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Rule-sets for semantic enrichment of bridge information models

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Contents

1 Introduction

This document defines rule-sets for semantic enrichment of bridge information model instances. Semantic enrichment refers to the automatic or semi-automatic addition of meaningful information to a digital model of a building or other structure by software that can deduce new information by processing rules. The Seebridge team has delivered a semantic enrichment system named SeeBIM, which parses the IFC file of a BIM model and applies forward chaining to infer additional facts about the model using sets of rules compiled in advance by experts in the domain of interest. The current version of SeeBIM is v2.0.

In the course of the SeeBridge project, several aspects of semantic enrichment have been identified as necessary for the Scan to BIM conversion process. They are:

- Classification
- Instantiation of abstract objects
- Numbering/identification
- Aggregation
- Geometry corrections
- Instantiation of missing objects

The rule sets detailed in this document provide the capabilities necessary for all of the above aspects. They include:

- Classification of the objects in the input model according to the bridge component types defined in the Information Delivery Manual (IDM).
- Instantiation of abstract bridge objects such as axes, spans and systems.
- Numbering of bridge objects according to the IDM specification for the purpose of unique identification of components for inspection and maintenance.
- Aggregation of bridge objects to systems and spans.
- Instantiation of missing objects and correction of objects' geometry. The need for these functions arises from the fact that some objects are wholly or partially absent from the input information, due either to occlusions in the laser scan or errors in the 3D reconstruction.

The success of model enrichment depends on the completeness and effectiveness of the inference rules used and on the quality of the input information (3D model objects and supplementary data) that is provided. An important achievement of the SeeBridge project research is the development of a rigorous method for deriving sets of rules for object classification that can be formally shown to be adequate for classifying all of the object types in a domain. The approach is detailed in section 2 below. This is significant because all of the subsequent aspects of semantic enrichment depend on correct classifications.

2 Classification rules for bridge components

2.1 Scope

The domain of Concrete Beam/Girder Bridges was selected for the development of this approach. The bridge component types for this type of bridge are defined in the IDM document and listed in Table 1.

Table 1 Bridge component types

Element Group	Element description	ID in IDM
Deck Superstructure	Primary Girder	111
	Capping beam	
	Transverse beam	201
	Deck slab panel	301
Substructure	Bearing	
	Plinth (capping beam)	
	Plinth (abutment)	
	Shear Key (capping beam)	
	Shear Key (abutment)	401
	Abutment	403
	Column	405
Non-structural	Lamp post	
	Safety barrier	507

Some assumptions are made for these object types:

- Columns are not necessarily parallel to one another, nor are they necessarily vertical.
- Abutments are extrusions perpendicular to the bridge axis
- The safety barrier is made of steel elements and the bridge has steel railings

2.2 Coordinate system alignment

The right side, left side, top, bottom, front and back faces of the bridge as a whole are defined relative to the global coordinate system as follows:

a) the 3D bridge geometry model derived from the point cloud data is placed in the coordinate system such that the deck road alignment direction is parallel to the global X axis.
b) the bridge model is translated along the X axis so that the left hand end of the alignment axis is placed at X=0.
c) The right hand face of the bridge model bounding box is the face with minimum Y
d) The left hand face is the face with maximum Y
e) The front side face is the face with minimum X

f) The back side face is the face with maximum X
g) The bottom face is the face with minimum Z
h) The top face is the face with maximum Z

2.3 Approach

The approach defined below is a rigorous procedure for the case of rule sets for identification of BIM object types (classification). Classification rules use two types of IF clauses: clauses that test for features of a single object, and clauses that test for topological relationships between pairs of objects. Rules used to identify object types therefore often depend on the prior identification of other relevant, related objects. If some objects cannot be identified due to lack of rigor in the rule set, enrichment will be partial, and interdependency within the rules can result in infinite loops in some cases. A rigorous and robust approach to compiling rules sets is preferable. Ideally, developers should be able to guarantee that if enough evidence is available in the data, then the set of rules will identify all objects in the domain and the rule set will not be redundant. This is the goal of the process developed and described below.

In the rigorous approach described below, rules for identifying BIM object types are compiled in seven steps:

1. A basic set of pairwise topological relationships that are most apparently relevant for object identification is defined in consultation with domain experts.
2. The experts are asked to express their knowledge in the form of matrices, one for each of the relationships. Each matrix represents a particular pairwise relationship of all the object pairs. The values in the cells are the logical results of the relationship.
3. The values for each given cell in the resulting set of matrices are strung together to generate a string in each corresponding cell of a composite pairwise spatial/topological relationship matrix. This is an NxN matrix (where N is the number of possible object types).
4. Each string is then compared with all the other strings. Any string that is unique implies that if the set of relationship result values it represents is found to hold for any pair of object instances in a BIM model that is being enriched, then the identity of both of the objects can be ascertained.
5. If any object type does not have at least one unique string, then additional pairwise relationships must be added, repeating the process from step 2. This is done repeatedly if necessary, until all object types have at least one unique string.
6. Next, each string is checked to determine whether it is unique.
7. Finally, a SeeBIM rule is compiled directly from each unique string.

An empty matrix for any type of pairwise relation is shown in Table 2. Possible answers in each cell of the table are ‘y’:= Yes; ‘n’:= No; ‘x’:= Not always; ‘0’:= not used.

Table 2 Template matrix

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	B	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	D	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	E	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	F	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	G	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	H	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	I	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	J	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	K	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	L	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	M	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	N	?	?	?	?	?	?	?	?	?	?	?	?	?	?

2.4 Matrices of Conditional pairwise relations

The following pairwise relations are evaluated:

Physical contact	Obj1 is in contact with obj2
Side contact	Obj1 is in contact with the side face of obj2
Contact front or back	Obj1 is in contact with front/back face of obj2
Contact with base	obj1 is in contact with the base of obj2
Contact with top	Obj1 is in contact with the top face of obj2
Parallel Axes	Extrusion axes of obj1 and obj2 are parallel
Aligned BB	Long edges of obj1 and obj2's BBs are parallel
Centroid elevation	The centroid of object 1 is higher than the centroid of object 2
Longer	Obj1 has a longer extrusion axis than Obj2
Volume	Obj1's volume is greater than Obj2's
Vertical	Obj1's extrusion axis is vertical
Road Aligned	Obj1's longest BB axis is parallel to road alignment
Skew Aligned	Obj1's longest BB axis is parallel to the skew angle of bridge supports
Horizontal	Obj1's shortest BB axis is nearly vertical
Obj1 is a bridge	Obj1 is a bridge
Obj2 is a bridge	Obj2 is a bridge
Wider	The dimension along the y axis of obj1's BB is greater than that of Obj2's BB
Taller	Obj1's height is greater than that of obj2

The detailed evaluation results for each pairwise relation are shown in tables 3 to 20.

Table 3 Physical contact conditions

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	x	x	n	x	n	x	x	x	x	x	x	x	x
	B	x	n	n	y	y	y	n	n	n	n	n	n	n	n
	C	x	n	n	n	n	x	y	n	y	n	n	y	n	n
	D	n	y	n	n	n	n	n	n	n	n	n	n	n	n
	E	x	y	n	n	x	n	n	n	n	n	n	n	n	n
	F	n	y	x	n	n	n	y	n	n	n	n	n	n	n
	G	x	n	y	n	n	y	n	n	n	n	n	n	n	n
	H	x	n	n	n	n	n	n	n	n	n	y	n	n	n
	I	x	n	y	n	n	n	n	n	n	n	n	n	n	n
	J	x	n	n	n	n	n	n	n	n	n	y	n	n	n
	K	x	n	n	n	n	n	n	y	n	y	n	n	n	n
	L	x	n	y	n	n	n	n	n	n	n	n	x	n	n
	M	x	n	n	n	n	n	n	n	n	n	n	n	n	n
	N	x	n	n	n	n	n	n	n	n	n	n	n	n	x

Table 4 Side contact conditions

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	n	x	n	x	n	n	n	y	y	x	x	x	x
	B	n	n	n	y	x	n	n	n	n	n	n	n	n	n
	C	x	n	n	n	n	n	n	n	n	n	n	n	n	n
	D	n	y	n	n	n	n	n	n	n	n	n	n	n	n
	E	x	x	n	x	x	n	n	n	x	x	n	n	n	n
	F	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	G	n	n	n	n	n	n	x	n	n	n	n	n	n	n
	H	n	n	n	n	n	n	n	x	n	n	n	n	n	n
	I	x	x	n	n	x	n	n	n	n	n	n	n	n	n
	J	x	n	n	n	n	n	n	n	n	n	x	n	n	n
	K	x	n	n	n	n	n	n	n	n	y	n	n	n	n
	L	x	n	n	n	n	n	n	n	n	n	n	x	n	n
	M	x	n	n	n	n	n	n	n	n	n	n	n	n	x
	N	x	n	n	n	n	n	n	n	n	n	n	n	x	x

Table 5 Contact front or back

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	x	n	n	x	n	n	x	n	y	y	n	x	x
	B	x	n	n	n	x	n	n	n	n	n	n	n	n	n
	C	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	D	n	n	n	n	x	n	n	n	n	n	n	n	n	n
	E	x	x	n	n	x	n	n	n	n	n	n	n	n	n
	F	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	G	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	H	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	I	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	J	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	K	n	n	n	n	x	n	n	n	n	n	n	n	n	n
	L	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	M	x	n	n	n	n	n	n	n	n	n	n	n	n	x
	N	x	n	n	n	n	n	n	n	n	n	n	n	x	n

Table 6 Contact with base

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	n	n	n	n	n	n	n	n	n	x	y	n	n
	B	n	n	n	n	n	y	n	n	n	n	n	n	n	n
	C	n	n	n	n	n	n	n	n	n	n	n	y	n	n
	D	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	E	n	y	n	x	n	n	n	n	n	n	n	n	n	n
	F	n	n	x	n	n	n	y	n	n	n	n	n	n	n
	G	n	n	y	n	n	n	n	n	n	n	n	n	n	n
	H	n	n	n	n	n	n	n	n	n	n	y	n	n	n
	I	n	n	x	n	n	n	n	n	n	n	n	n	n	n
	J	n	n	n	n	n	n	n	n	n	n	x	n	n	n
	K	x	n	n	n	n	n	n	n	n	n	n	n	n	n
	L	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	M	n	n	n	n	n	n	n	n	x	x	n	n	n	n
	N	n	n	n	n	n	n	n	n	n	n	n	n	n	n

Table 7 Contact with top

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	n	n	n	n	n	n	n	n	n	n	n	y	x
	B	n	n	n	n	y	n	n	n	n	n	n	n	n	n
	C	n	n	n	n	n	x	y	n	x	n	n	n	n	n
	D	n	n	n	n	x	n	n	n	n	n	n	n	n	n
	E	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	F	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	G	n	y	n	n	n	y	n	n	n	n	n	n	n	n
	H	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	I	n	n	n	n	n	n	n	n	n	n	n	n	x	n
	J	n	n	n	n	n	n	n	n	n	n	n	n	x	n
	K	n	n	n	n	n	n	n	y	n	x	n	n	n	n
	L	n	n	x	n	n	n	n	n	y	n	n	n	n	n
	M	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	N	x	n	n	n	n	n	n	n	n	n	n	n	n	n

Table 8 Parallel Axes

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	y	n	n	n	n	n	n	n	n	n	n	n	y
	B	y	y	n	n	n	n	n	n	n	n	n	n	n	y
	C	n	n	y	x	n	n	n	n	n	n	x	n	n	n
	D	n	n	x	y	n	n	n	n	n	n	x	n	n	n
	E	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	F	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	G	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	H	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	I	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	J	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	K	n	n	x	x	n	n	n	n	n	n	x	n	n	n
	L	n	n	n	n	n	n	n	n	n	n	n	x	x	n
	M	n	n	n	n	n	n	n	n	n	n	n	x	y	n
	N	y	y	x	n	n	n	n	n	n	n	n	n	n	y

Table 9 Aligned BB

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	x	x	x	x	x	x	x	x	x	x	x	x	x
	B	x	y	n	n	y	x	x	x	x	x	n	n	n	y
	C	x	n	y	y	n	x	x	x	x	x	y	n	n	n
	D	x	n	y	y	n	x	x	x	x	x	y	n	n	n
	E	x	y	n	n	y	x	x	x	x	x	n	x	n	y
	F	x	x	x	x	x	y	x	x	x	x	x	x	x	x
	G	x	x	x	x	x	x	y	x	x	x	x	x	x	x
	H	x	x	x	x	x	x	x	y	x	x	x	x	x	x
	I	x	x	x	x	x	x	x	x	y	x	x	x	x	x
	J	x	x	x	x	x	x	x	x	x	y	x	x	x	x
	K	x	n	y	y	n	x	x	x	x	x	y	n	n	n
	L	x	n	n	n	x	x	x	x	x	x	n	y	y	n
	M	x	n	n	n	n	x	x	x	x	x	n	y	y	n
	N	x	y	n	n	y	x	x	x	x	x	n	n	n	y

Table 10 Centroid elevation

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	x	x	x	x	x	x	x	x	x	x	x	x	x
	B	x	x	n	x	y	n	n	n	x	x	x	n	y	y
	C	x	y	x	y	y	y	y	x	y	x	x	n	y	y
	D	x	x	n	x	y	x	x	x	x	x	x	n	y	y
	E	x	n	n	n	x	n	n	n	n	n	n	n	y	y
	F	x	y	n	c	y	x	n	x	x	x	x	n	y	y
	G	x	y	n	x	y	y	x	x	x	x	x	n	y	y
	H	x	y	x	x	y	x	x	x	x	x	n	n	y	y
	I	x	x	n	x	y	x	x	x	x	x	x	n	y	y
	J	x	x	x	x	y	x	x	x	x	x	x	n	y	y
	K	x	x	x	x	y	x	x	y	x	y	x	x	y	y
	L	x	y	y	y	y	y	y	y	y	y	x	x	y	y
	M	x	n	n	n	n	n	n	n	n	n	n	n	x	n
	N	x	n	n	n	n	n	n	n	n	n	n	n	y	x

Table 11 Longer

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	n	n	n	n	n	n	n	n	n	n	n	x	n
	B	y	x	x	n	n	n	n	n	n	n	x	x	x	x
	C	y	x	x	n	n	n	n	n	n	n	x	x	x	x
	D	y	y	y	x	n	n	n	n	n	n	y	y	x	x
	E	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	F	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	G	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	H	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	I	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	J	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	K	y	x	x	n	n	n	n	n	n	n	x	x	x	x
	L	y	x	x	n	n	n	n	n	n	n	x	x	x	x
	M	x	x	x	x	n	n	n	n	n	n	x	x	x	x
	N	y	x	x	x	n	n	n	n	n	n	x	x	x	x

Table 12 Volume

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	n	n	x	n	n	n	n	n	n	n	n	n	n
	B	y	x	x	n	n	n	n	n	n	n	x	x	n	n
	C	y	x	x	n	n	n	n	n	n	n	x	x	n	n
	D	y	y	y	x	x	n	x	x	x	x	x	y	x	x
	E	y	y	y	x	x	n	x	x	x	x	y	y	x	x
	F	y	y	y	y	y	x	x	x	y	y	y	y	y	y
	G	y	y	y	x	x	x	x	x	x	x	y	y	x	x
	H	y	y	y	x	x	x	x	x	x	x	y	y	x	x
	I	y	y	y	x	x	n	x	x	x	x	y	y	x	x
	J	y	y	y	x	x	n	x	x	x	x	y	y	x	x
	K	y	x	x	x	n	n	n	n	n	n	x	x	n	n
	L	y	x	x	n	n	n	n	n	n	n	x	x	n	n
	M	y	y	y	x	x	n	x	x	x	x	y	y	x	x
	N	y	y	y	x	x	n	x	x	x	x	y	y	x	x

Table 13 Vertical

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	n	n	n	n	n	n	n	n	n	n	x	y	n
	B	0	n	n	n	n	n	n	n	n	n	n	x	y	n
	C	0	n	n	n	n	n	n	n	n	n	n	x	y	n
	D	0	n	n	n	n	n	n	n	n	n	n	x	y	n
	E	0	n	n	n	n	n	n	n	n	n	n	x	y	n
	F	0	n	n	n	n	n	n	n	n	n	n	x	y	n
	G	0	n	n	n	n	n	n	n	n	n	n	x	y	n
	H	0	n	n	n	n	n	n	n	n	n	n	x	y	n
	I	0	n	n	n	n	n	n	n	n	n	n	x	y	n
	J	0	n	n	n	n	n	n	n	n	n	n	x	y	n
	K	0	n	n	n	n	n	n	n	n	n	n	x	y	n
	L	0	n	n	n	n	n	n	n	n	n	n	x	y	n
	M	0	n	n	n	n	n	n	n	n	n	n	x	y	n
	N	0	n	n	n	n	n	n	n	n	n	n	x	y	n

Table 14 Road Aligned

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	y	n	n	y	x	x	x	x	x	n	n	n	y
	B	0	y	n	n	y	x	x	x	x	x	n	n	n	y
	C	0	y	n	n	y	x	x	x	x	x	n	n	n	y
	D	0	y	n	n	y	x	x	x	x	x	n	n	n	y
	E	0	y	n	n	y	x	x	x	x	x	n	n	n	y
	F	1	y	n	n	y	x	x	x	x	x	n	n	n	y
	G	0	y	n	n	y	x	x	x	x	x	n	n	n	y
	H	0	y	n	n	y	x	x	x	x	x	n	n	n	y
	I	0	y	n	n	y	x	x	x	x	x	n	n	n	y
	J	0	y	n	n	y	x	x	x	x	x	n	n	n	y
	K	0	y	n	n	y	x	x	x	x	x	n	n	n	y
	L	0	y	n	n	y	x	x	x	x	x	n	n	n	y
	M	0	y	n	n	y	x	x	x	x	x	n	n	n	y
	N	0	y	n	n	y	x	x	x	x	x	n	n	n	y

Table 15 Skew Aligned

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	n	y	x	n	0	x	x	n	n	y	y	n	n
	B	0	n	y	x	n	0	x	x	n	n	y	y	n	n
	C	0	n	y	x	n	0	x	x	n	n	y	y	n	n
	D	0	n	y	x	n	0	x	x	n	n	y	y	n	n
	E	0	n	y	x	n	0	x	x	n	n	y	y	n	n
	F	0	n	y	x	n	1	x	x	n	n	y	y	n	n
	G	0	n	y	x	n	0	x	x	n	n	y	y	n	n
	H	0	n	y	x	n	0	x	x	n	n	y	y	n	n
	I	0	n	y	x	n	0	x	x	n	n	y	y	n	n
	J	0	n	y	x	n	0	x	x	n	n	y	y	n	n
	K	0	n	y	x	n	0	x	x	n	n	y	y	n	n
	L	0	n	y	x	n	0	x	x	n	n	y	y	n	n
	M	0	n	y	x	n	0	x	x	n	n	y	y	n	n
	N	0	n	y	x	n	0	x	x	n	n	y	y	n	n

Table 16 Horizontal

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	x	x	x	y	y	x	x	n	n	n	n	n	n
	B	0	x	x	x	y	y	x	x	n	n	n	n	n	n
	C	0	x	x	x	y	y	x	x	n	n	n	n	n	n
	D	0	x	x	x	y	y	x	x	n	n	n	n	n	n
	E	0	x	x	x	y	y	x	x	n	n	n	n	n	n
	F	0	x	x	x	y	y	x	x	n	n	n	n	n	n
	G	0	x	x	x	y	y	x	x	n	n	n	n	n	n
	H	0	x	x	x	y	y	x	x	n	n	n	n	n	n
	I	0	x	x	x	y	y	x	x	n	n	n	n	n	n
	J	0	x	x	x	y	y	x	x	n	n	n	n	n	n
	K	0	x	x	x	y	y	x	x	n	n	n	n	n	n
	L	0	x	x	x	y	y	x	x	n	n	n	n	n	n
	M	0	x	x	x	y	y	x	x	n	n	n	n	n	n
	N	0	x	x	x	y	y	x	x	n	n	n	n	n	n

Table 17 Obj1 is a bridge

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	B	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	C	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	D	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	E	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	F	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	G	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	H	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	I	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	J	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	K	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	L	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	M	y	n	n	n	n	n	n	n	n	n	n	n	n	n
	N	y	n	n	n	n	n	n	n	n	n	n	n	n	n

Table 18 Obj2 is a bridge

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	y	y	y	y	y	y	y	y	y	y	y	y	y	y
	B	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	C	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	D	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	E	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	F	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	G	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	H	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	I	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	J	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	K	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	L	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	M	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	N	n	n	n	n	n	n	n	n	n	n	n	n	n	n

Table 19 Wider

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	n	x	n	n	n	n	n	n	n	x	n	n	n
	B	y	x	y	x	y	n	x	x	x	x	y	x	x	x
	C	y	n	x	n	n	n	n	n	n	n	x	n	n	n
	D	y	x	y	x	x	x	x	x	x	x	y	x	x	n
	E	y	n	y	x	x	n	x	x	n	n	y	x	x	n
	F	y	y	y	x	y	x	y	x	x	x	y	y	x	x
	G	y	x	y	x	x	n	x	x	x	x	y	x	x	x
	H	y	x	y	x	x	x	x	x	x	x	y	x	x	x
	I	y	x	y	x	y	x	x	x	x	x	y	x	x	x
	J	y	x	y	x	y	x	x	x	x	x	y	x	x	x
	K	x	n	x	n	n	n	n	n	n	n	x	n	n	n
	L	y	x	y	x	x	n	x	x	x	x	y	x	x	x
	M	y	x	y	x	x	x	x	x	x	x	y	x	x	x
	N	y	x	y	y	y	x	x	x	x	x	y	x	x	x

Table 20 Taller

		Obj1													
Element Group		Bridge	Deck Superstructure				Substructure							Non-structural	
	Element description	Bridge	Primary girder	Capping beam	Transverse beam	Deck slab panel	Bearing	Plinth (capping beam)	Plinth (abutment)	Shear key (capping beam)	Shear key (abutment)	Abutment	Column	Lamp post	Safety barrier
			111		201	301					401	403	405		507
	#	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Obj2	A	0	n	n	n	n	n	n	n	n	n	n	n	n	n
	B	y	x	x	x	n	n	n	n	x	x	x	y	y	x
	C	y	x	x	x	n	n	n	n	x	x	x	y	y	x
	D	y	x	x	x	n	n	n	n	x	x	x	y	y	x
	E	y	y	y	y	x	x	x	x	y	y	y	y	y	y
	F	y	y	y	y	x	x	x	x	y	y	y	y	y	y
	G	y	y	y	y	x	x	x	x	y	y	y	y	y	y
	H	y	y	y	y	x	x	x	x	y	y	y	y	y	y
	I	y	x	x	x	n	n	n	n	x	x	x	y	y	x
	J	y	x	x	x	n	n	n	n	x	x	x	y	y	x
	K	y	x	x	x	n	n	n	n	x	x	x	x	x	x
	L	y	n	n	n	n	n	n	n	n	n	x	x	x	n
	M	y	n	n	n	n	n	n	n	n	n	x	x	x	n
	N	y	x	x	x	n	n	n	n	x	x	x	y	y	x

2.5 Selected rules for object classification

The selected rules for identification of all the bridge component types are shown in

Table 21. For example, the second column in the table is interpreted as follows:

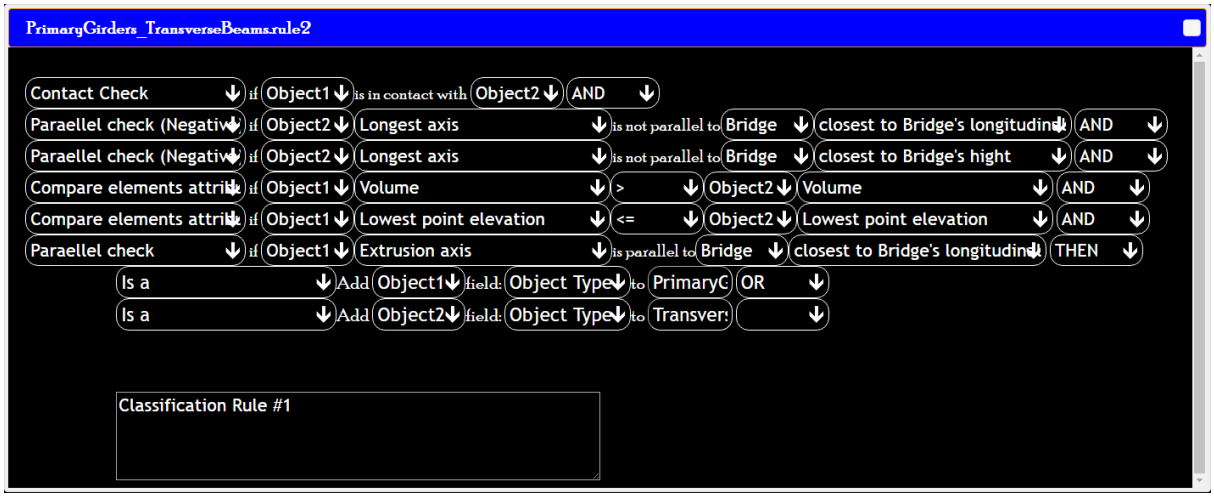
IF obj1 is_in_contact_with obj2
AND
obj1 is_not_in_contact_with obj2 front/back face
AND
obj1 is_not_in_contact_with obj2 base
AND
obj1 extrusion_axes not_parallel obj2
AND
obj1 long_edges not_parallel obj2
AND
obj1 extrusion_axis is_not_vertical
AND
obj1 longest_bb_axis is_parallel bridge_X_axis
AND
obj1 longest_bb_axis is_not_parallel bridge supports skew angle
AND
obj1 is_not_a bridge
AND
obj2 is_not_a bridge
THEN
obj1 is_a Primary girder
AND
obj2 is_a Transverse beam

Table 21 Selected rules for classification of object pairs

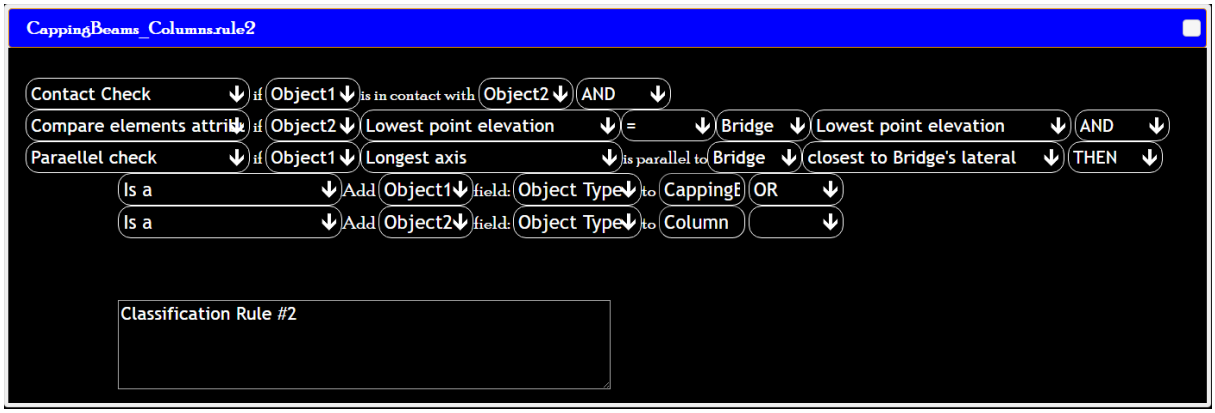
Rules for classification of object type pairs	Primary girder Transverse beam	Capping beam Column	Primary girder Deck slab	Shear key (abutment) Bridge	Shear key (capping beam) Bridge	Plinth (capping beam) Bridge	Abutment Bridge
Rule Number	1	2	3	4	5	6	7
Obj1 is in contact with obj2	y	y	y	x	x	x	x
Obj1 is in contact with the side face of obj2	y	x	x	y	y	n	x
Obj1 is in contact with front/back face of obj2	n	n	x	y	n	n	y
obj1 is in contact with the base of obj2	n	n	y	n	n	n	x
Obj1 is in contact with the top face of obj2	n	x	n	n	n	n	n
Extrusion axes of obj1 and obj2 are parallel	n	n	n	n	n	n	n
Long edges of obj1 and obj2's BBs are parallel	n	n	y	x	x	x	x
The centroid of object 1 is higher than the centroid of object 2	x	y	n	x	x	x	x
Obj1 has a longer extrusion axis than Obj2	y	x	n	n	n	n	n
Obj1's volume is greater than Obj2's	y	x	y	n	n	n	n
Obj1's extrusion axis is vertical	n	n	n	n	n	n	n
Obj1's longest BB axis is parallel to road alignment	y	n	y	x	x	x	n
Obj1's longest BB axis is parallel to the skew angle of bridge supports	n	y	n	n	n	x	y
Obj1's shortest BB axis is nearly vertical	x	x	x	n	n	x	n
Obj1 is a bridge	n	n	n	n	n	n	n
Obj2 is a bridge	n	n	n	y	y	y	y
The dimension along the y axis of obj1's BB is greater than that of Obj2's BB	x	y	n	n	n	n	x
Obj1's height is greater than that of obj2	X	n	y	n	n	n	n

The following figures are screen captures of the rules in the SeeBIM interface.

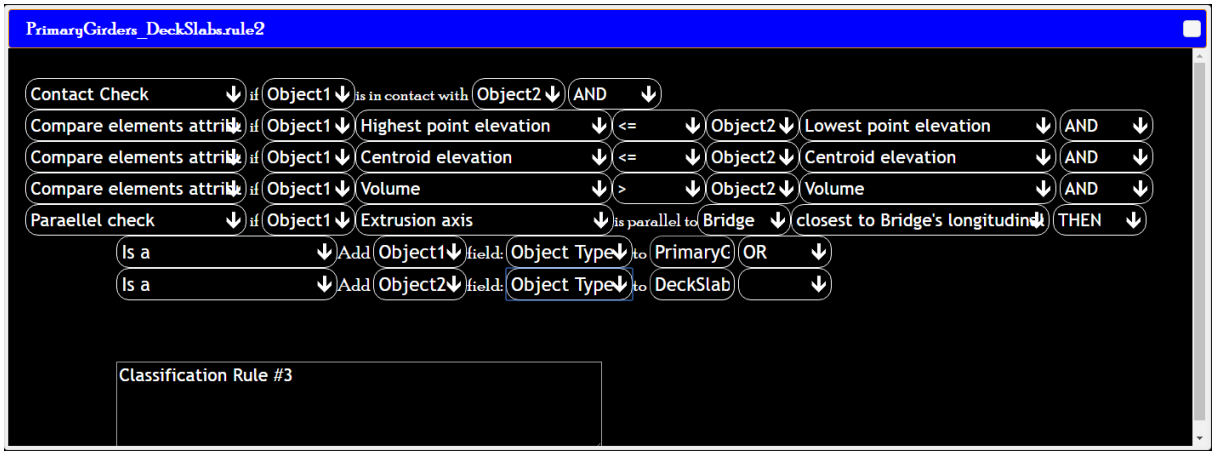
Classificaton Rule #1



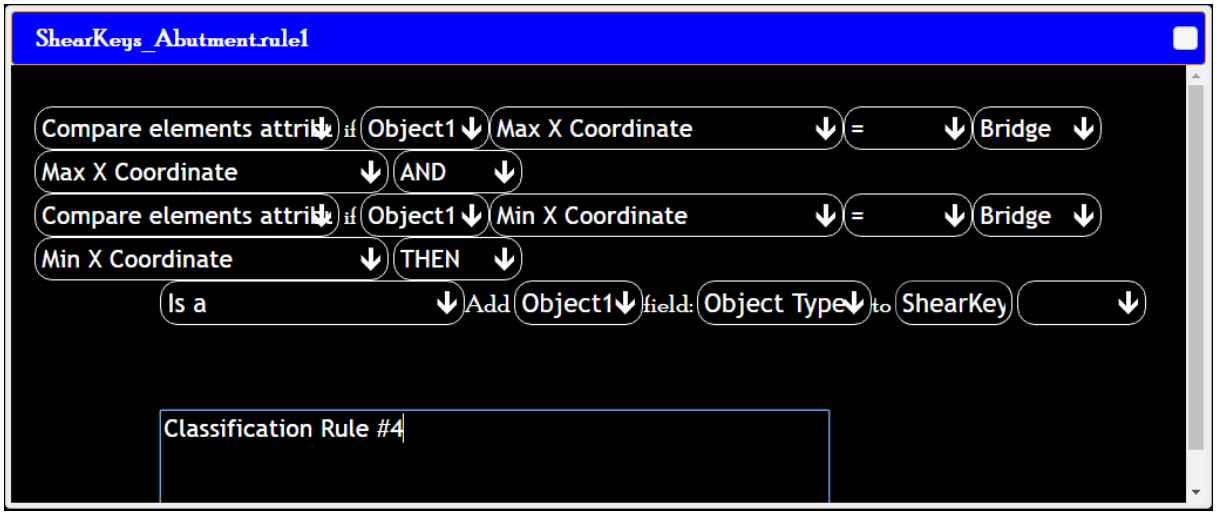
Classificaton Rule #2



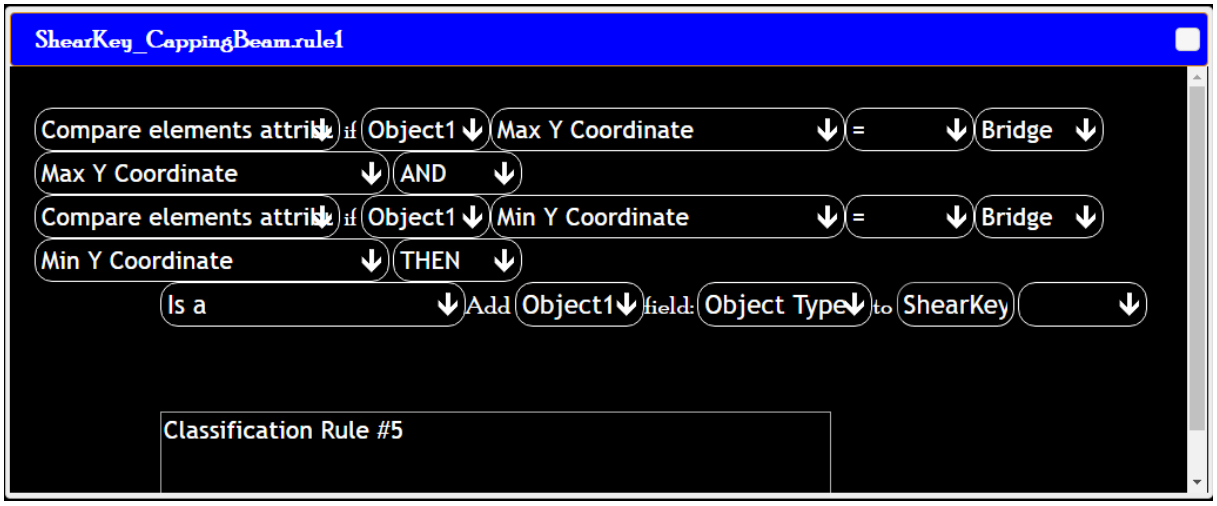
Classificaton Rule #3



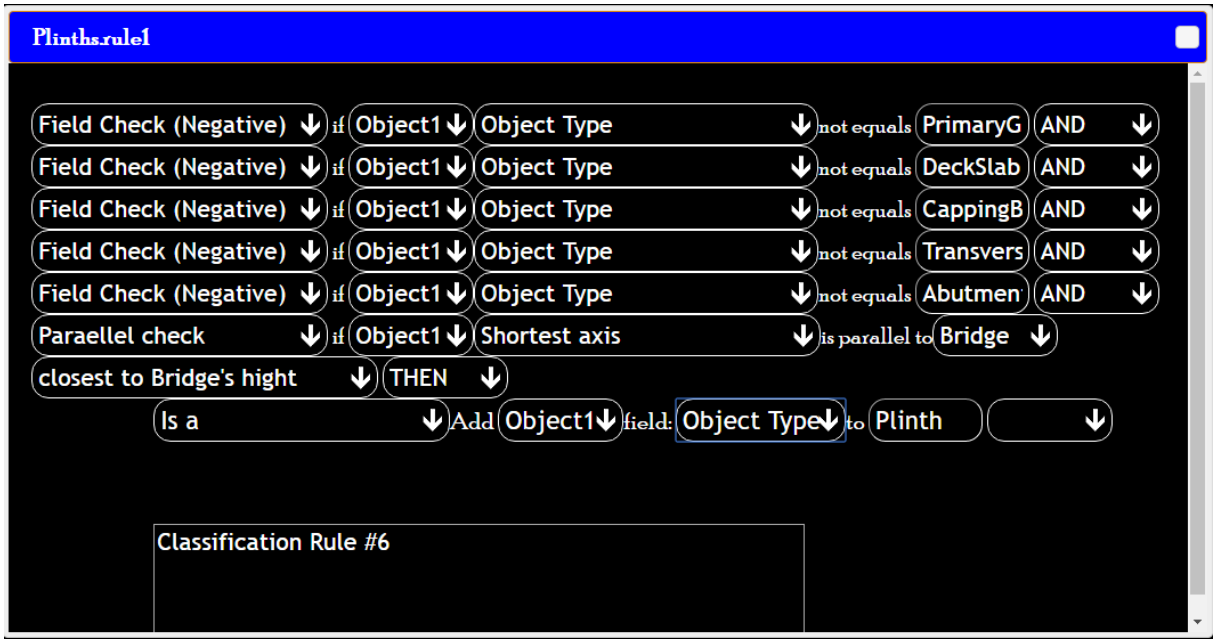
Classificaton Rule #4



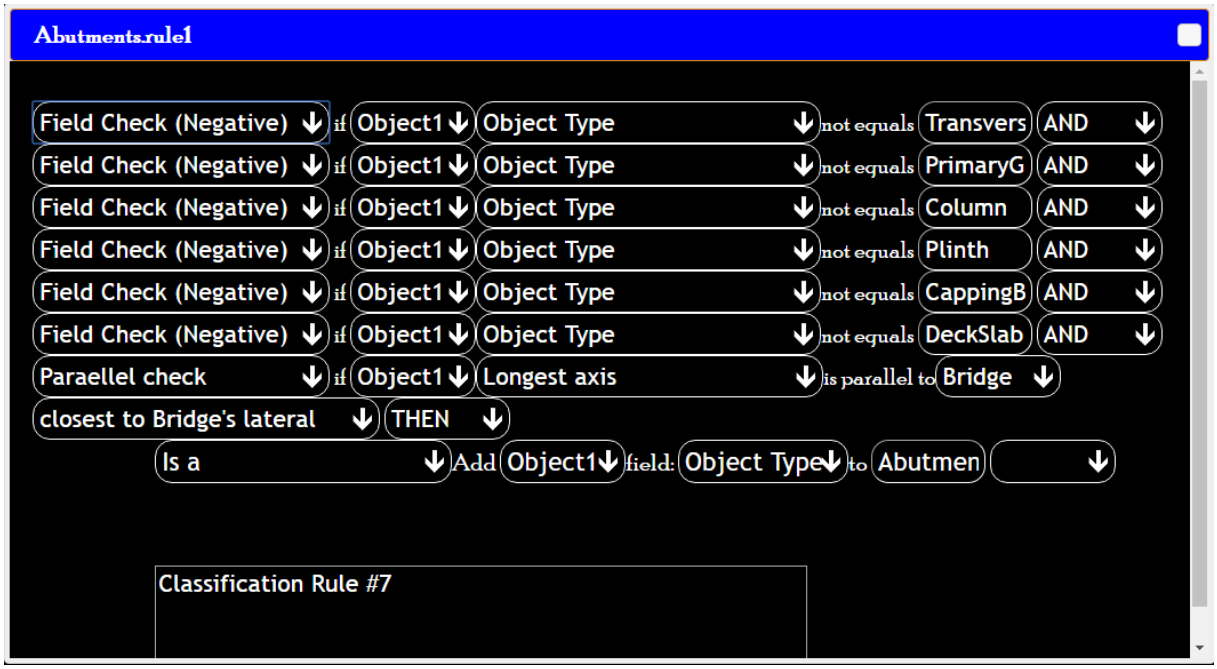
Classificaton Rule #5



Classificaton Rule #6



Classificaton Rule #7



3 Rules for identification of bridge grids

The bridge grids are created and numbered using three rules. Each of the rules checks whether the axis that is needed already exists (the objects and the axes are associated), and only creates a new axis where none exists.

3.1 Longitudinal Axes

Longitudinal axes are created along the center-lines of all primary girders (see Figure 1). The operator checks for redundancy and will not duplicate axes.

IF obj1 is_a PrimaryGirder
THEN
Create_Axis Longitudinal

This operation also labels the longitudinal axes incrementally.

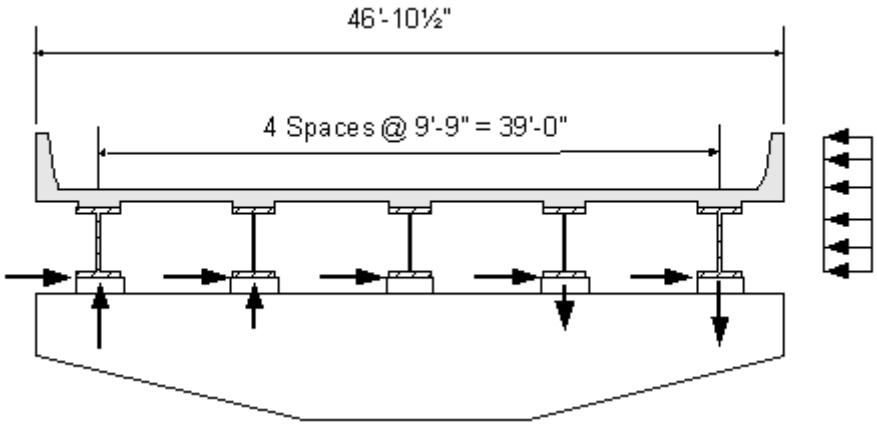


Figure 1 The centre lines of the primary girders define the longitudinal axes

3.2 Transvers Axes

Transverse axes are created along the center lines of capping beams and of abutments (see Figure 2).

IF obj1 is_a Capping Beam
THEN
Create_Axis Transverse

IF obj1 is_a Abutment
THEN
Create_Axis Transverse

The operator is the same one used for the longitudinal axes, and will not duplicate axes on successive loops over the objects by the inference engine. These operations also label the transverse axes incrementally.

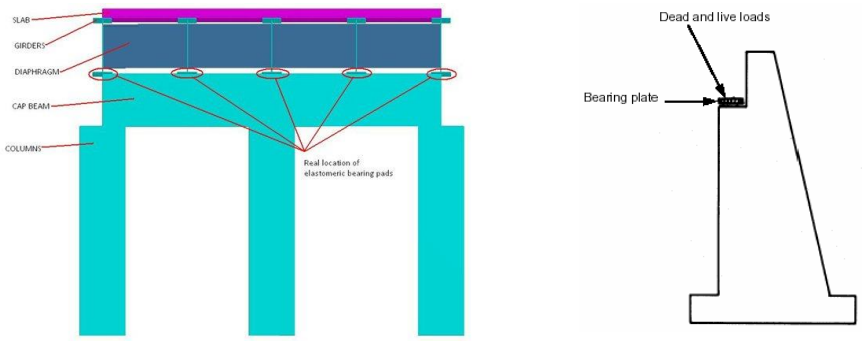


Figure 2 The centre lines of capping beams and of bearing arrays on abutments define the transverse axes

3.3 Correcting axis extents

The longitudinal axes are generated along the lengths of the primary girders. However, as a result, their start and end points are incorrect due to the gaps between adjacent girders and/or possible occlusion of part of the lengths for some of the girders and/or in cases where 3D modelling errors result in girders that extend beyond the centre lines of their supports. These axes are extended or trimmed to meet the adjacent transverse axes.

The resulting longitudinal axes are line segments in the grids, and they are labelled with their original number and the label of the two adjacent transverse axes. Figure 3 shows an example of a bridge model with labelled grids after application of these rules.

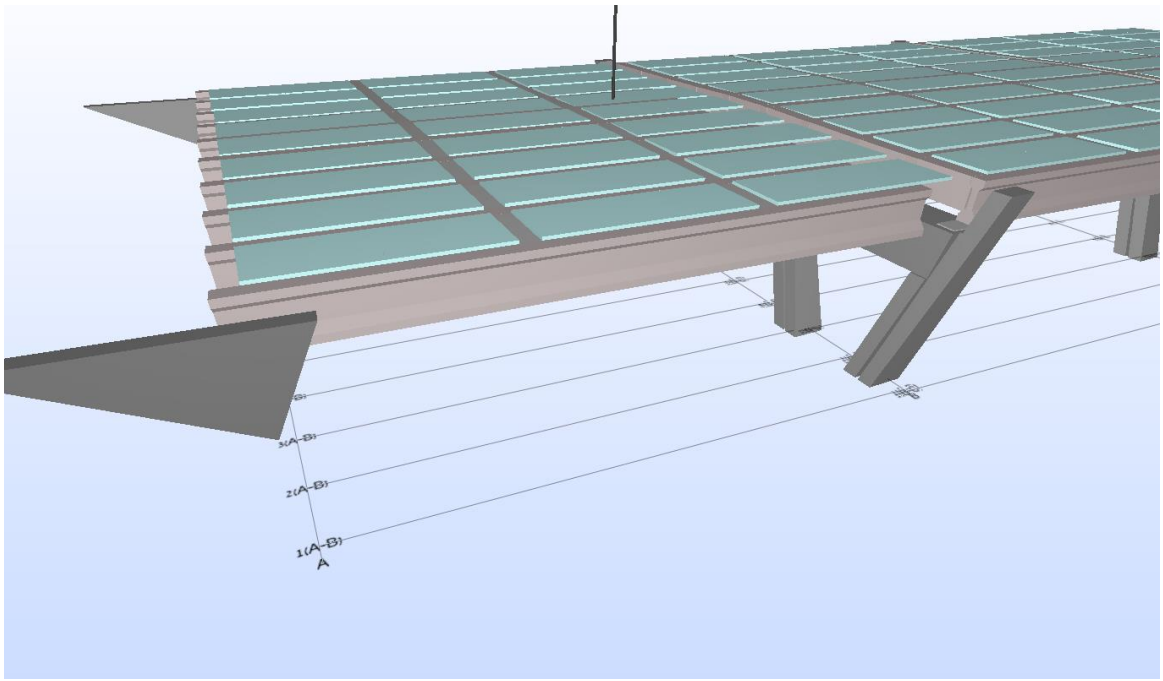


Figure 3 Example of generated grids, showing the labels

4 Rules for numbering bridge objects

All objects in the bridge must be uniquely identified with numbering series that are unique within the scope of each object type, in line with the bridge inspection guides and as defined in the SeeBridge IDM. The numerating index is composed of two tags:

a) one tag for the axis or the span to which the particular entity belongs

b) a second tag for sequential indexing of similar objects of the same type along the axis or within the span

Supplementing objects' with identification tags is executed using just five kinds of rule:

1. In the SeeBIM rules that classify bridge objects, each one is assigned an 'axis ID' field and an 'Object ID' field.
2. If one of a pair of objects is an object that defines an axis (capping beam, abutment or girder), the second object is assigned the axis ID label of the first object.
3. If the axis ID label of the first object is updated for any reason, then the axis ID label of the second object is reset and its Object ID is reset to "1".
4. If two objects of the same type have the same transverse axis ID and the same object ID, then the object ID of the object whose centroid's Y coordinate is greater, is incremented by one plus the other object's ID value.
5. If two objects of the same type have the same longitudinal axis ID and the same object ID, then the object ID of the object whose centroid's X coordinate is greater, is incremented by plus the other object's ID value.

4.1.1 Assigning labels to Columns

Rule for setting the Axis ID of a Column:

IF obj1 is_a Capping beam
AND
obj2 is_a Column
AND
obj1 is_in contact with obj2
AND
obj1.axis_tag != obj2.axis_tag
THEN
obj2.axis_tag = obj1.axis_tag
AND
obj2.numerator_tag = 1 // numerator tag is the object ID

Rule for sorting the Object ID of the Columns along a transverse axis

IF obj1 is_a Column
AND
obj2 is_a Column
AND
obj1.axis_tag == obj2.axis_tag
AND
obj1.numerator_tag == obj2.numerator_tag
AND
obj1.centroid.y < obj2.centroid.y
THEN
obj2.numerator_tag = obj1.numerator_tag + 1

4.1.2 Assigning Labels to Plinths

Rules for setting the Axis ID of a Plinth:

IF obj1 is_a Capping beam
AND
obj2 is_a Plinth
AND
obj1 is_in_contact with obj2
AND
obj1.axis_tag != obj2.axis_tag
THEN
obj2.axis_tag = obj1.axis_tag
AND
obj2.numerator_tag = 1 // numerator tag is the object ID

IF obj1 is_a Abutment
AND
obj2 is_a Plinth
AND
obj1 is_in_contact with obj2
AND
obj1.axis_tag != obj2.axis_tag
THEN
obj2.axis_tag = obj1.axis_tag
AND
obj2.numerator_tag = 1 // numerator tag is the object ID

Rule for sorting the Object ID of the Plinths along a transverse axis

IF obj1 is_a Plinth
AND
obj2 is_a Plinth
AND
obj1.axis_tag == obj2.axis_tag
AND
obj1.numerator_tag == obj2.numerator_tag
AND
obj1.centroid.y < obj2.centroid.y

THEN
obj2.numerator_tag = obj1.numerator_tag + 1

4.1.3 Assigning Labels to Bearings

Rules for setting the Axis ID of a Bearing:

IF obj1 is_a Capping beam
AND
obj2 is_a Bearing
AND
obj2 is_above obj1
AND
obj1.axis_tag != obj2.axis_tag
THEN
obj2.axis_tag = obj1.axis_tag
AND
obj2.numerator_tag = 1 // numerator tag is the object ID

IF obj1 is_a Abutment
AND
obj2 is_a Bearing
AND
obj2 is_above obj1
AND
obj1.axis_tag != obj2.axis_tag
THEN
obj2.axis_tag = obj1.axis_tag
AND
obj2.numerator_tag = 1 // numerator tag is the object ID

Rules for sorting the Object ID of the Bearings along a transverse axis

IF obj1 is_a Bearing
AND
obj2 is_a Bearing
AND
obj1.axis_tag == obj2.axis_tag
AND
obj1.numerator_tag == obj2.numerator_tag
AND
obj1.centroid.x < obj2.centroid.x
AND
obj1.centroid.y < obj2.centroid.y
THEN
obj2.numerator_tag = obj1.numerator_tag + 1

IF obj1 is_a Bearing
AND
obj2 is_a Bearing

AND
obj1.axis_tag == obj2.axis_tag
AND
obj1.numerator_tag == obj2.numerator_tag
AND
obj1.centroid.x < obj2.centroid.x
THEN
obj2.numerator_tag = obj1.numerator_tag + 1

5 Aggregation rules

5.1 Generating systems and associating objects

There are two operators for generating systems and assigning objects to the systems:

5.1.1 Non-unique system assignment

Assign_to_System <object> to <IfcSystem Name>

The non-unique assignment operator first checks whether the object is already assigned to the system, and if so, it does nothing. If not, it assigns the building object to the system whose name is provided by the user in the rule. The system must be an IfcSystem object. If the system does not exist, the operator will create it and add it to the model.

Example:

IF obj1 is_a Deck Slab
THEN
Assign_to_System obj1 to Superstructure

5.1.2 Unique system assignment

Assign_uniquely_to_System <object> to <IfcSystem Name>

The unique assignment operator works in the same way as the non-unique operator, but with one extra action - if the object has any prior assignments to any other systems, those assignments are deleted. In this way the new assignment is the only system assignment for the object.

Example:

IF obj1 is_a Primary Girder
THEN
Assign_uniquely_to_System obj1 to Superstructure

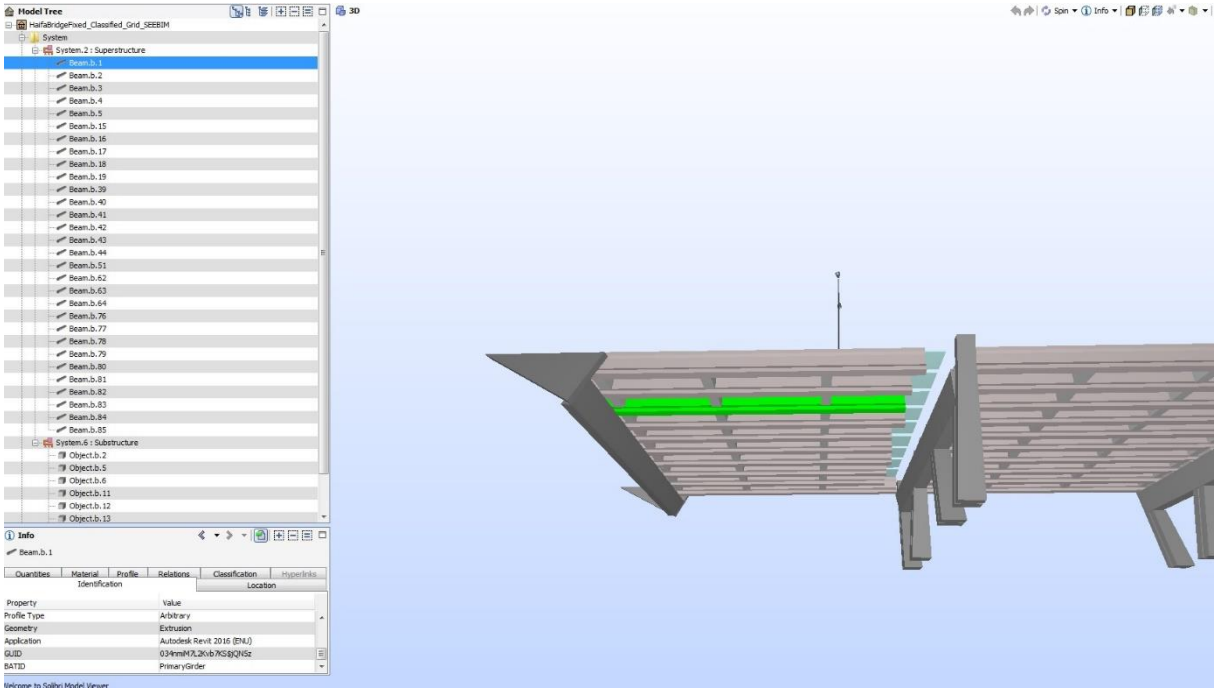


Figure 4. Assignment of a primary girder to the superstructure system

5.1.3 Object to System assignment tables

One system assignment rule is needed for each entry in the following lists of object – system relationships.

Table 22. Object to System Assignment Table

System Name	Object List		Unique / Non-unique
Superstructure	111	Primary girder	Unique
	131	slab	Non-unique
	201	Secondary Deck element - Transverse Beam/Diaphragm	Non-unique
	301	Deck Slab - (Concrete Beam/Girders, Box Girder, Composite)	Non-unique
	202	Half Joints	Unique
	204	Cantilever	Unique
	702	Aprons, parapets, edge beams	Non-unique
	709	Expansion joints	Non-unique
Substructure	401	Shear Keys	Unique
	402	Foundations / Pilecaps/Piles	Unique
	403	Abutments / Arch springing / End w alls	Unique
	404	Head wall / Spandrel wall	Unique
	405	Pier / Column / Arch support / Pylon	Unique
	406	Cross-head / Capping beam	Non-unique
	407	Bearings	Unique
	408	Bearings Plinth/Pedestal/shelf	Unique

System Name	Object List		Unique / Non-unique
	706	Wings walls	Unique
	707	Retaining Walls	Unique
Drainage	501	Superstructure Drainage	Non-unique
	502	Substructure Drainage / Drainage channel	Non-unique
Durability protection	503	Waterproofing (all elements)	Non-unique
	504	Bridge deck Expansion Joints	Non-unique
	505	Finishes & protective coatings: Superstructure	Non-unique
	506	Finishes & protective coatings: Substructure	Non-unique
	507	Finishes & protective coatings: parapets / safety barriers	Non-unique
	709	Expansion joints	Non-unique
Safety	601	Access / Walkw ays / Stairs	Non-unique
	602	Safety Barriers / handrails	Non-unique
	603	Carriageway surfacing	Non-unique
	604	Footway / verge / shoulders / footbridge surfacing	Non-unique
	702	Aprons, parapets, edge beams	Non-unique
	703	Fenders / cutw aters / collision protection	Non-unique
Lighting	903	Lighting	Non-unique
Signs	902	Sign	Unique
Utilities (water, electrical, communication)	712	Machinery	Unique
		Miscellaneous	Non-unique
	904	Services/Utilities	Non-unique
Traffic		Traffic markings	Unique
	711	Curbs	Unique

5.2 Space definition and aggregation of objects to spaces

An IfcSpace object is created for every bridge span. The boundaries of the space are defined by a four-sided polygon whose four coordinates are the ends of an adjacent pair of transverse axes. The 3D geometry of the space is modelled as an area extruded solid using the polygon as a profile and extruding it through the full height of the bridge's bounding box. The extrusion direction is the global z direction. The span spaces are created by the operators that generate the axes and are embedded in the space hierarchy of the bridge as a whole using IfcRelContainedInSpatialStructure relationships.

A span aggregates all the objects that are fully contained in the span boundaries (box) by executing the following rule:

IF <object> is_contained_in <another object>
AND
<another object> is_a <space hierarchy object with geometry>
THEN
Space_aggregate <object> <another_object>

Example:

IF obj1 is_contained_in obj2
AND

obj2 is_a Span
THEN
Space_aggregate obj1 obj2

Figure 5. A space boundary for a span and containment of a bridge object in the span.

6 Rules for fixing occlusion problems (under development)

Bridge element	Occluded conditions	Shape creation/fix	Rule	Drawings
Primary Girder	Length is incorrect due to occlusion by the transverse beams, capping beams and abutments	Extend the length of the girder	Assume the aligned adjacent girders have the same clearance to the support axis	
Transverse beam	Boundary is unknown due to occlusion by the girders and abutments			
Deck slab plank	Thickness and edge are unknown			
Bearing	Invisible	Create solid boundary		
Plinth	Thickness is incorrect due to occlusion by the capping beams			
Abutment	Depth is unknown			
Shear key				
Column				
Lamp post				
Capping beam				
Safety barrier				