards Summary

Comparable Effort	Governing Body	Resolution	Scale	Phase	Coordination
NIEM	Four governing committees	Low	National	Operations	Monitor
bSDD	bSI	High	International	All	Align
ISO 19650	ISO	High	International	All	Align
IFC4 Precast	buildingSMART Deutschland	High	International	Construction	Align
NBIMS-US™ V3	NIBS	High	National	Design and Construction	Align
CDX	Construction Progress Coalition	High	National	Design and Construction	Inform
CSI Project Dynamo	CSI	High	National	Design and Construction	Inform

Table 2 summarizes the comprable efforts to create transportation-domain standards. The AASHTOWare Data Integration Framework project is a candidate for collaboration with the TPF-5(372) project in order to serve the data integration needs of States that use AASHTOWare Bridge products.

Table 2: Transportation Standards Summary

Comparable Effort	Governing Body	Resolution	Scale	Phase	Coordination
MIRE	FHWA Safety Program Office	Low	National	Operations	Align
IFC Infra Overall Architecture & IFC-Alignment	bSI	High	International	All	Align
IFC Road	bSI	High	International	All	Align
AASHTOWare Data Integration Framework	AASHTO SCOA	Medium	National	All	Collaborate

Table 3 summarizes the comprable efforts to create bridge-specific standards. The IFC Bridge project is an ongoing project to extend the IFC standard to support bridge geometry and semantics that are common globally. The TPF-5(372) project should collaborate with the IFC Infra Room to advocate for the inclusion of geometry and semantics that are critical for US bridges in the official IFC standard. The NBI and Manual for Bridge Element Inspection are sources of critical US bridge data that may be unique to US-based bridge owners. The BrIM Data Dictionary and the Project Delivery Workflow and National Library project are two ongoing efforts that are parallel to the TPF-5(372) project and are candidates for collaboration.

Table 3: Bridge Standards Summary

Comparable Effort	Governing Body	Resolution	Scale	Phase	Coordination
IFC Bridge	bSI	High	International	All	Collaborate
NBI	FHWA	Medium	National	Operations	Align
Manual for Bridge Element Inspection	AASHTO COBS	Medium	National	Operations	Align
BrIM Data Dictionary	NSBA	High	National	Construction	Collaborate
Project Delivery Workflow and National Library Project	FHWA	High	National	Design and Construction	Collaborate

Chapter 3 – Compendium of Terms

The compendium of recommended terminology serves two purposes. Firstly, it will enable the creation of a data dictionary to support the Design to Fabrication IDM as part of the IFC Development and Verification task of the TPF 5(372) project. Secondly, it will support the outreach and stakeholder engagement activities.

Terminology is essential for the streamlined communication of information between stakeholders and information systems. Terminology describes what information is being exchanged, as well as the intent and how the terms are used in the context of a specific use case. Semantically rich data structures, such as schemas, taxonomies, and ontologies, are used to define the intent and usage of the terms. The purpose of the data dictionary is to serve as the central repository of terms and relevant information needed to produce workflows and data exchanges. Developers can then use the data dictionary to create the various taxonomies and other semantic data structures. (Costin, 2016)

The various organization structures and formats relating to terminology described below are visually represented in Figure 22:

- **Taxonomy**: A hierarchical structure of defined terms that represent the relationships and attributes among those terms.
- **Data Dictionary**: Centralized repository of terms, relevant information about the terms, metadata, and other user-defined information. Each term is assigned a Globally Unique Identifier (GUID) that keeps each term unique.
- **Dictionary**: A collection of terms with definitions and examples of use. Additional information about the terms (origin, phonetics, grammar, etc.) may be included.
- **Glossary**: A collection of specialized terms with definitions used in a particular domain. A glossary defines the meaning of the terms that apply to a specific publication.
- **Classification System**: A formalized structure that organizes terms based on shared qualities or characteristics. ISO 22274:2013 is the relevant standard for developing classification systems.

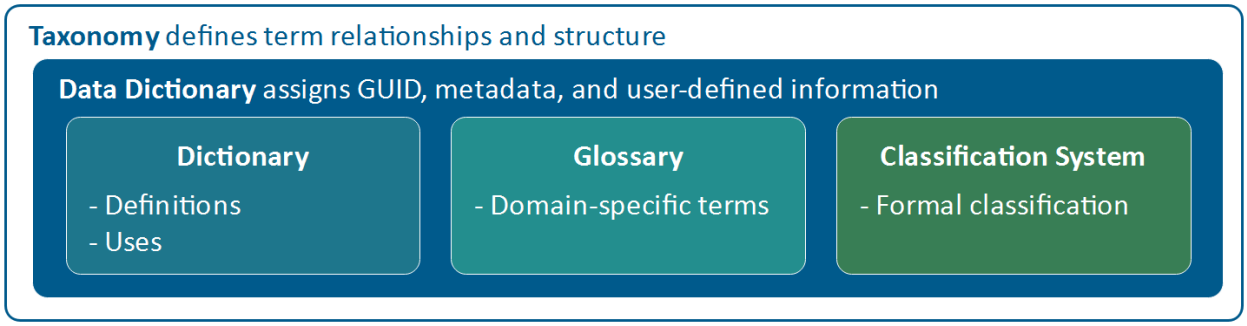

Figure 22 : Structure of an Data Dictionary (Adapted from Costin, 2016)

Terminology Identification

There is a plethora of terminology that exists in a variety of formats. The first step was to identify the intent and scope of the terms needed. The following subjects were identified:

- **General Bridge and Transportation Terms:** Information that describes bridges and other transportation related terms are important for high-level information, such as project information and structure types. There are further sub-categories, e.g., NBI data, transportation structures, policy, etc.
  Sources include the AASHTO Transportation Glossary, AASHTO LRFD Bridge Design Specification, various State manuals and guides, and the OmniClass® classification.
- **Bridge Data:** Each workflow requires detailed information about that specific use case. Detailed bridge information for a specific use case may include fabrication data, design data, analysis data, or asset management data. The specific data that need to be collected will be based on a specific intent or use case.
  Sources include AASHTO and NSBA standards, AASHTO bridge guides, and industry specifications (e.g., American Institute of Steel Construction, American Concrete Institute, Precast/Prestressed Concrete Institute).
- **General BIM Terms:** Information that describes general BIM terms are needed to maintain consistency with other BIM efforts.
  Sources include the U.S. National BIM Standard, ISO BIM Standards, and buildingSMART International guides.
- **BIM Processes and Workflows:** In order to create the processes and workflow for BIM data exchanges, terms that relate to describing the processes for managing these are needed.
  Sources include the U.S. National BIM Standard, ISO Standard for Business Process Model and Notation, and ISO Standard for IDMs.

Terminology Aggregation

Various reports and standards were explored to identify relevant terminology. A terminology database was created to store and sort the information. The metadata that was recorded includes (but is not limited to):

- the term,
- abbreviation,
- definition,
- definition notes,
- related terms,
- source,
- reference, and
- publication year.

Due to the large amount of terminology, the current database only includes terms relevant to BIM, including general terms, processes, and workflows.

Recommendations

The collected terms and definitions are often vague and can be prone to misuse, especially the ones relevant to BIM processes and workflows. Although most are published in a standardized format (e.g., ISO), there are variations among the sources that define the same term. Additionally, there are many terms that are very similar by definition that could potentially cause confusion and misuse. Therefore, recommendations for the creation of a standard dictionary of terms to minimize the issues are:

- Curate the terminology and definitions for their intended purpose. For example, each derivative product such as the process maps, data dictionary, and stakeholder outreach materials should have their own glossary of terms.
- Select the most appropriate definition based on the intent, while referencing the original source. This will enable a clear definition and usage for terms that otherwise may be vague.
- Provide detailed examples and usages of how each term is properly used.

There is no single source that is exhaustive of terminology or processes for a specific purpose. For example, the OmniClass® tables currently lack entities needed for bridges and other transportation assets, but these are available in many ISO standards. Therefore, it is recommended that:

- Collect all sources of terminology in a central repository.
- Incorporate linked data to connect to the variety of sources.
- Terminology that best fits the intent can be selected and assigned.

A few current efforts have similar goals, but the processes, terminology, and definitions vary. Therefore, it is recommended to:

- Create a collaboration mechanism so that related efforts can be aligned.
- Identify a central entity that can be a mutual liaison amongst the efforts.
- Create a central repository so that terms, processes, and information can be shared.

Future Goals

The data dictionary could serve as the central repository for terminology used to create workflows and interoperable data exchanges for bridges. Specifically, this data dictionary will be used for the other tasks within this project, such as the use for the Design to Fabrication IDM. As seen in Figure 21, the data dictionary includes classification systems. This creates an opportunity to collaborate with CSI to create classification tables for bridges elements. Furthermore, there is an opportunity to collaborate with the bSI Infra Room to incorporate elements from the data dictionary into the bSDD. Finally, being an open data repository, the data dictionary can serve as an alignment mechanism for the other ongoing efforts, e.g., the BrIM Data Dictionary, CDX, the FHWA Highway Data Element Dictionary, (US Department of Transportation, 2018) and the FHWA Workflows and National Library project.

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