

# Towards a U.S. National Bridge and Infrastructure Data Dictionary: An Introduction

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# Agenda



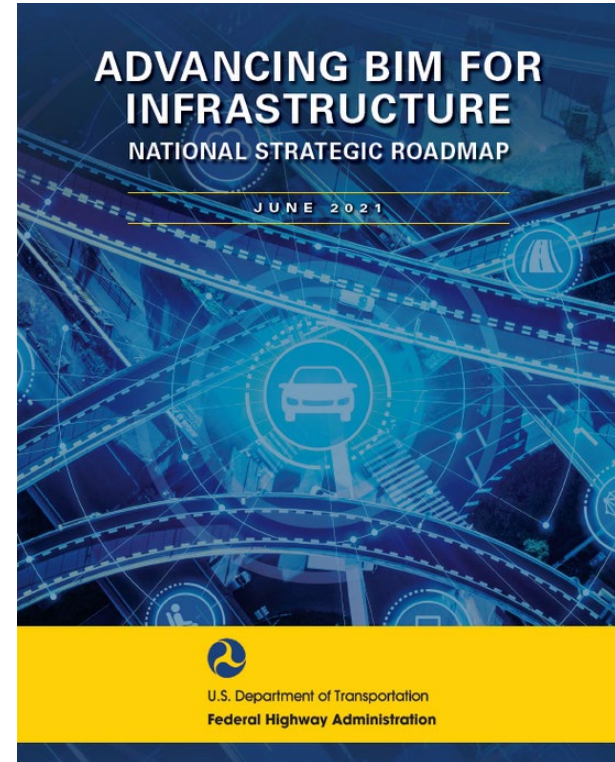
- Background and Motivation
- Challenge
- Related Works
- Research Aim and Goals
- Proposed solution: Automated Data Dictionary Mapping
- Open Challenge

# Background and Motivation

- Push in the U.S. to define a national BIM for bridge and infrastructure standard
- Adoption industry foundation classes (IFC) as the standard data schema
  - for the exchange of electronic engineering data
- Coordinated effort to integration BIM and IFC into transportation workflows
- Need for a standard U.S. bridge and infrastructure knowledge base



**UF** UNIVERSITY of  
**FLORIDA**  
*The Foundation for The Gator Nation*



# Challenge

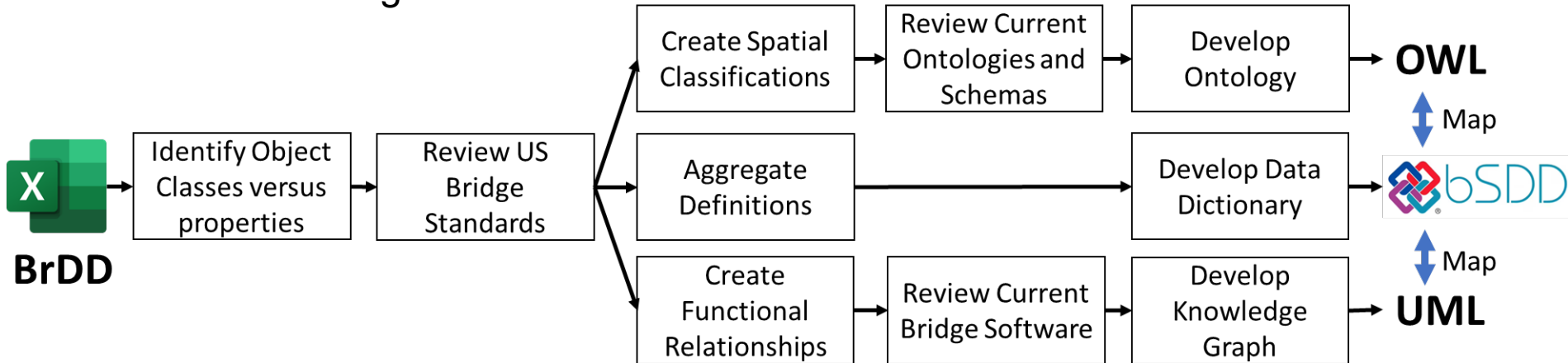
- Lack of a consistent U.S. bridge knowledge base
- Inconsistent and conflicting data
- Gap in industry experts and software/technical developers
- Coordination between the various efforts



	B	C	D
1	<b>Term</b>	<b>Definition</b>	<b>Reference</b>
2	"A" Car	A motive-powered unit so designed that it may be used as the c	AASHTO. (2009).
3	"B" Car	A motive-powered unit designed primarily for use in combinati	AASHTO. (2009).
4	"C" Car	A self-propelled rail car that does not have a control cab (may	AASHTO. (2009).
5	3C Process	A process for planning transportation services that is required b	AASHTO. (2009).
6	AASHTO	American Association of State Highway and Transportation Off	FHWA. (2012). Bri
7	Abandonment	The relinquishment of the public interest in right-of-way or activ	AASHTO. (2009).
8	Abrasion	Loss of section or coating of a culvert by the mechanical action	AASHTO. (2020).
9	abrasion	wearing or grinding away of material by friction; usually caused	FHWA. (2012). Bri
10	Abrasion	1) Loss of section or coating of a culvert by the mechanical acti	AASHTO. (2009).
11	Absolute Block	A block governed by the principle that no train shall enter the bl	AASHTO. (2009).
12	Absolute Permissive	On a track that is signaled in both directions, the section betwe	AASHTO. (2009).
13	absorption	the process of a liquid being taken into a permeable solid (e.g.,	FHWA. (2012). Bri
14	Absorption	1) The assimilation or taking up of water or other solutions by soil	AASHTO. (2009).
15	Absorption Test	A test made to determine the absorption of concrete.	AASHTO. (2009).
16	Abstract of Title	A document showing the condensed history of the title to prop	AASHTO. (2009).
17	Abstraction	That portion of rainfall that does not become runoff. It includes	AASHTO. (2009).
18	Abutment	An end support for a bridge superstructure.	AASHTO. (2020).
19	Abutment	A structure that supports the end of a bridge span, and provide	AASHTO. (2020).
20	abutment	part of bridge substructure at either end of bridge which transfe	FHWA. (2012). Bri
21	Abutment	The earth-retaining structure that supports the superstructure	AASHTO. (2009).
22	Accelerate Stop Distance	The distance required to accelerate an airplane to a specified s	AASHTO. (2009).
23	Acceptance	Sampling and testing, or inspection, to determine the degree of	AASHTO. (2009).
24	Acceptance Constant	The minimum allowable quality index.	AASHTO. (2009).
25	Acceptance Limit	In variable acceptance plans, the limiting upper or lower value	AASHTO. (2009).
26	Acceptance Number	In attribute acceptance plans, the maximum number of defectiv	AASHTO. (2009).
27	Acceptance Plan	An acceptable method of taking samples and making measure	AASHTO. (2009).
28	Acceptance Sampling and	Sampling, testing, and the assessment of test results done to d	AASHTO. (2009).
29	Accepted Method of Analysis	A method of analysis that requires no further verification and th	AASHTO. (2020).
30	Access	Permission, liberty or ability to enter, approach, or to make use	AASHTO. (2009).

# Research Aim and Goals

- Create a bridge and infrastructure data dictionary
- Single source of truth
- Extend to ontological models



# Related Works – IFC



- IFC 4.3<sup>1</sup>- multiple civil infrastructure updates
  - Limitations for full bridge representation
  - E.g., Only 10 defined spatial elements
- IFC for finite element analysis (FEA) (*Shishlov et al. 2023*)
- 3D alignment expansion for railways (*Kwon et al 2020*)
- buildingSMART Data Dictionary (bSDD)<sup>2</sup>

<sup>1</sup> <https://ifc43-docs.standards.buildingsmart.org/>

<sup>2</sup> <https://www.buildingsmart.org/users/services/buildingsmart-data-dictionary/>



# Related Works – Bridge Ontology

- BrMontology ontological knowledgebase for bridge maintenance (*Ren et al. 2019*)
- Bridge Ontology Architecture for Knowledge Management in Bridge Maintenance (*Banujan and Vasanthapriyan (2020)*)
- Bridge Topology Ontology (BROT) (*Hamdan et al. 2020*)
  - Bridge Components Ontology (BRCOMP)
  - Building Material Ontology (BMAT)
  - Bridge Structure Ontology (BRSTR)
  - Bridge Classification Ontology (BRIDGE).
- Ontology for bridge inspection (ASB-ING Ontology) (*Göbels and Beetz 2021*)

# Data Dictionary



- *Centralized repository of information about data such as meaning, relationships to other data, origin, usage, and format<sup>1</sup>*
  - Used to catalog and communicate the structure and content of data
  - Provides meaningful descriptions for individually named data objects
  - Gives context to the data being stored

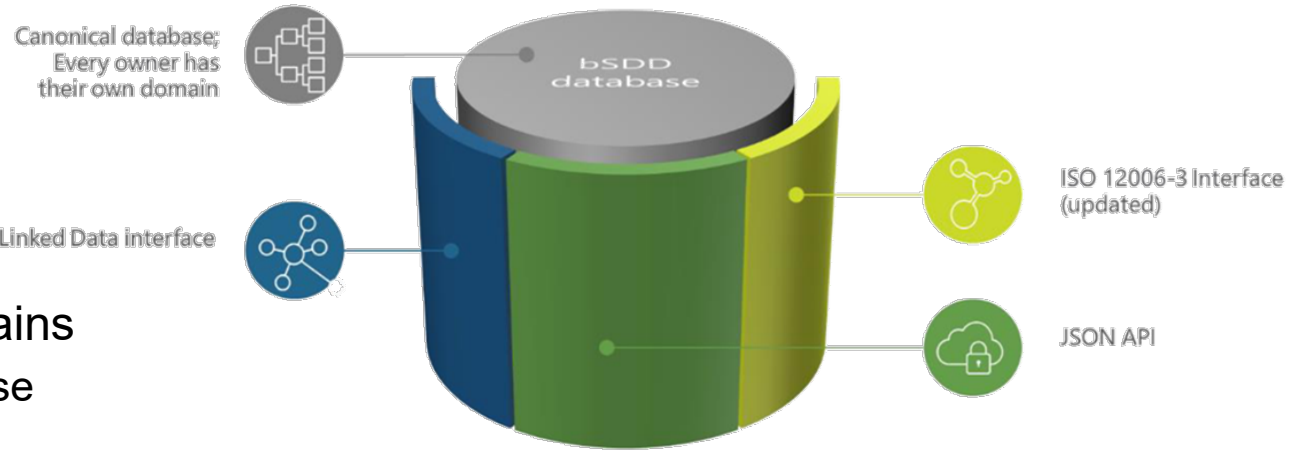
<sup>1</sup>*IBM Dictionary of Computing*, McGraw-Hill Education - Europe; 10th edition (August 1, 1993)



# US Data Dictionary



- Part of the buildingSMART International Data Dictionary (bSDD)
  - Incorporates the industry foundation classes (IFC) and other bSI technologies
  - Accepted internationally
- Defined the US based definitions
  - Collaboration among domain organizations
- Can host multiple domains
  - Enable linkages for reuse



via "Technical Roadmap buildingSMART", April 2020

# Data Dictionary Example: Bridge



## Domain Metadata

*Owners/Stewards*

Field	DataType	Required	Translatable	Description
OrganizationName	Text	Yes	No	buildingSMART International
DomainName	Text	Yes	No	IFC
DomainVersion	Text	Yes	No	2.2
VersionDate	Date	No	No	2017-10-01
LanguageCode	Text	Yes	No	de-DE
LanguageOnly	Boolean	Yes	No	yes
License	Text	No	No	No license

## Property Metadata

*Data specification*

Field	DataType	Required	Translatable	Description
Id	Text	Yes	No	ifc-99088-01
PropertyName	Text	Yes	Yes	IsExternal
ClassificationId	Text	Yes	No	ifc-00123-01
Dimension	Text	No	No	1 0 -2 0 0 0 0
MethodOfMeasurement	Text	No	Yes	Thermal transmittance
DataType	Text	No	No	integer

## Classifications Metadata

*clarifications*

Field	DataType	Required	Translatable	Description
Id	Text	Yes	No	ifc-00123-01
ClassificationName	Text	Yes	Yes	IfcBridge
Definition	Text	No	Yes	A Bridge is civil ..
Status	Text	No	No	Active
DocumentReference	Text	No	No	ISO 6707 1 2014
CountryOfOrigin	Text	No	No	DE
CountriesOfUse	Text	No	No	EN;NL;DE
SubdivisionsOfUse	Text	No	Yes	US-MT
ClassificationType	Text	No	No	ComposedProperty

## IfcClassifications

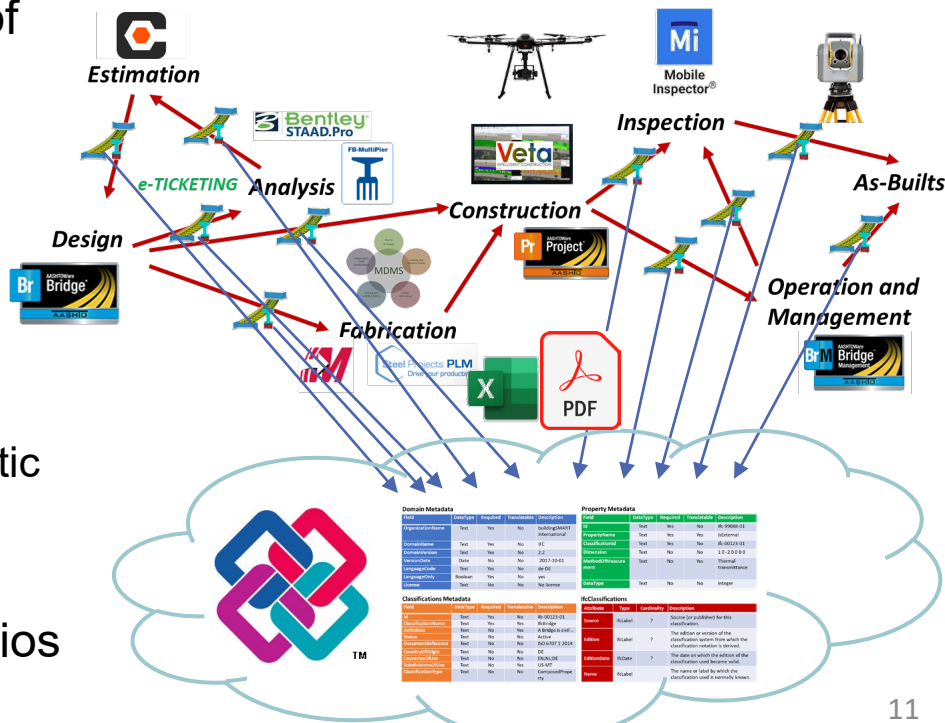
*Domain specific data*

Attribute	Type	Cardinality	Description
Source	IfcLabel	?	Source (or publisher) for this classification.
Edition	IfcLabel	?	The edition or version of the classification system from which the classification notation is derived.
EditionDate	IfcDate	?	The date on which the edition of the classification used became valid.
Name	IfcLabel		The name or label by which the classification used is normally known.

# Why the Data Dictionary?



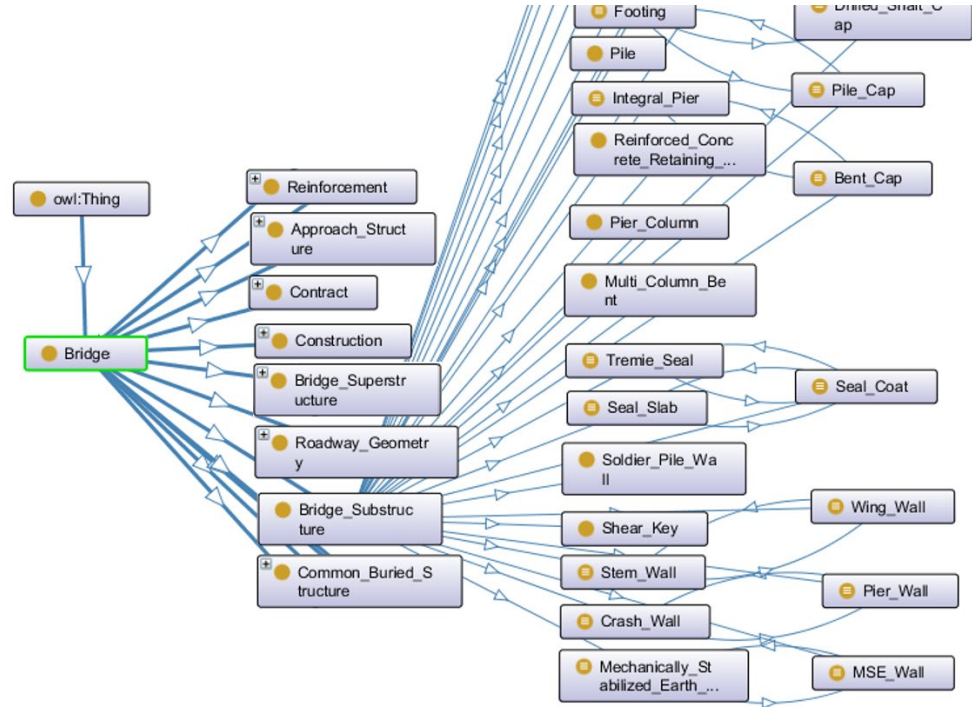
- Defines the structure and the meaning of concepts and terms
  - ◻ Ensures their consistent use by all stakeholders over the life cycle of a construction
- Efficient way to organize knowledge for subsequent retrieval
  - ◻ Querying the Semantic Web.
  - ◻ BIM and web-based context for the semantic annotation of model object
- Further enhance exchange and interoperability in data exchange scenarios



# Issues with Current US Data



- Spatial hierarchy vs functional hierarchy
- Excel and PDF Based
- Missing Terms
- No national infrastructure classification system



# How do we get there?



- Approach #1: Manual Mapping to bSDD
- Approach #2: Map the terminology to .owl then to bSDD
- Both have limitations and challenges
- Need an Automated Approach that goes bi-directional

Information Group	Entity	Property	Property Set
Bridge Superstructure	Bearing	Anchor Bolt	Diameter Length Location Type
		General Properties	Connected By Connected Elements Description Dimension Identification Location Material Quantity Type
	Layout	Bearing Spacing Centerline of Bearing Offset Distance from Centerline of	
	Properties	Allowable Directional Movement Allowable Directional Rotation	

Adjust BSDD information spreadsheet

Sheet1

	A	B	C	D
10	Bridge Superstructure Sidewalk Features		Utilities	
11	Bridge Superstructure Sidewalk General Properties	Connected By		
12	Bridge Superstructure Sidewalk General Properties	Connected Elements		
13	Bridge Superstructure Sidewalk General Properties	Description		
14	Bridge Superstructure Sidewalk General Properties	Dimension		
15	Bridge Superstructure Sidewalk General Properties	General Properties		
16	Bridge Superstructure Sidewalk General Properties	Identification		
17	Bridge Superstructure Sidewalk General Properties	Location		
18	Bridge Superstructure Sidewalk General Properties	Material		
19	Bridge Superstructure Sidewalk General Properties	Quantity		
20	Bridge Superstructure Sidewalk General Properties	Type		
21	Bridge Superstructure Sidewalk Layout	Length		
22	Bridge Superstructure Sidewalk Layout	Location		
23	Bridge Superstructure Sidewalk Layout	Width		

Transformation Rules (C:\Users\marin\OneDrive - University of Florida\Documents\1post doc\test5.json)

Add Edit Delete Load Rules

Sheet Name	Start Column	End Column	Start Row	End Row	Rule
Sheet1	A	A	1	+	Class: @A*
Sheet1	B	B	1	+	Class: @B* SubclassOf: @A*

Create a set of transformation rules in .json

owl:Thing

- Bridge
  - Approach\_Structure
  - Approach\_Slab
  - Sleeper\_Slab
- Bridge\_Substructure
  - Mechanically\_Stabilized\_Earth\_Wall
  - Pier\_Wall
  - Seal\_Coat
  - Footing
  - Abutment/End\_Bent

Insert to protégé to create new ontology

# \*Research Update\*



be aS Do Dos

- LDAC 2023 Hackathon
  - Artur Tomczak
  - Rueben Kruiper
  - Giulia Maslov
  - Rebekka Benfer
  - Aaron Costin
- Challenge: How to automate the linking to similar terms and properties



# Natural Language Processing (NLP)



Classification  
 IfcWindow English

Code  
IfcWindow

Classification type  
IfcWindow

Namespace URI  
http://www.aecsim.com/ontology/IfcWindow

Description  
A window is a vertical or horizontal opening in a wall, typically used to provide natural light, ventilation, or a view. It is often framed by a lintel or sill. A window can be a single pane or a multi-pane unit. It is used to describe the relationship between the IfcWindow and the IfcSpace. The window will then have a Description attribute which uses the IfcText with the assembly of elements. There are two main representations for windows: Occurrence and Placement. The profile of the IfcWindow can be used if the window is an IfcWindowType that references IfcWindowTypeProperties and IfcWindowTypeProfile.

GRAPHQL API

SpaR.txt

CSV



SUGGEST TRIPLES

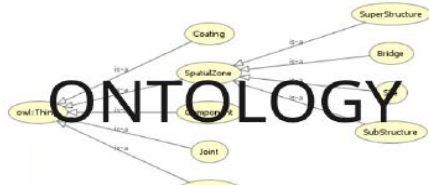


EXCEL

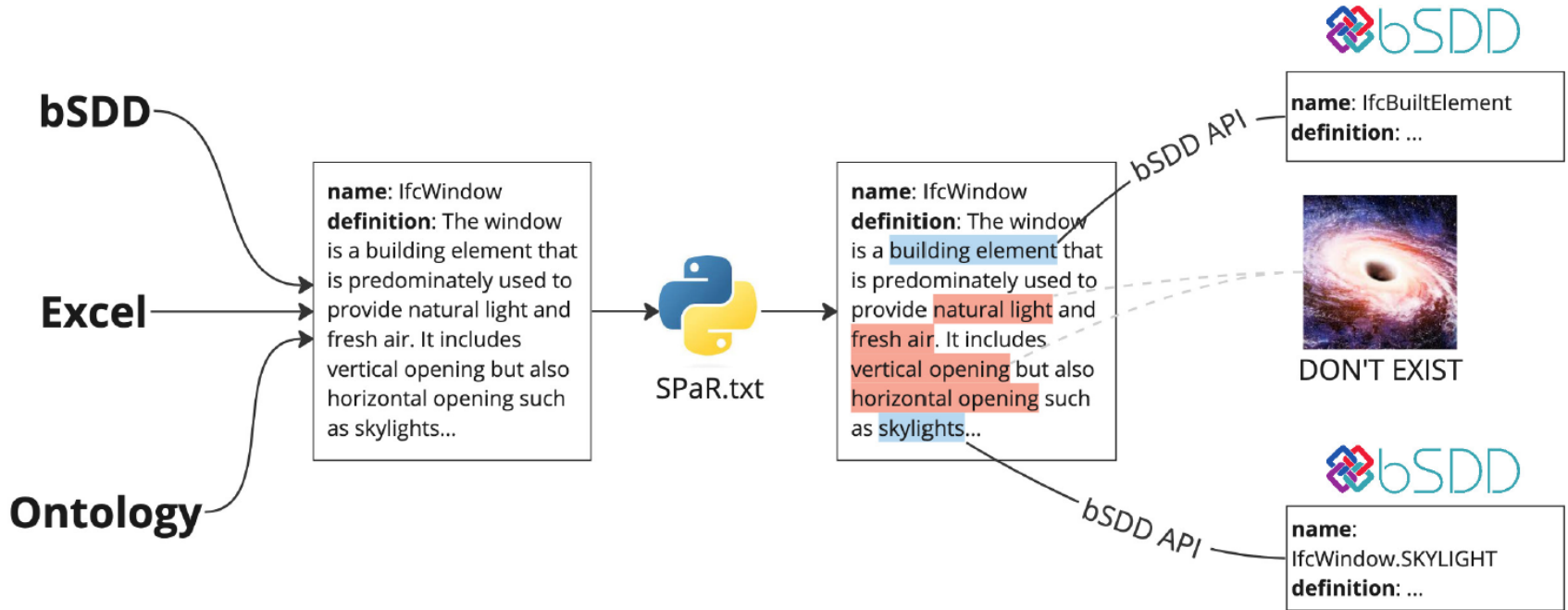
Line Item	Description	Quantity	Unit	Material Code	Material Name	Material Description
1	Concrete	100	cu yd	010100	Concrete	Structural concrete, cast-in-place, 4000 psi, 4" min. aggregate, 10% air, 10% water-reducing admixture, 10% shrinkage-reducing admixture, 10% corrosion-inhibiting admixture, 10% dye.
2	Reinforcing Steel	100	lb	010500	Reinforcing Steel	Structural steel, reinforcing, 60,000 psi yield strength, 1/2" dia.
3	Formwork	100	sq yd	010700	Formwork	Formwork, 2" thick, 4" deep, 4' x 8' panels, 1/2" gage, 10% water-reducing admixture, 10% shrinkage-reducing admixture, 10% corrosion-inhibiting admixture, 10% dye.
4	Formwork Release Agent	100	gal	010800	Formwork Release Agent	Formwork release agent, 10% water-reducing admixture, 10% shrinkage-reducing admixture, 10% corrosion-inhibiting admixture, 10% dye.
5	Formwork Bracing	100	lb	010900	Formwork Bracing	Formwork bracing, 1/2" dia., 6' long, 10% water-reducing admixture, 10% shrinkage-reducing admixture, 10% corrosion-inhibiting admixture, 10% dye.

SPARQL

Discover related terms



# NLP Term Search





# NLP Semantic Similarity



**name:** IfcWindow  
**definition:** The window is a building element that is predominately used to provide natural light and fresh air. It includes vertical opening but also horizontal opening such as skylights...



**name:** Window  
**definition:** space access object for light entry only

THOSE ARE SIMILAR!



Semantic Similarity

# Before

Classification

IfcWall English

Code

IfcWall

Classification type

Class

Namespace URI

<https://identifier.buildingsmart.org/uri/buildingsmart/ifc-4.3/class/ifcWall>

Description

The wall represents a vertical construction that may bound or subdivide spaces. Wall are usually vertical, or nearly vertical, planar elements, often designed to bear structural loads. A wall is however not required to be load bearing. (.extDef)A wall may have openings, such as wall openings, openings used for windows or doors, or niches and recesses. They are defined by an IfcOpeningElement attached to the wall using the inverse relationship HasOpenings pointing to IfcRelVoidsElement. Walls with openings that have already been modeled within the enclosing geometry may use the relationship IfcRelConnectsElements to associate the wall with embedded elements such as doors and windows. There are two main representations for all occurrences: IfcWall

None  
Classification relations



# After

Classification

IfcWall English

Code

IfcWall

Classification type

Class

Namespace URI

<https://identifier.buildingsmart.org/uri/buildingsmart/ifc-4.3/class/ifcWall>

Description

The wall represents a vertical construction that may bound or subdivide spaces. Wall are usually vertical, or nearly vertical, planar elements, often designed to bear structural loads. A wall is however not required to be load bearing. (.extDef)A wall may have openings, such as wall openings, openings used for windows or doors, or niches and recesses. They are defined by an IfcOpeningElement attached to the wall using the inverse relationship HasOpenings pointing to IfcRelVoidsElement. Walls with openings that have already been modeled within the enclosing geometry may use the relationship IfcRelConnectsElements to associate the wall with embedded elements such as doors and windows. There are two main representations for all occurrences: IfcWall

## Classification relations

URI	Name	Relation type
<a href="https://identifier.buildingsmart.org/uri/buildingsmart/ifc-4.3/class/ifcWindow">https://identifier.buildingsmart.org/uri/buildingsmart/ifc-4.3/class/ifcWindow</a>	IfcWindow	HasReference
<a href="https://identifier.buildingsmart.org/uri/buildingsmart/ifc-4.3/class/ifcDoor">https://identifier.buildingsmart.org/uri/buildingsmart/ifc-4.3/class/ifcDoor</a>	IfcDoor	HasReference
<a href="https://identifier.buildingsmart.org/uri/molio/cciconstruction-1.0/class/L-QQA">https://identifier.buildingsmart.org/uri/molio/cciconstruction-1.0/class/L-QQA</a>	Wall	equivalentClass



# Open Challenges



- How best to organize the data?
- How best to determine modularity?
- How to store each stakeholder's data requirements?
- How best to automate the classes and properties?
- How to be bi-directional from the diagrams (industry knowledge) to .owl?



# Thank you



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