LBD and Maintenance Data Transformations

Semantic Lifting of Legacy Data

Summer School of LDAC 2024

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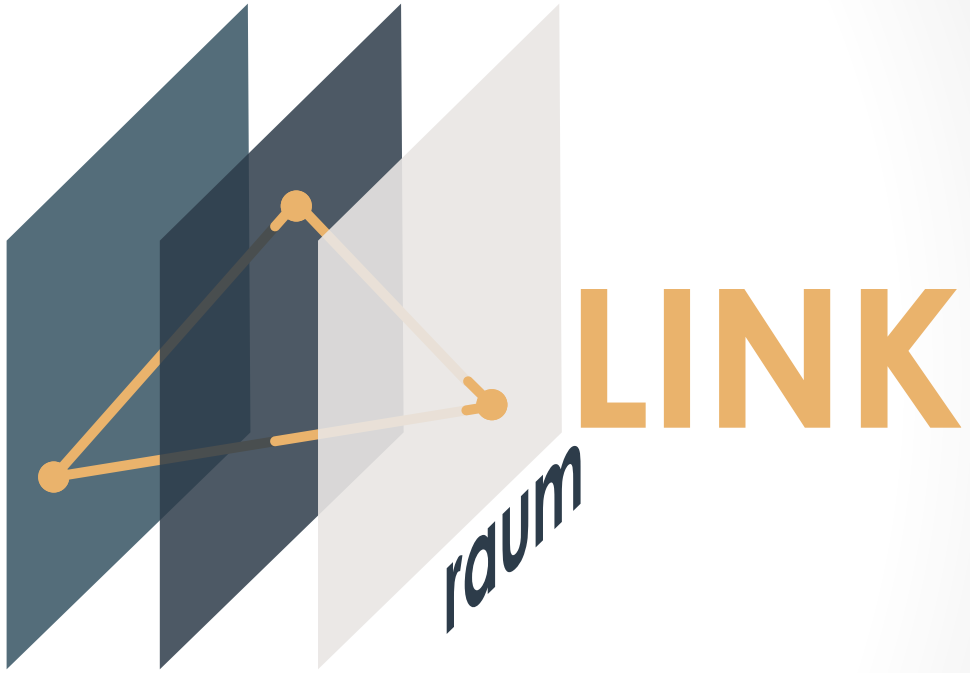
Since 2020
Research on **Linked Data for Bridge Maintenance**

Research Background

- Raumlink Project – DFG SPP 100+
- Spatially superimposing existing bridge data sets

→creating spatial links of heterogeneous data

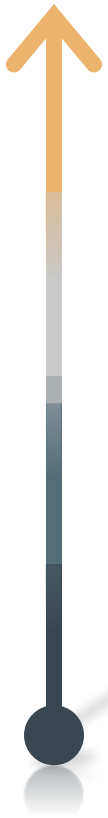
Spoiler Alert!
Next Session



Content

semantically rich LBD graphs

Hands-on: Transfer of inspection data into RDF graph



How to integrate legacy bridge data with BIM models?

How to represent legacy maintenance data in RDF?

What are the challenges of maintenance data & legacy systems?

How to enrich existing maintenance data with concepts of LBD ontologies?

How can LBD approaches help to solve them?

legacy data

Challenges of maintenance data & legacy systems

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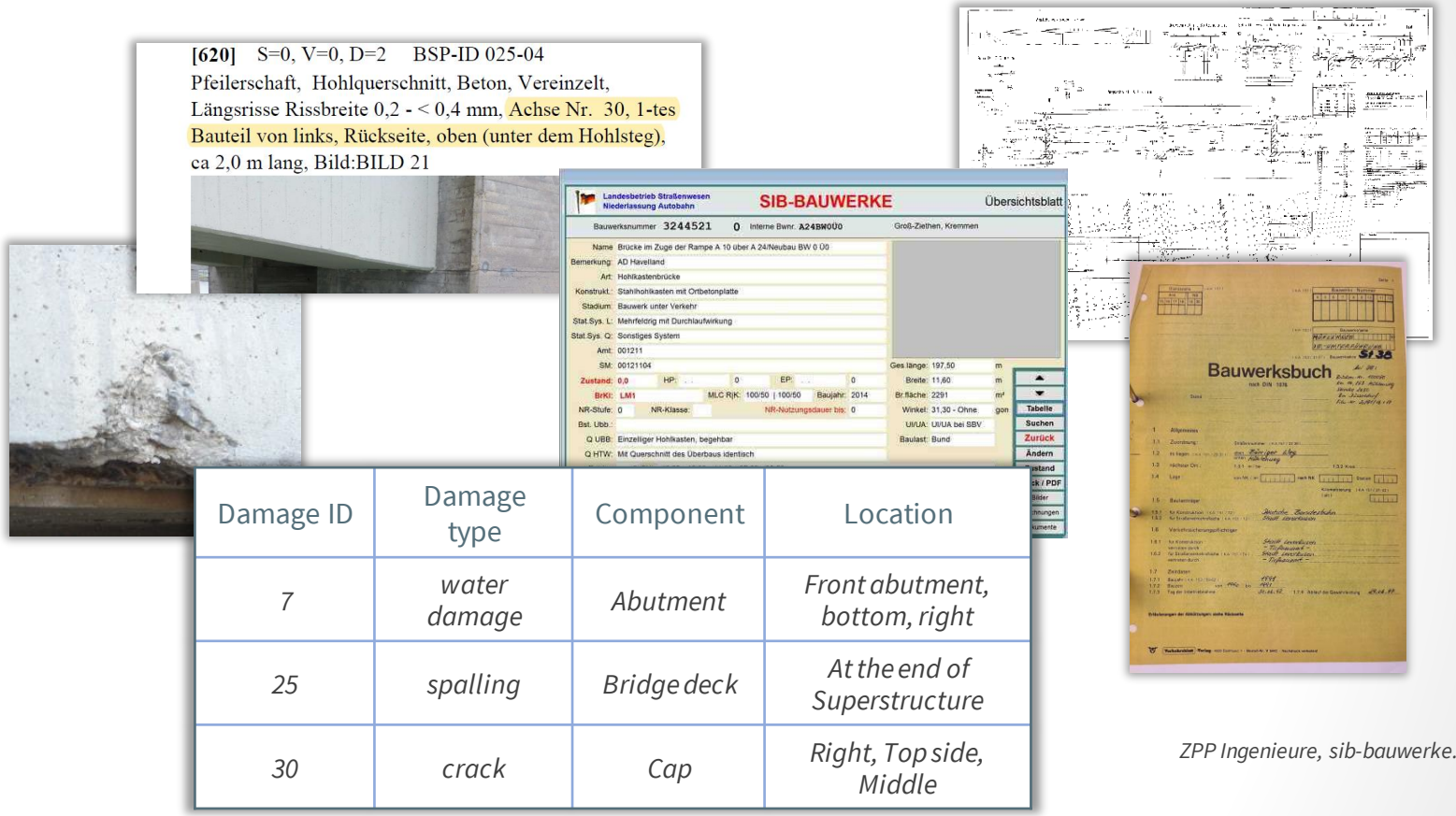
- **Large amount of data**
  - History of the asset
  - Stored in heterogeneous files
- **Dependent on implicit (human expert) knowledge**
  - Not machine-readable
  - Not intersubjective
  - No comprehensive queries
- **Stored in outdated data management systems**
  - Mainly based on natural language text
  - No support for 3D or BIM models
  - Based on relational data model and hierarchical list structures
  - Closed / unflexible data models, proprietary software



Damage ID	Damage type	Component	Location
7	*water damage*	*Abutment*	*Front abutment, bottom, right*
25	*spalling*	*Bridge deck*	*At the end of Superstructure*
30	*crack*	*Cap*	*Right, Top side, Middle*

ZPP Ingenieure, sib-bauwerke.de

Challenges of maintenance data & legacy systems

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→ **Automatization**

→ **Interlink files across formats and provenances**

→ **Enable comprehensive structured queries**

→ **Convert implicit knowledge into explicit (machine-readable) statements**

→ **Transformation for "semantic lifting"**

- → **Processing of textual data**
- → **Integration with 3D/BIM models**
- → **Implementing object-orientation**
- → **Using open data format/standards**

Linked (Building) Data approaches

- Automatization
- Enable comprehensive structured queries
- Interlink files
- Convert implicit knowledge into explicit (machine-readable) statements

→ Transformation for “semantic lifting”

- Integration with 3D/BIM models
- Processing of textual data
- Implementing object-orientation
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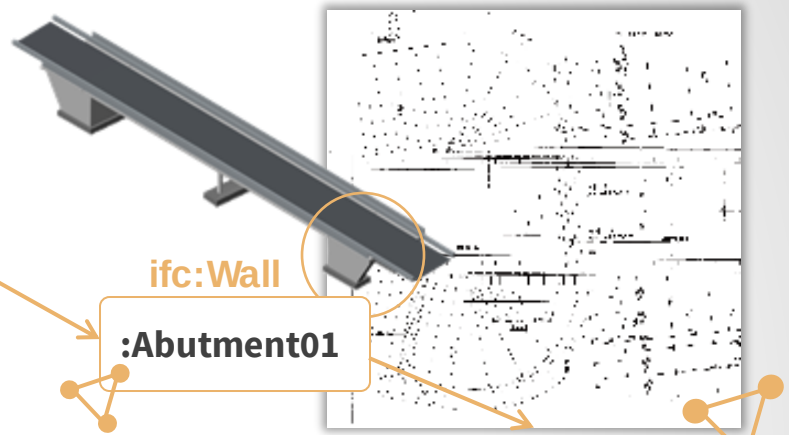

brot:Component

:ComponentX

ifc:Wall

:Abutment01

dot:hasDamage

:Damage21

Predicate	Object (Value)
rdf:type	asb:Schaden **(Damage);**
asb:Schaden-ID-Nummer **(Damage ID)**	**21;**
asb:Schaden_Schaden **(Damage type)**	asbkey:ArtSchaden_Wasserschaden **(Water damage);**
asb:ASBING13_Bauteil **(Component)**	asbkey13:130011910000000_Widerlager **(Abutment);**
asb:Schaden_Ortsangabe **(Location description)**	asbkey:Ortsangabe_WiderlagerVorn **(Abument, Front)**

→ Using metatdata ontology to represent documents (ICDD)

→ Using LBD ontologies to represent geometry data

→ Using LBD ontologies for improved data structure

→ Representing data in RDF

Linked (Building) Data approaches

- Automatization
- Enable comprehensive structured queries
- Interlink files
- Convert implicit knowledge into explicit (machine-readable) statements

→ Transformation for “semantic lifting”

- Integration with 3D/BIM models
- Processing of textual data
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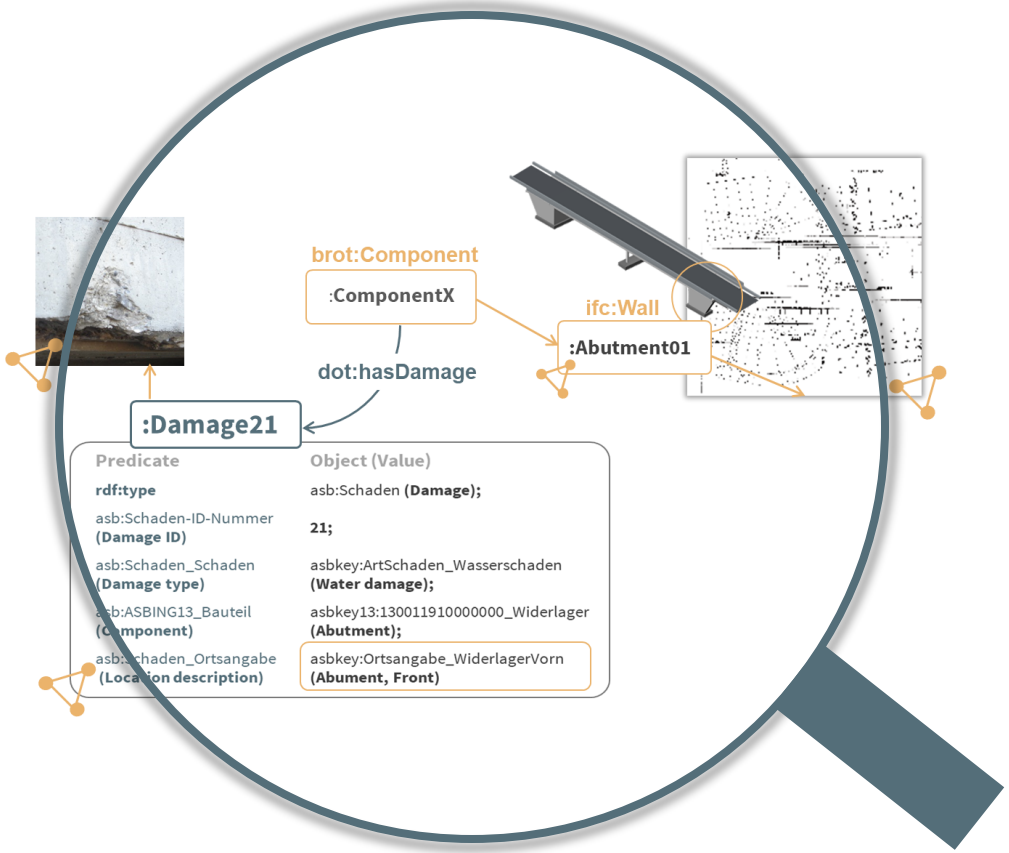

→ Automize process (e.g., using rdflib, R2ML..)

→ Query dataset using SPARQL

→ Using meta data ontology to represent documents (ICDD)

→ Using LBD ontologies to represent geometry data

→ Using LBD ontologies for improved data structure

→ Representing data in RDF

Represent legacy maintenance data as RDF graphs

Represent legacy maintenance data as RDF graphs

- **Analyse legacy data**
  - Underlying data model available? yes
    - Use existing data model as ontology/vocabulary
    - Extract structure from instance data (e.g., R2ML/DM[1])
  - Type of implementation (relational database, XML file, PDF, text file etc.) & access points

    → constrains technical processing options
- **Define purpose of transformation**
  - Linking of maintenance documents (pictures, reports etc.)
  - Adjusting/changing inner structure/content

1: https://www.w3.org/TR/rdb-direct-mapping/

Defined national data model

Damage ID	Damage type	Component	Location
7	*water damage*	*Abutment*	*Front abutment, bottom, right*
25	*spalling*	*Bridge deck*	*At the end of Superstructure*
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Relational database with implicit textual information

Closed software, no API

German Bridge Maintenance Data

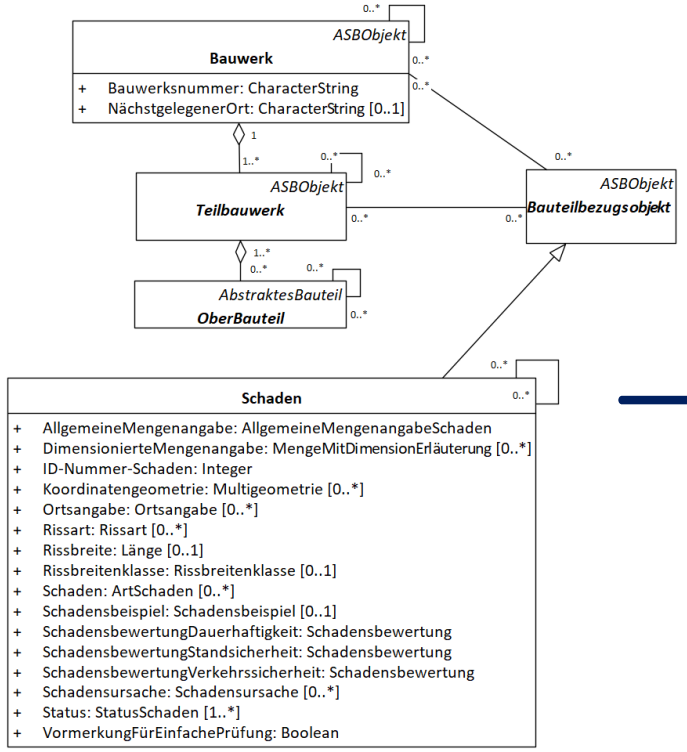
Represent legacy maintenance data as RDF graphs

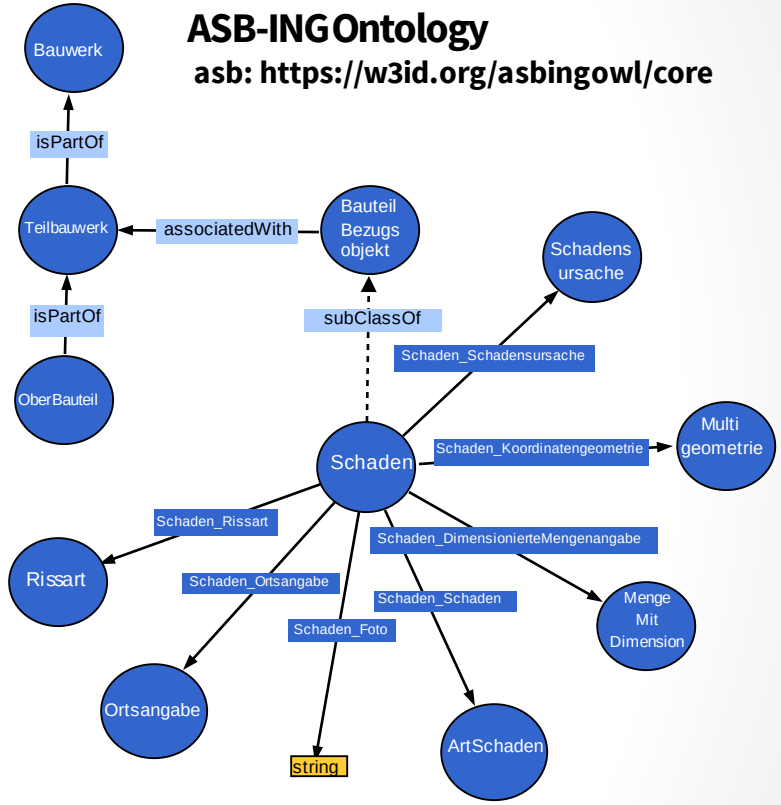
Ontology creation

UML model

Anweisung Straßeninformationsbank, Teilsystem Bauwerksdaten

[Instruction for the Road Information Database, subsystem structural data]





ASB-ING 2013, BMDV (BASt), Landesamt für Straßenbau und Verkehr Mecklenburg-Vorpommern

Represent legacy maintenance data as RDF graphs

Instance data transformation

Damage ID	Damage type	Component	Location
21	*water damage*	*Abutment*	*Front abutment, bottom, left*
25	*spalling*	*Bridge deck*	*At the end of Superstructure*
30	*crack*	*Cap*	*Right, Top side, Middle*

database table

ASB-ING Ontology

Tranformation process: python – rdflib, sqlite3
[options: R2ML, other RDF and SQL packages]

Subject :W30EL9G_Schaden

Predicate	Object (Value)
rdf:type	asb:Schaden **(Damage);**
asb:Schaden-ID-Nummer **(Damage ID)**	**21;**
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rdf graph

Enrich legacy data with concepts of LBD ontologies

Enrich legacy data with LBD ontology concepts

Analyse legacy content

Subject :W30EL9G_Schaden

Predicate	Object (Value)
rdf:type	asb:Schaden **(Damage);**
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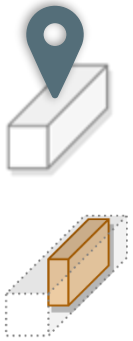
Damage data

Describes component

Describes component location

Describes damage location



Enrich legacy data with LBD ontology concepts

Application of existing ontologies

Damage data

Damage Topology Ontology (DOT)

dot: https://w3id.org/dot#

- Enables component-based damage documentation
- Offers Damage Area, Element, and Pattern definition

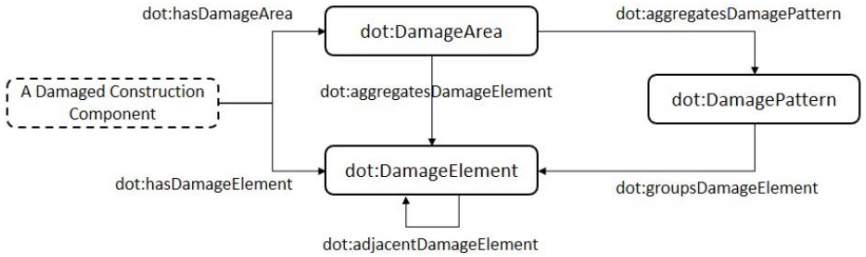


Fig. 1: Overview of the topological classes and object properties defined by DOT.

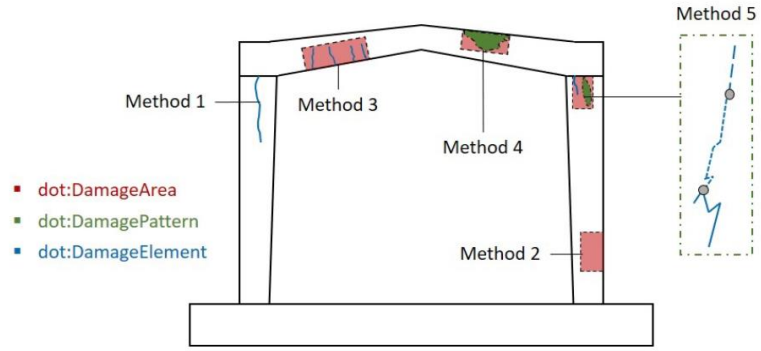


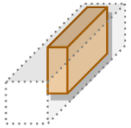
Fig. 2: A structural frame with examples of the five methods to define damages in DOT

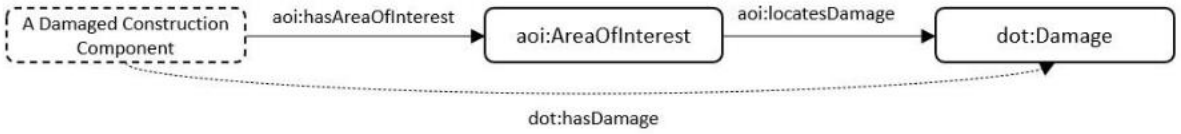
Source:
Hamdan, A.-H., Bonduel, M., & Scherer, R. J. (2019).
An ontological model for the representation of damage to constructions.
Proceedings of the 7th Linked Data in Architecture and Construction Workshop - (LDAC), 64–77.

Enrich legacy data with LBD ontology concepts

Application of existing ontologies

Damage Location





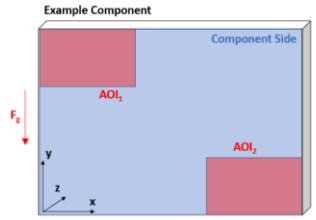
Area of Interest Ontology (AOI)

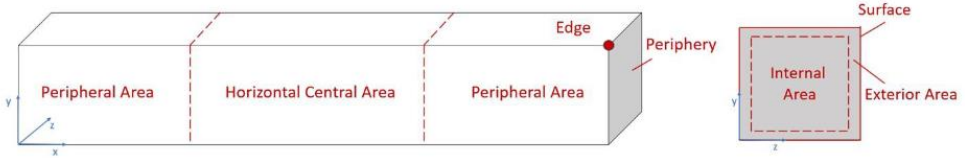
aoi: https://w3id.org/aoi#

- Enables the definition of subareas of component sides

→ representing the location of the damage

- Split side into 3 parts per direction





Source:
Hamdan, A.-H., & Scherer, R. J. (2020). Areas of Interest—Semantic description of component locations for damage assessment. *EG-ICE 2020 Proceedings: Workshop on Intelligent Computing in Engineering*.

Enrich legacy data with LBD ontology concepts

Application of existing ontologies

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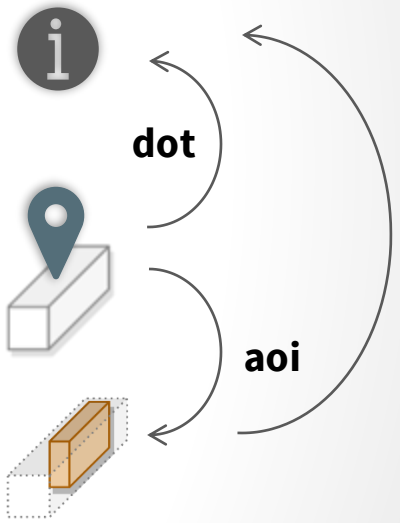
Damage data

Describes component

Describes component location

Describes damage location



Enrich legacy data with LBD ontology concepts

Application of existing ontologies

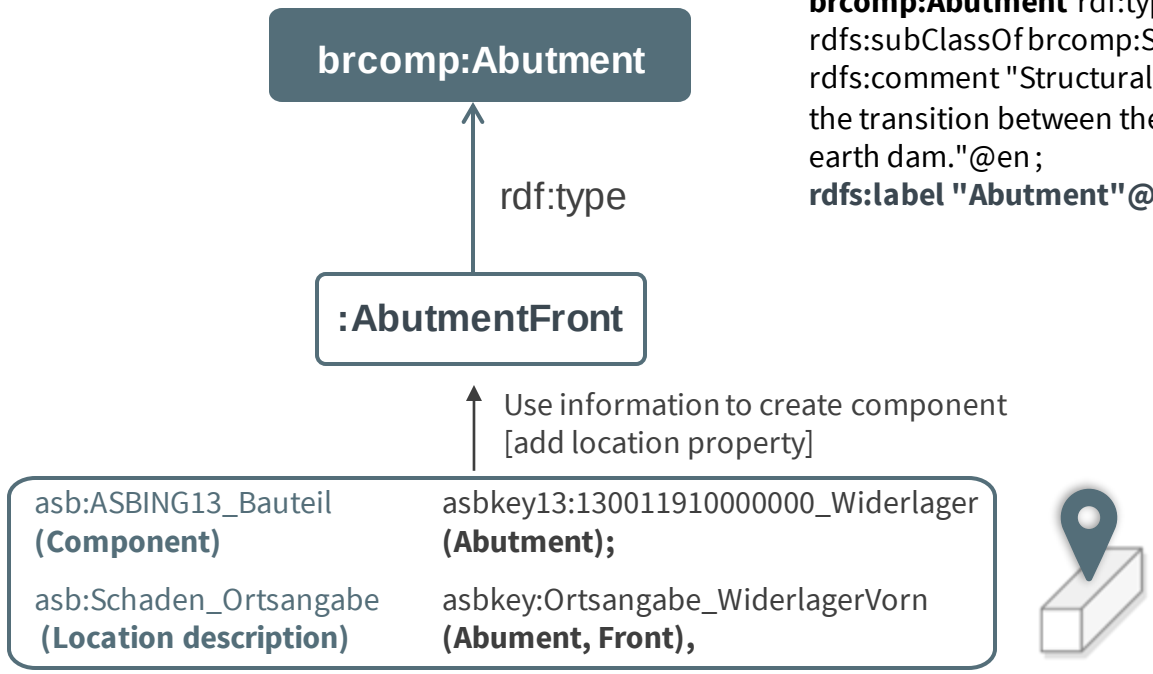
Represent component

OPTION 1

- Use BOT / BROT Ontology
- bot: https://w3id.org/bot#

For bridges:

- brot: https://w3id.org/brot#
- brcomp: https://w3id.org/brcomp#
- Create new component based on information of the damage documentation
- Choose general class or specific component type class (manually or based on mapping)



brcomp:Abutment rdf:type owl:Class ;
rdfs:subClassOf brcomp:SubStructureComponent ;
rdfs:comment "Structural component that creates the transition between the bridge structure and the earth dam."@en ;
rdfs:label "Abutment"@en ,"Widerlager"@de .

Hamdan, A.-H., & Scherer, R. J. (2020). Integration of BIM-related bridge information in an ontological knowledgebase. *Proceedings of the 8th Linked Data in Architecture and Construction Workshop - (LDAC)*, 77–90.

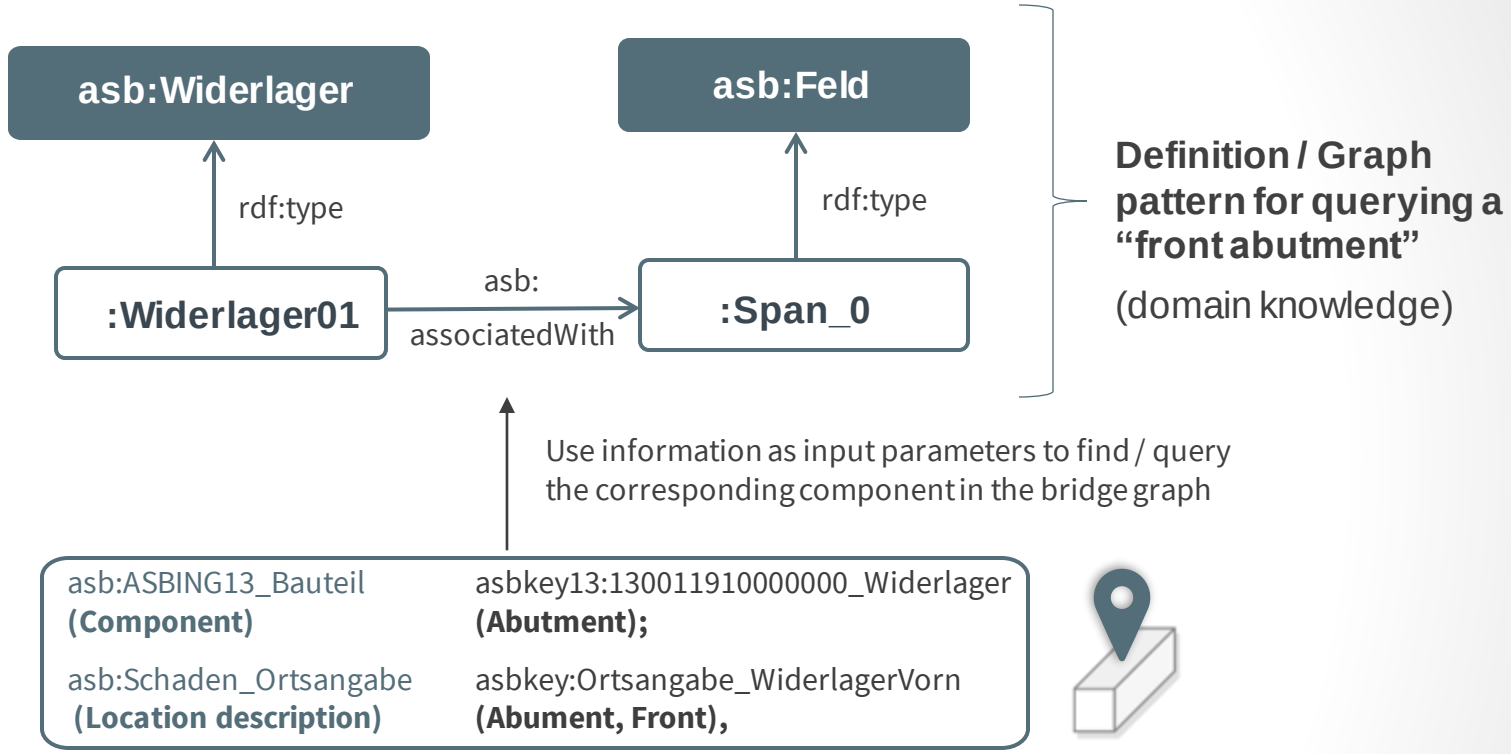
Enrich legacy data with LBD ontology concepts

Application of existing ontologies

Represent component

OPTION 2

- Use component information to find existing component in converted maintenance graph
- Via SPARQL query



Enrich legacy data with LBD ontology concepts

Application of existing ontologies

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:Widerlager01

Enrich legacy data with LBD ontology concepts

Application of existing ontologies

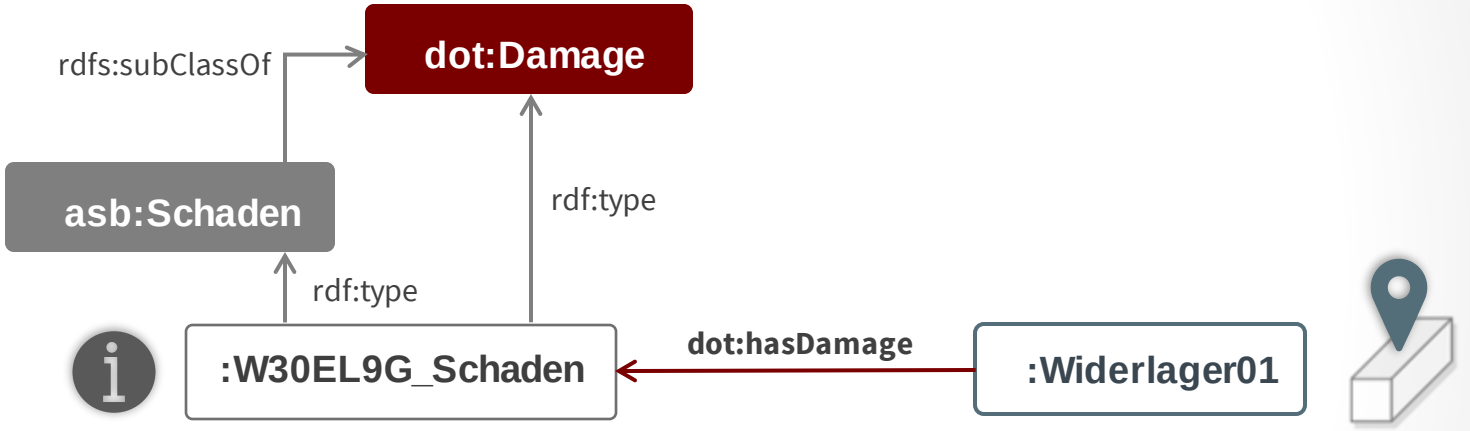
Represent and link Damage

OPTION 1

- Declare original damage element additionally as dot:Damage

OPTION 2

- Declare legacy damage class as **rdfs:subClassOf** dot:Damage
- Ontology alignment



Enrich legacy data with LBD ontology concepts

Application of existing ontologies

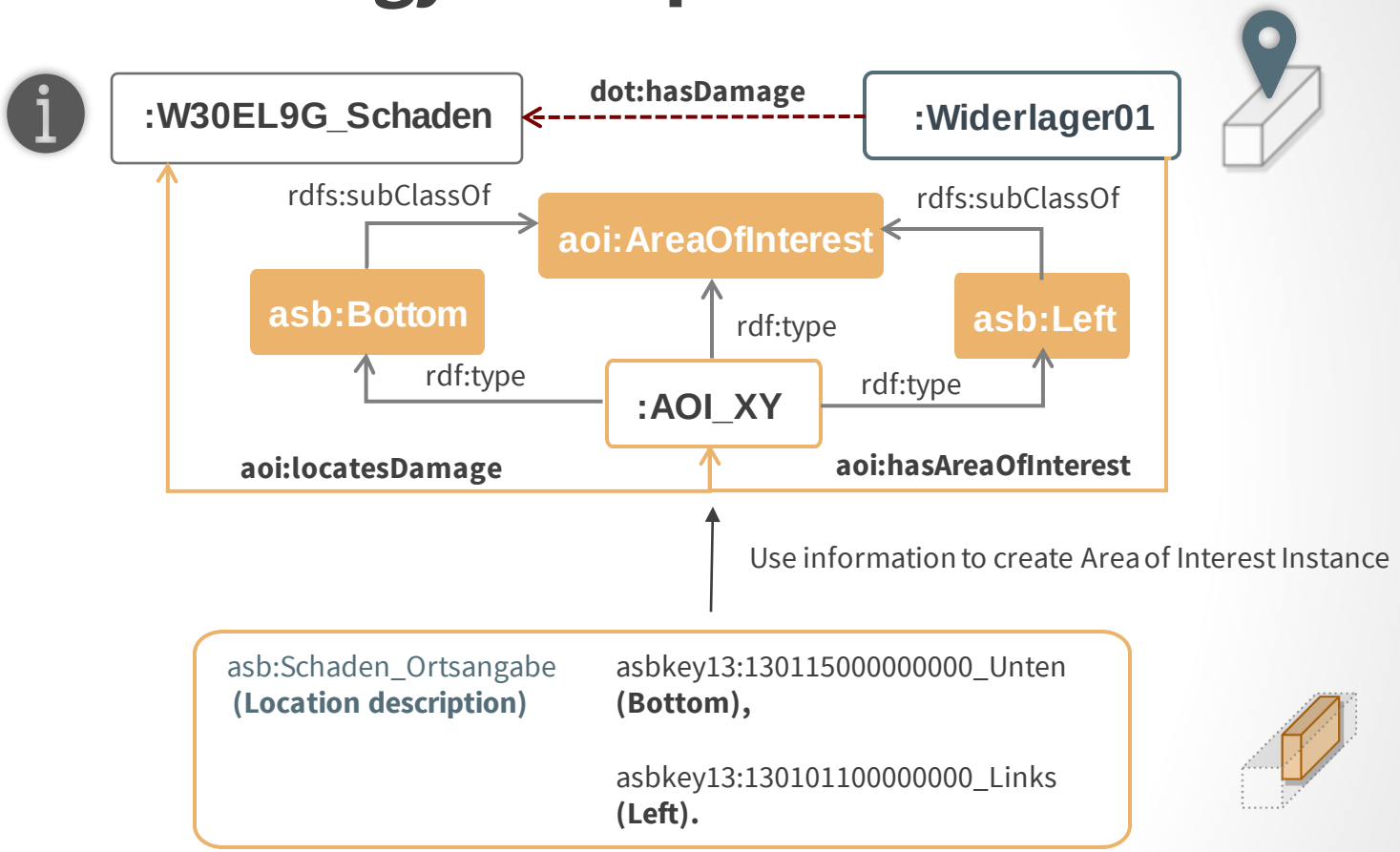
Represent and link Damage Area

OPTION 1

- Create AreaOfInterest Instance, and declare it using the legacy location classes and the main AOI class

OPTION 2

- Declare legacy location classes as **rdfs:subClassOf** aoi:AreaOfInterest or subclasses of it (e.g., aoi:Bottom, aoi:PheriperalArea)
- Ontology alignment



Enrich legacy data with LBD ontology concepts

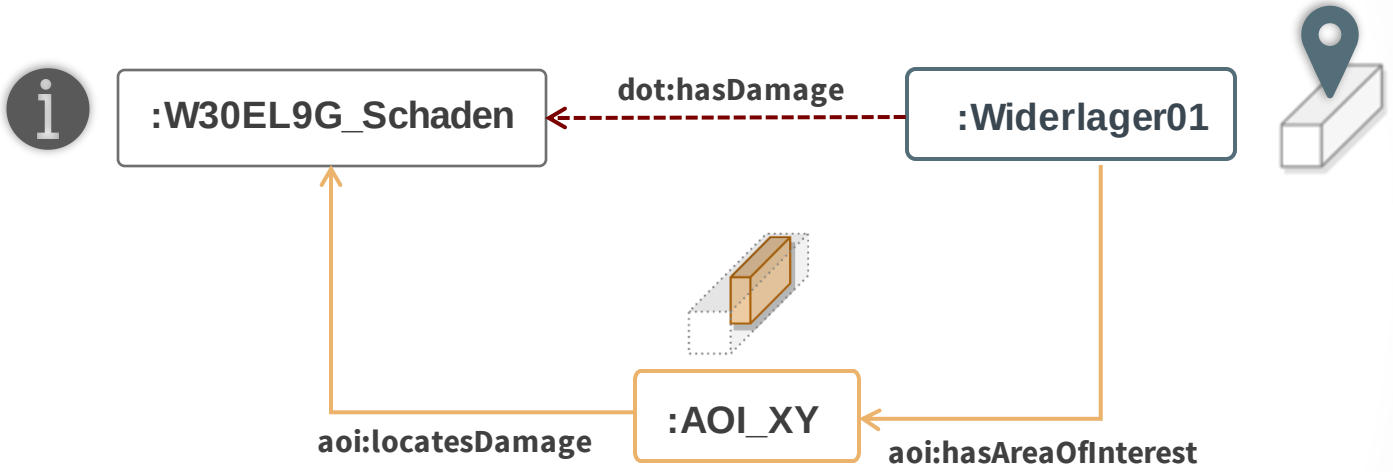
Application of existing ontologies

- Implemented Object-oriented damage documentation
- Converted unstructured collection of location descriptions in explicit semantic links between component and damage

→ **Enabled object-based and area-specific queries for damage occurrence**

→ **Better data basis for assessment of individual component condition**

→ **Basis for linking to Geometry model and geometric representation of damage**



Integrate legacy data with BIM models

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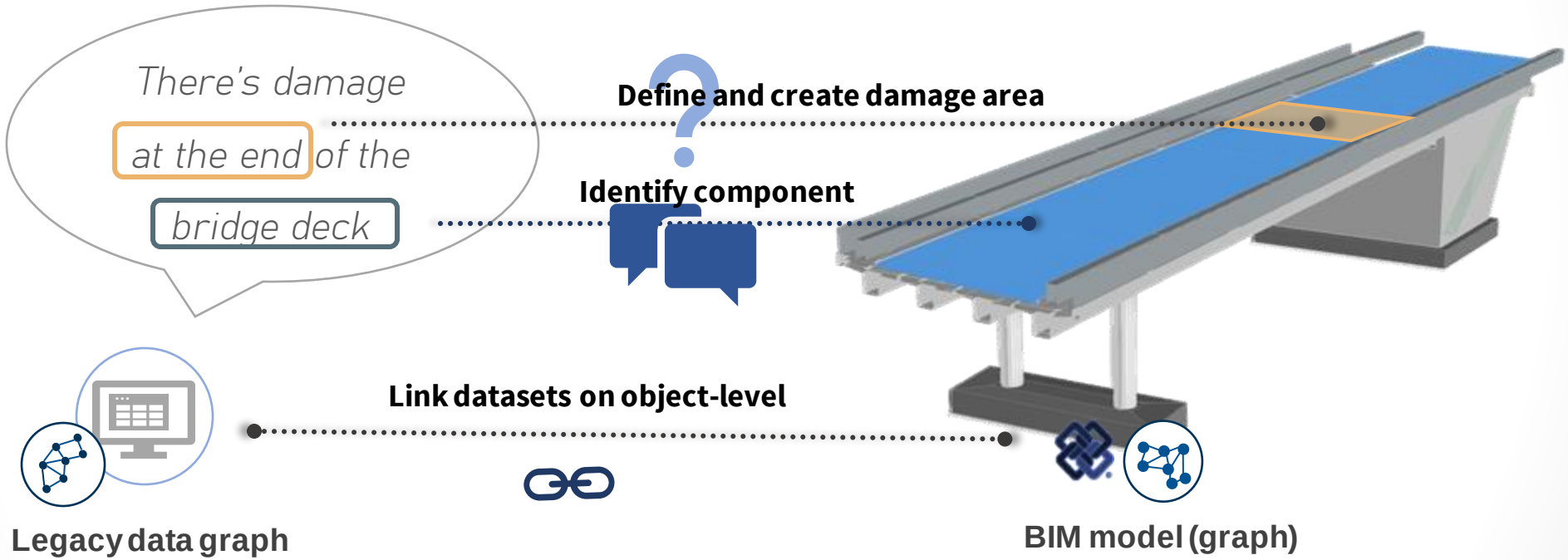
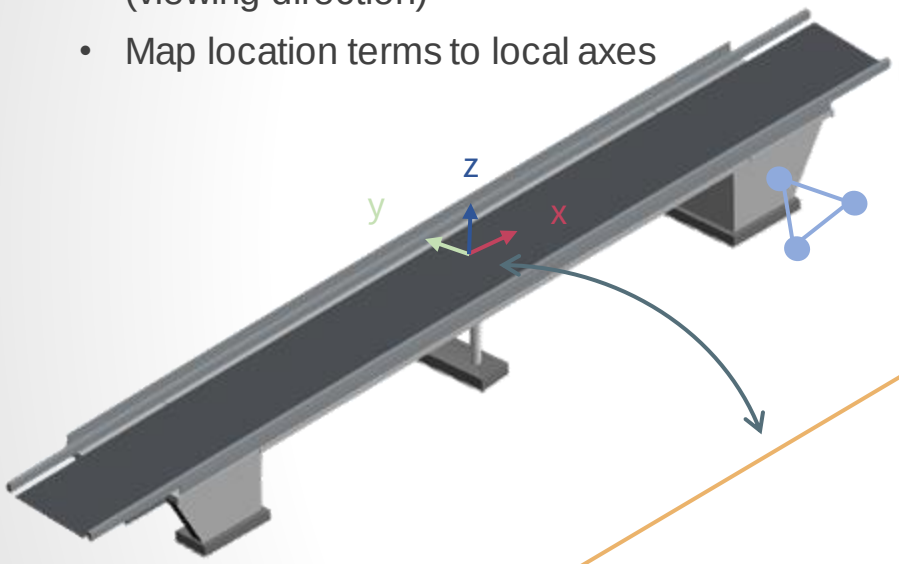


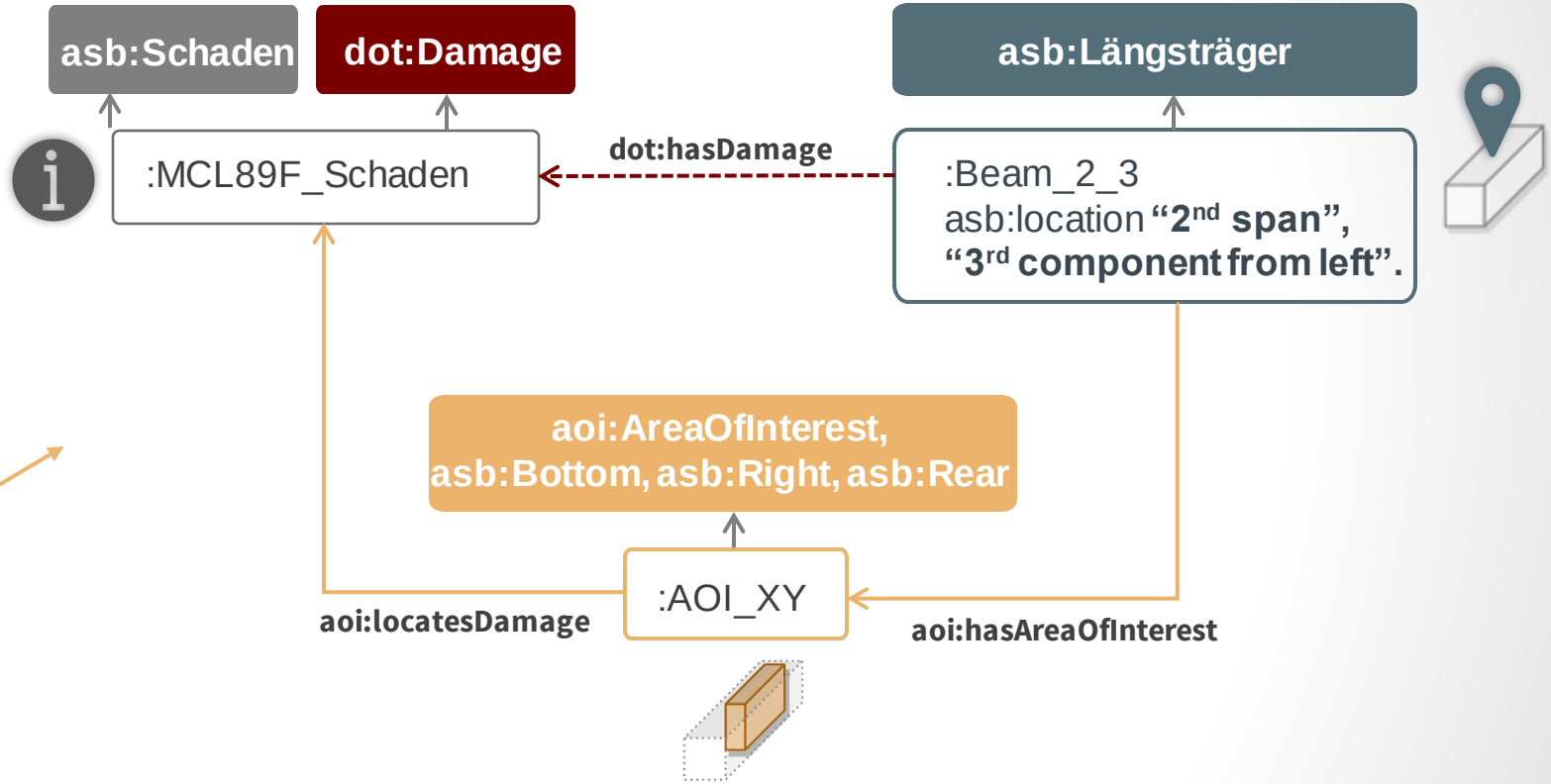
Integrate legacy data with BIM models

Link components to IFC model elements

- Align spatial reference systems of BIM model and legacy data (viewing direction)
- Map location terms to local axes



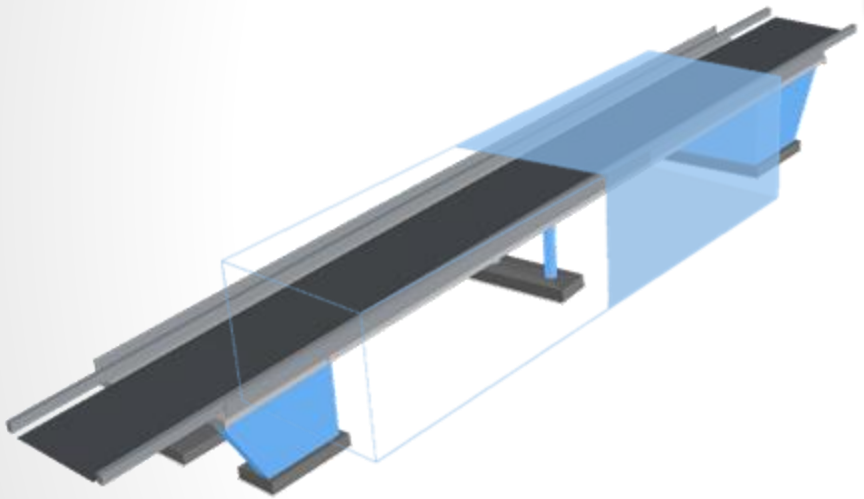
https://github.com/Design-Computation-RWTH/IFCtoLBD

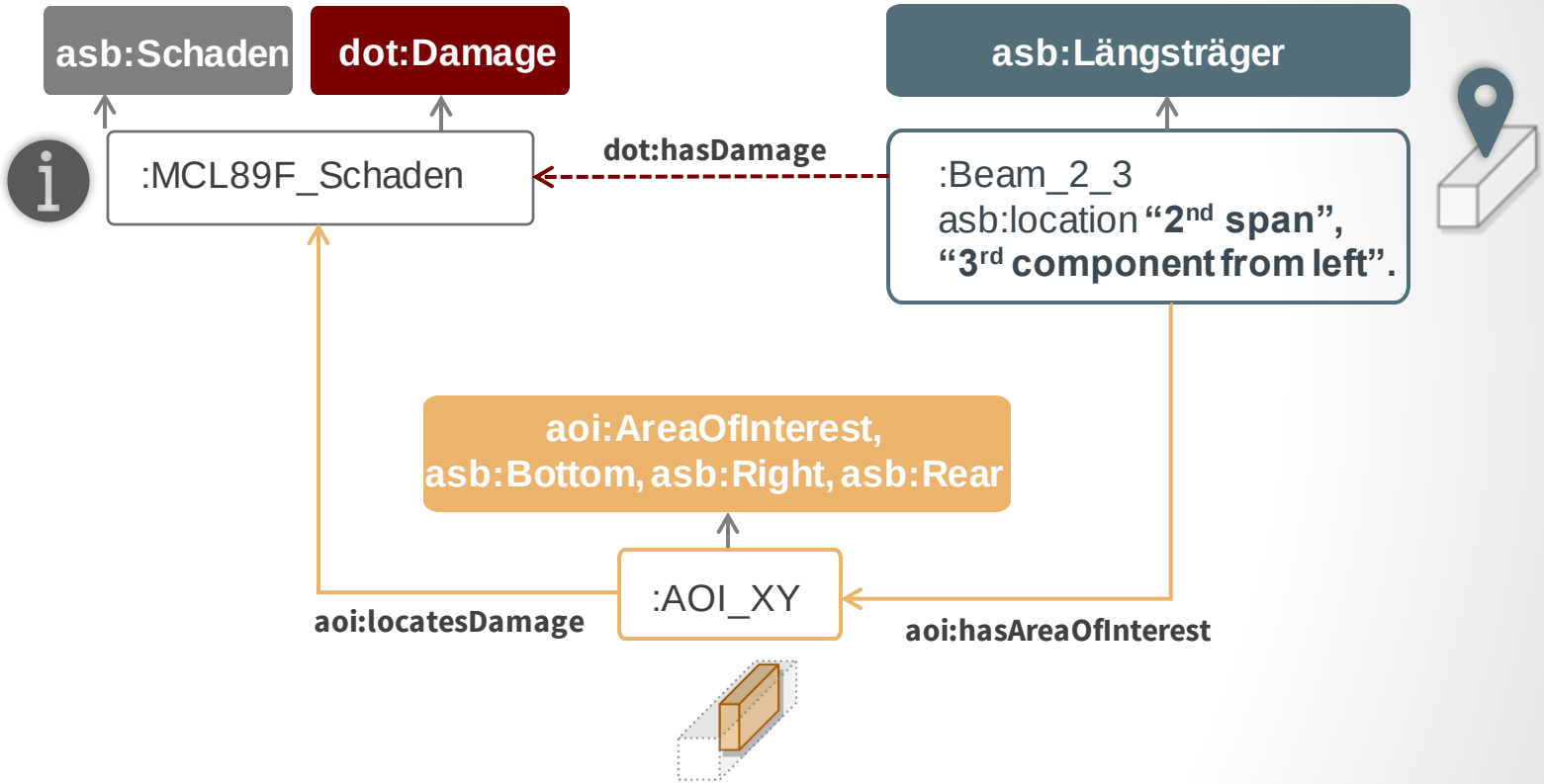


Integrate legacy data with BIM models

Link components to IFC model elements

- Define abstract spatial concepts (zones) as bounding boxes in BIM model (resp. store the corresponding bounding value)

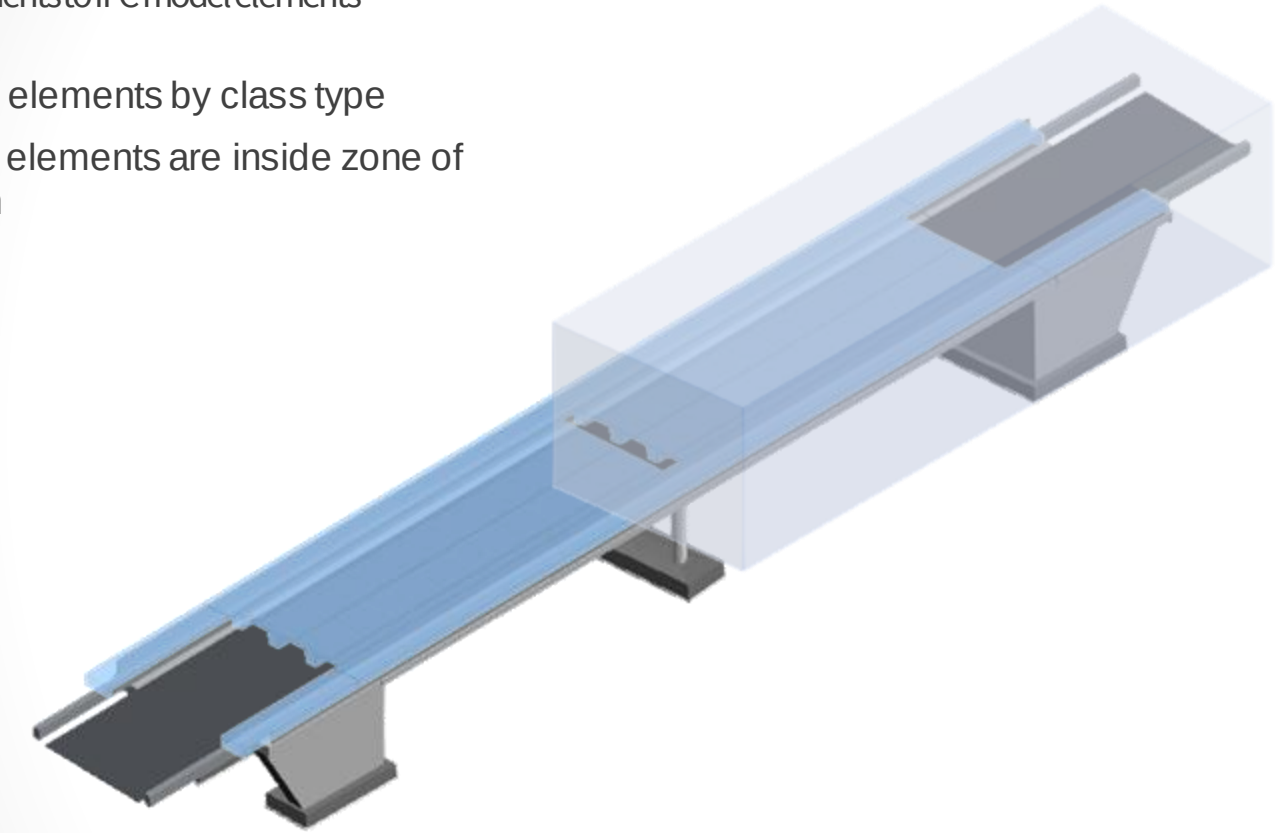


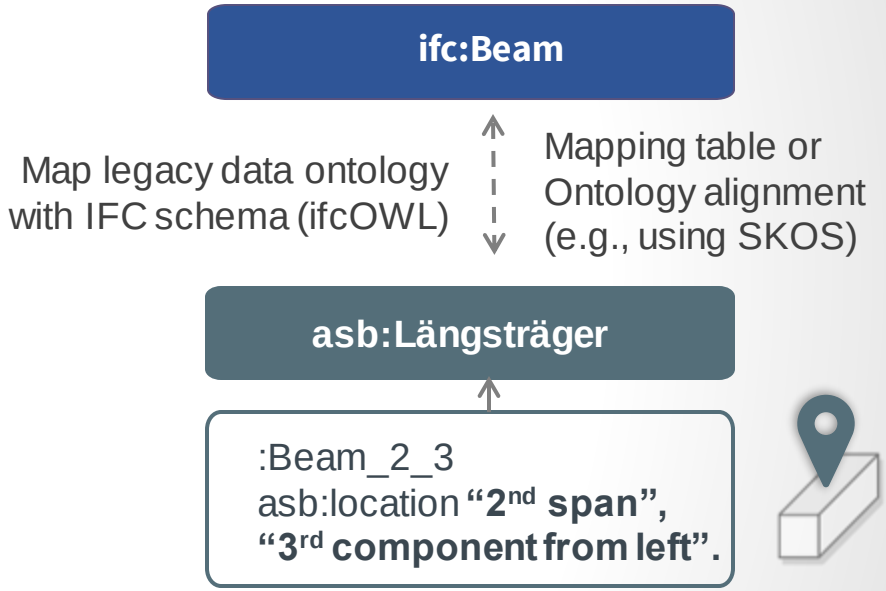


Integrate legacy data with BIM models

Link components to IFC model elements

- Filter for elements by class type
- Check if elements are inside zone of 2nd span

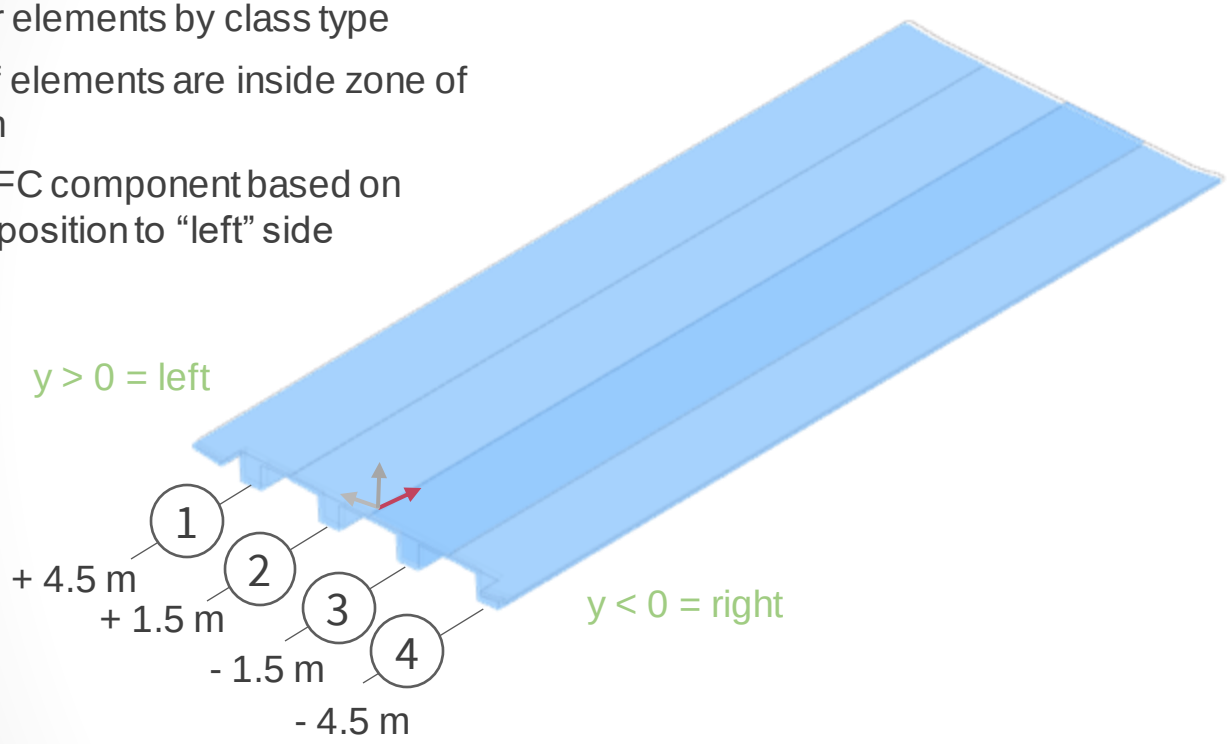


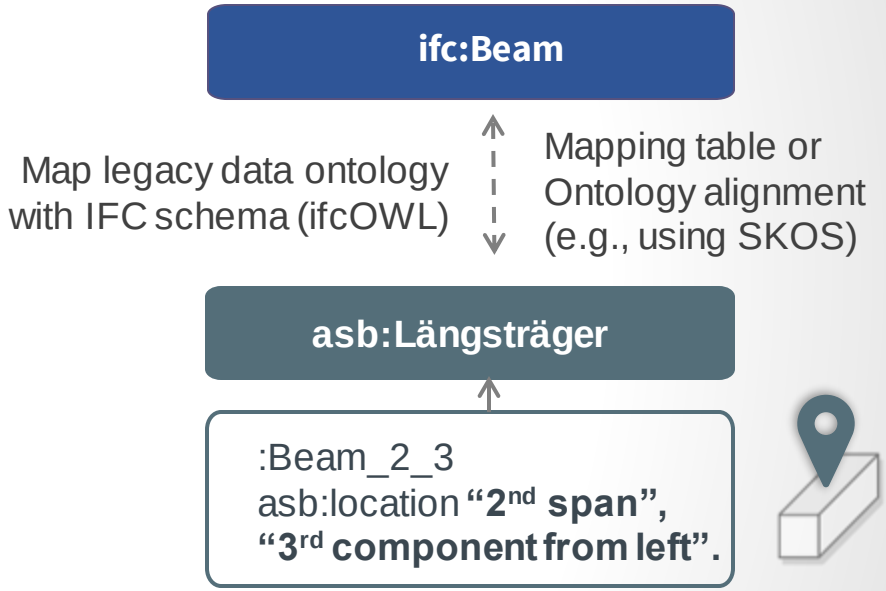


Integrate legacy data with BIM models

Link components to IFC model elements

- Filter for elements by class type
- Check if elements are inside zone of 2nd span
- Select IFC component based on relative position to “left” side

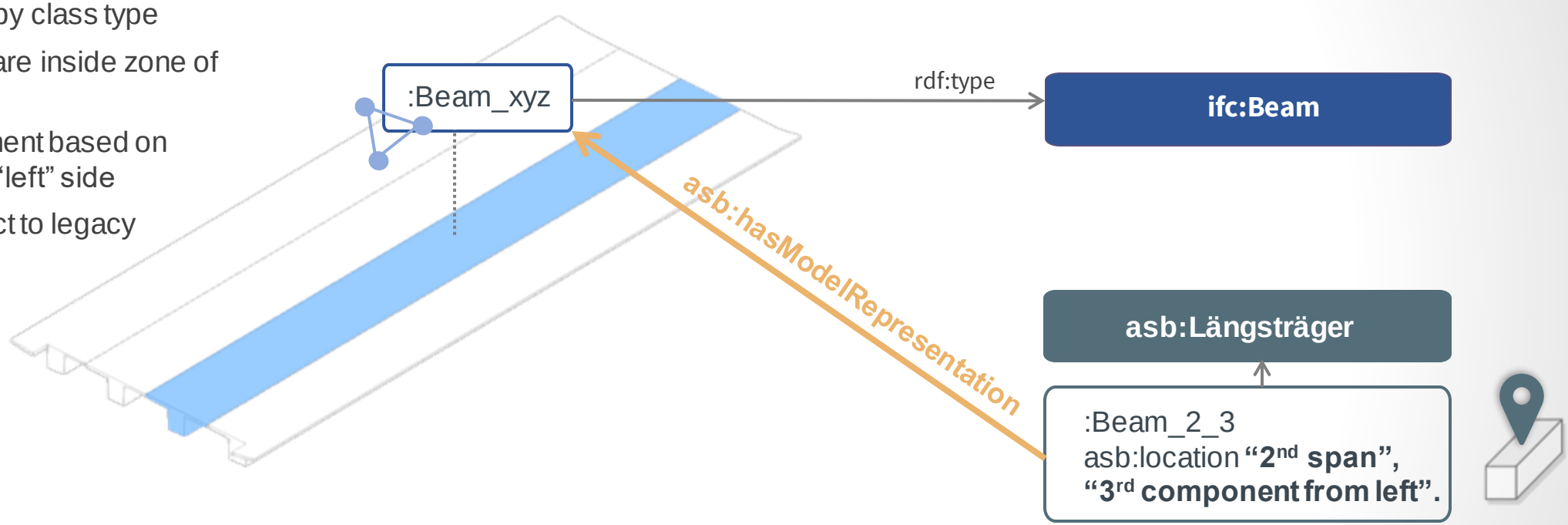




Integrate legacy data with BIM models

Link components to IFC model elements

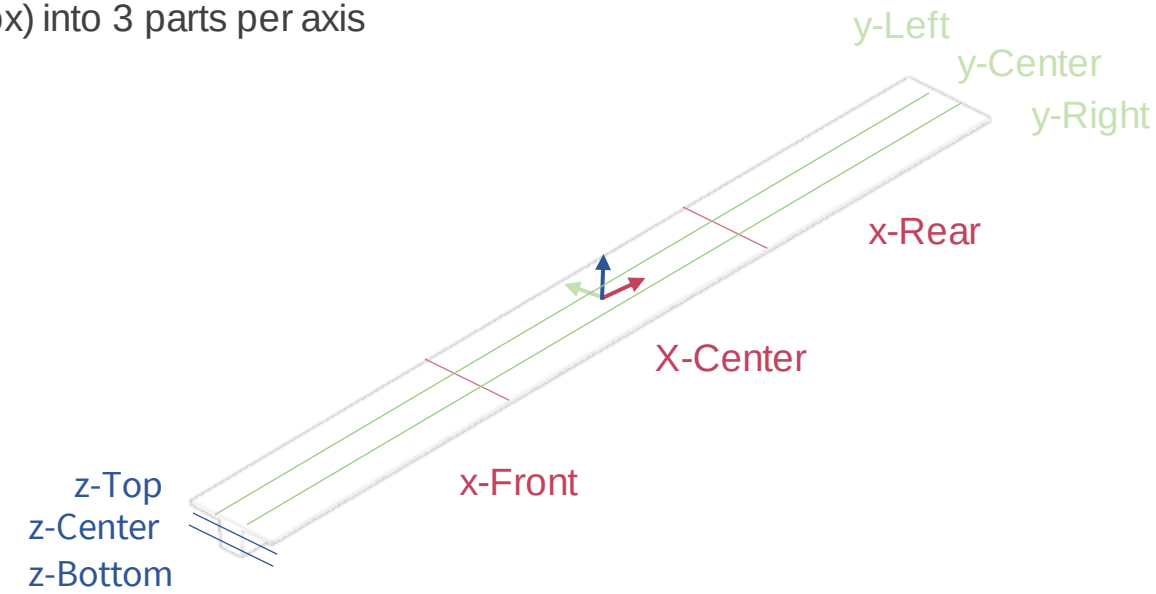
- Filter for elements by class type
- Check if elements are inside zone of 2nd span
- Select IFC component based on relative position to “left” side
- Link ifc Beam object to legacy data beam object

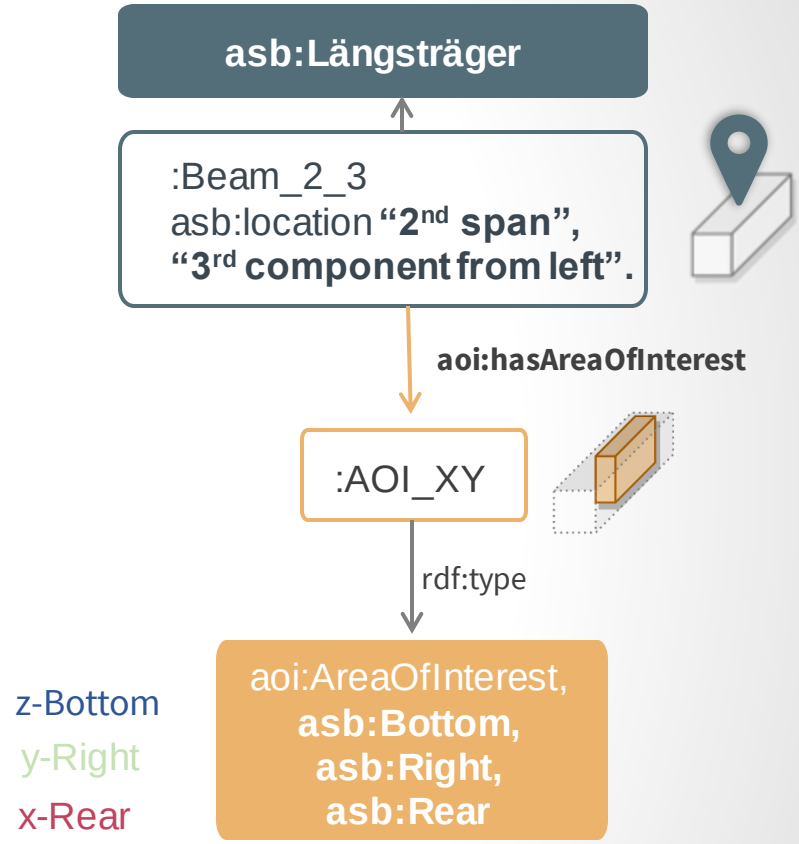


Integrate legacy data with BIM models

Create Damage Area Object in BIM model

- Split IFC element (surrounding bounding box) into 3 parts per axis

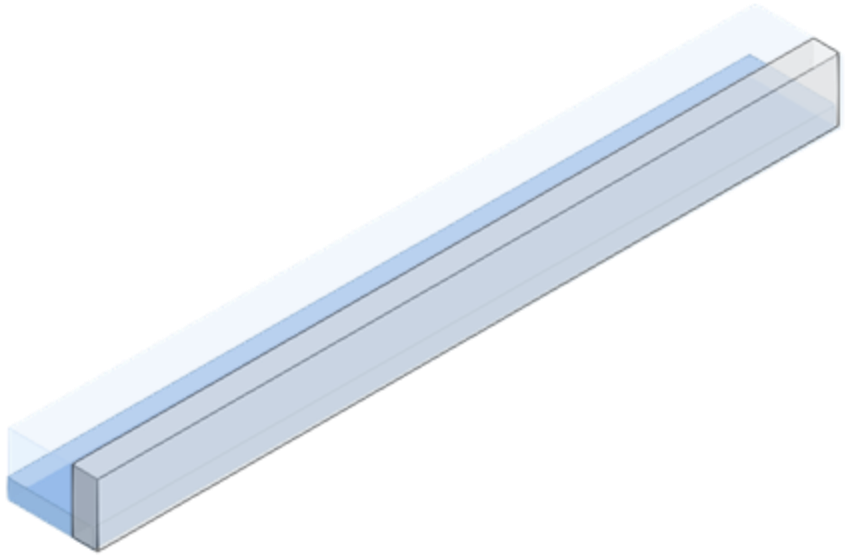


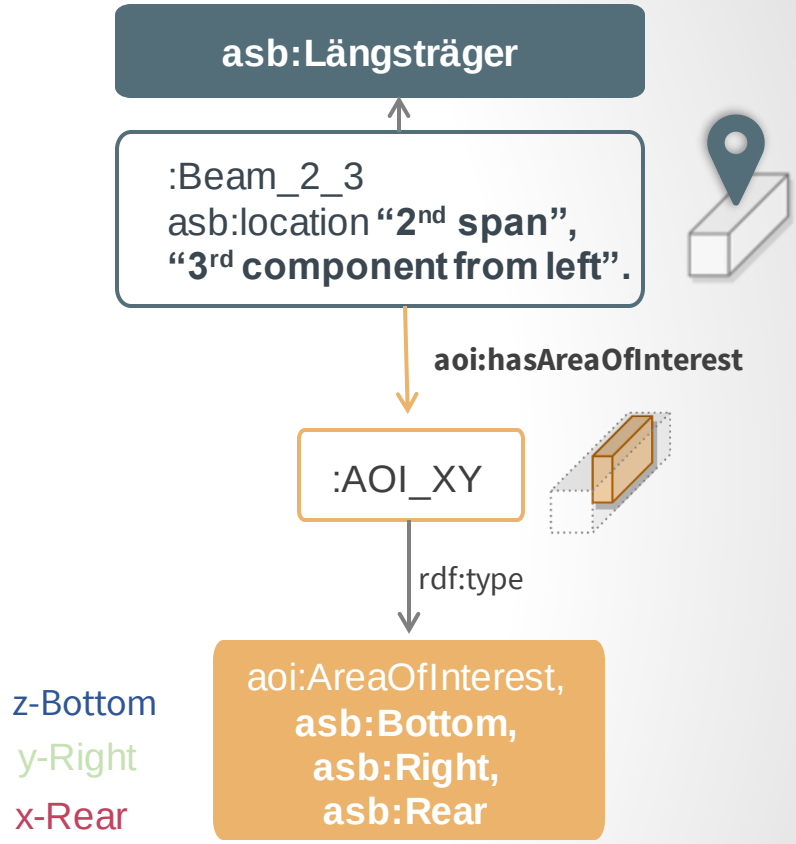


Integrate legacy data with BIM models

Create Damage Area Object in BIM model

- Intersect respective sub-parts with each other

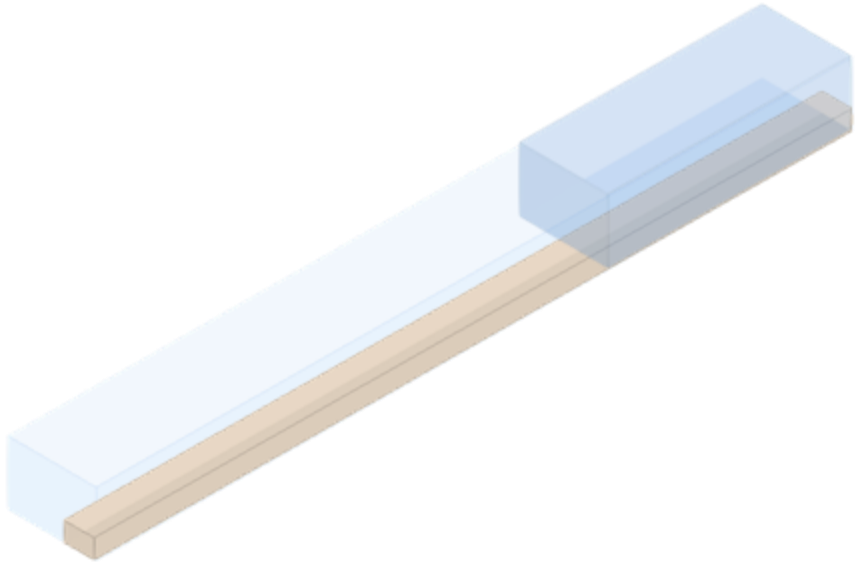


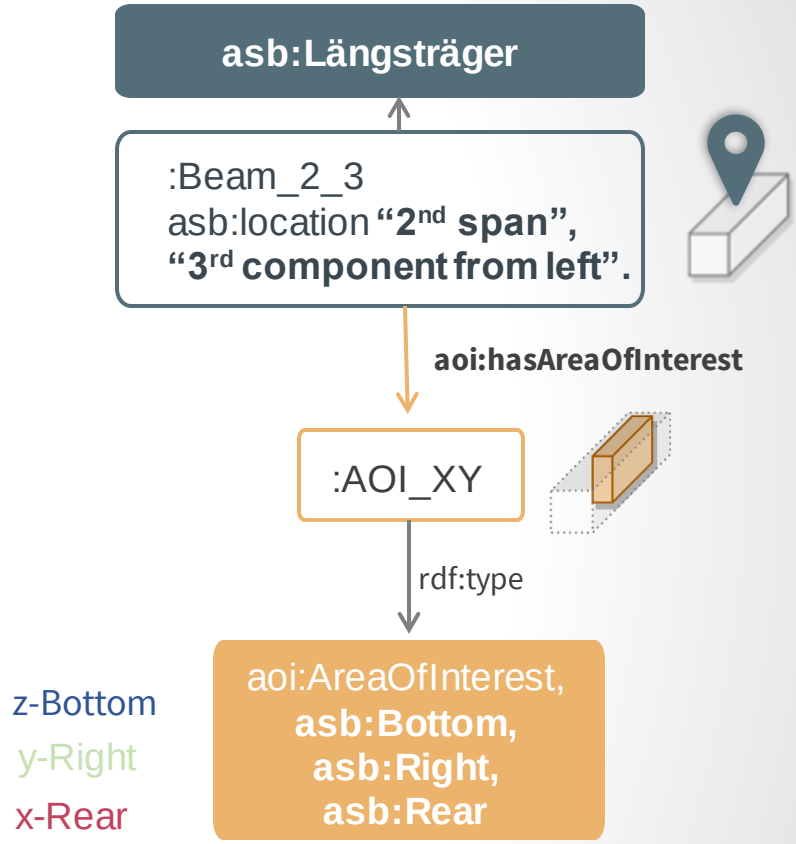


Integrate legacy data with BIM models

Create Damage Area Object in BIM model

- Intersect respective sub-parts with each other

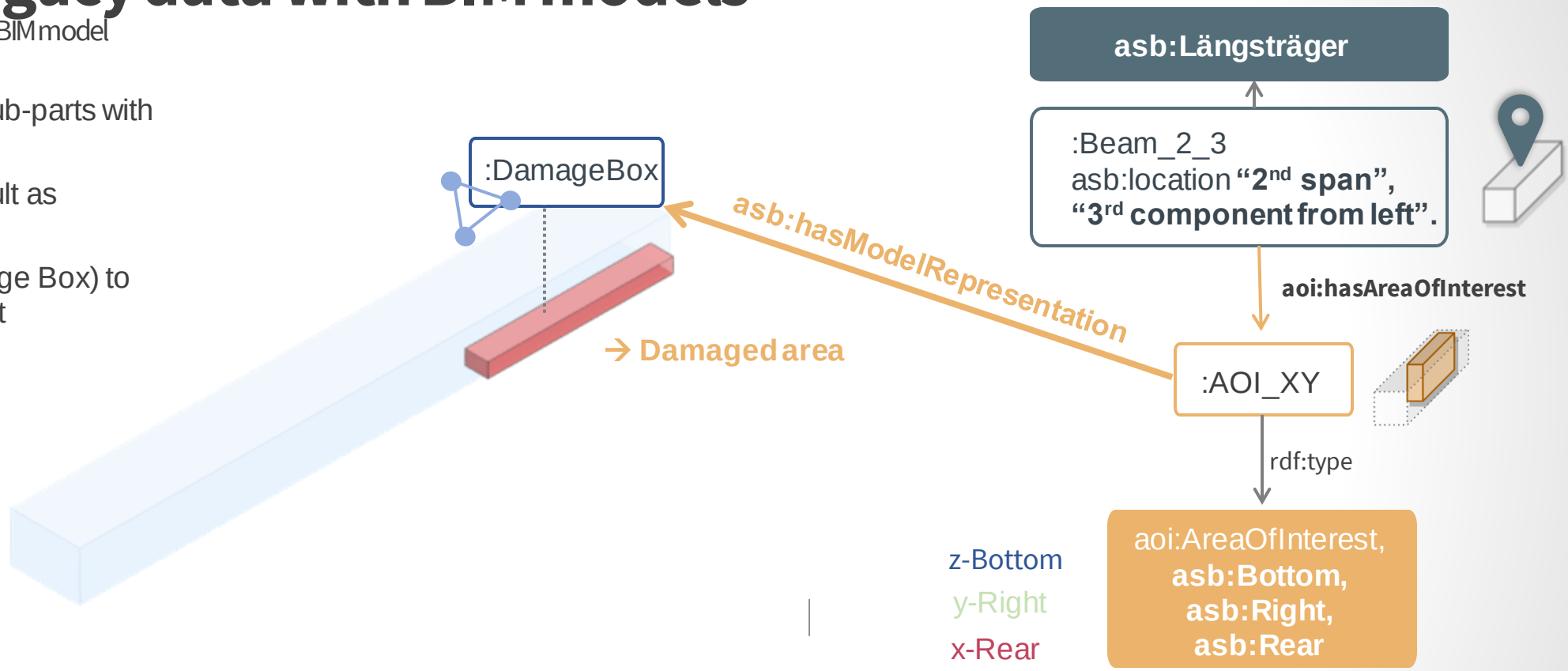




Integrate legacy data with BIM models

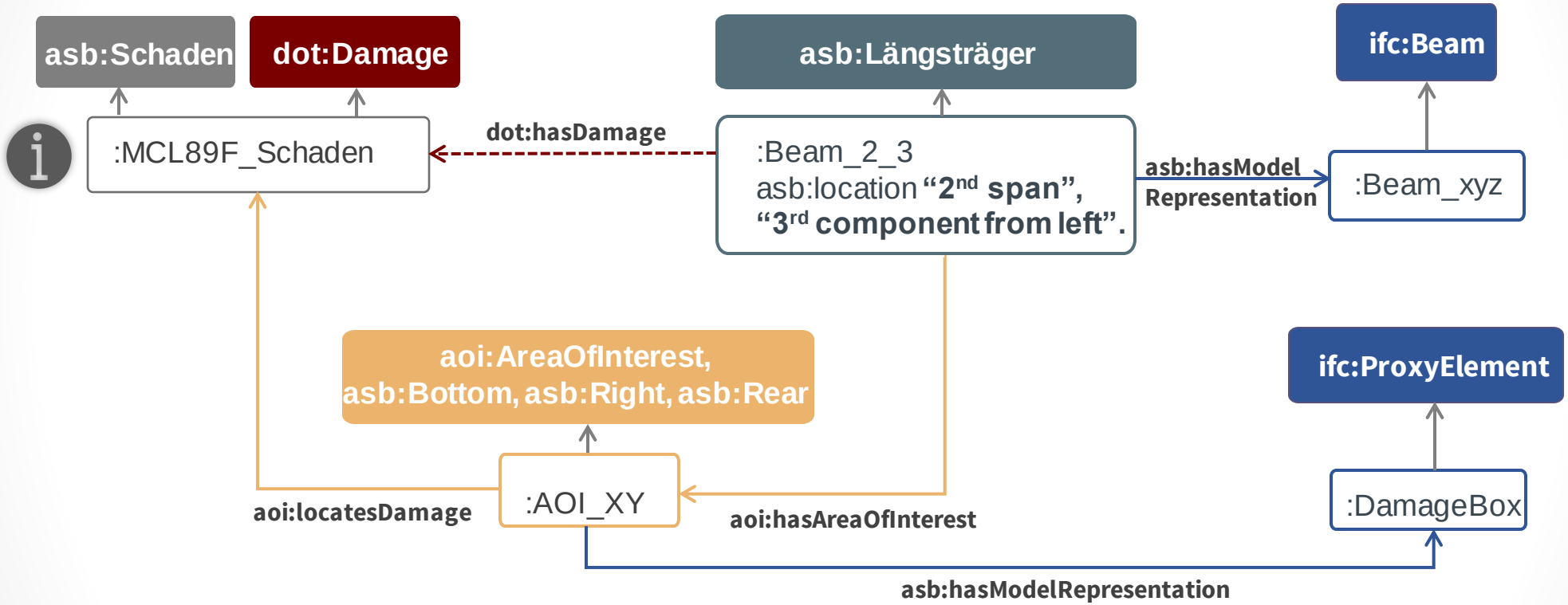
Create Damage Area Object in BIM model

- Intersect respective sub-parts with each other
- Store intersection result as Bounding Box (Proxy)
- Link Geometry (Damage Box) to Area of Interest Object



Integrate legacy data with BIM models

Interlinked structure of legacy maintenance and BIM data

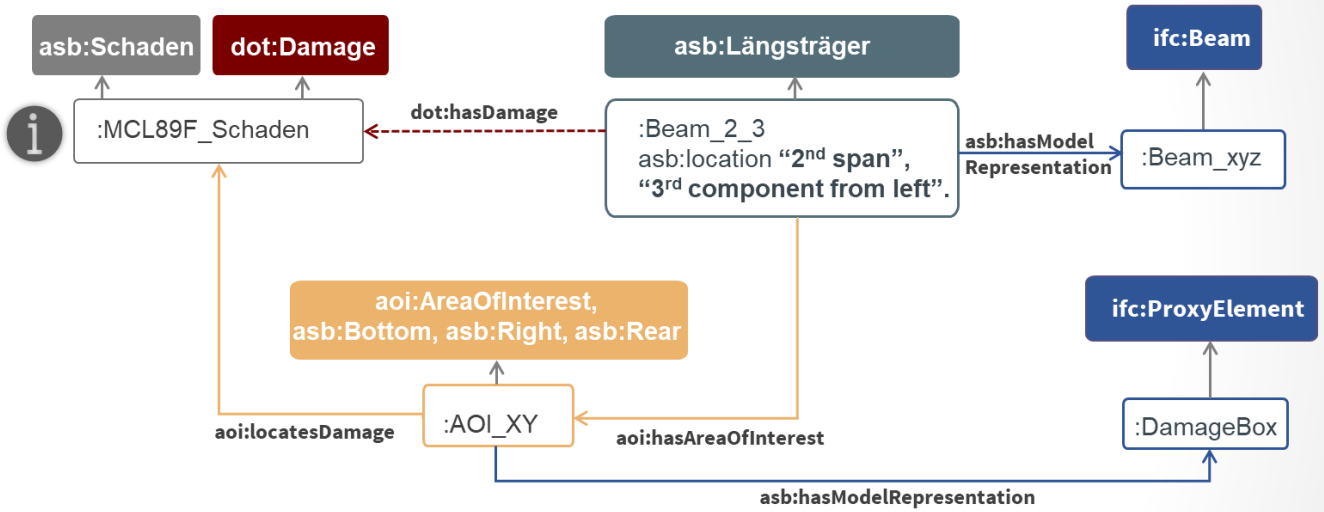


Integrate legacy data with BIM models

Interlinked structure of legacy maintenance and BIM data

Query interlinked data

- Damage per component
- Damage per component type
- Damage of a specific component area
- Most damaged component (type)
- Typical affected component area
- Typical affected component type of a damage type
- ….



Integrate legacy data with BIM models

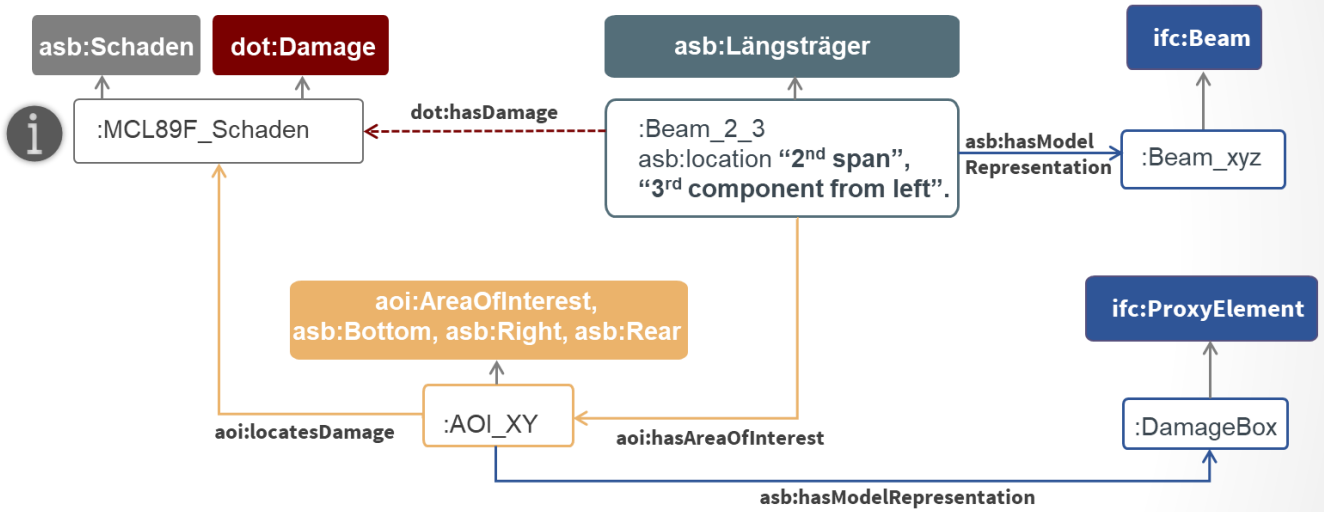
Interlinked structure of legacy maintenance and BIM data

Query interlinked data

Damage per component

```
PREFIX aoi: <https://w3id.org/aoi#>
PREFIX dot: <https://w3id.org/dot#>

select  ?damage
where {
    <component>
     dot:hasDamage |
    aoi:hasAreaOfInterest  / aoi:locatesDamage
     ?damage.
}
```



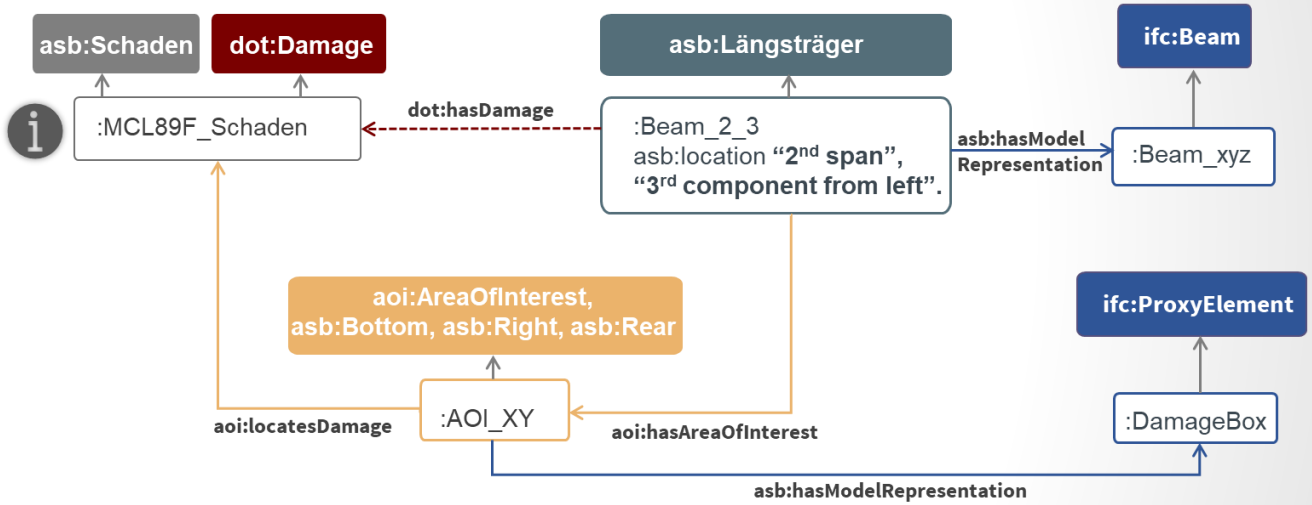
Integrate legacy data with BIM models

Interlinked structure of legacy maintenance and BIM data

Query interlinked data: Most affected areas per component type

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX asb: <https://w3id.org/asbingowl/core#>
PREFIX aoi: <https://w3id.org/aoi#>

select ?compType ?aoiLabel (count(?aoiClass)as ?nrOfAoi)
where {
        ?comp aoi:hasAreaOfInterest ?aoi ;
                a ?compType.
        ?aoi a ?aoiClass .
        ?aoiClass rdfs:label ?aoiLabel.
filter  (?aoiClass != aoi:AreaOfInterest)
}
group by  ?compType ?aoiLabel
order by  ?compType DESC (?nrofaoi)
```

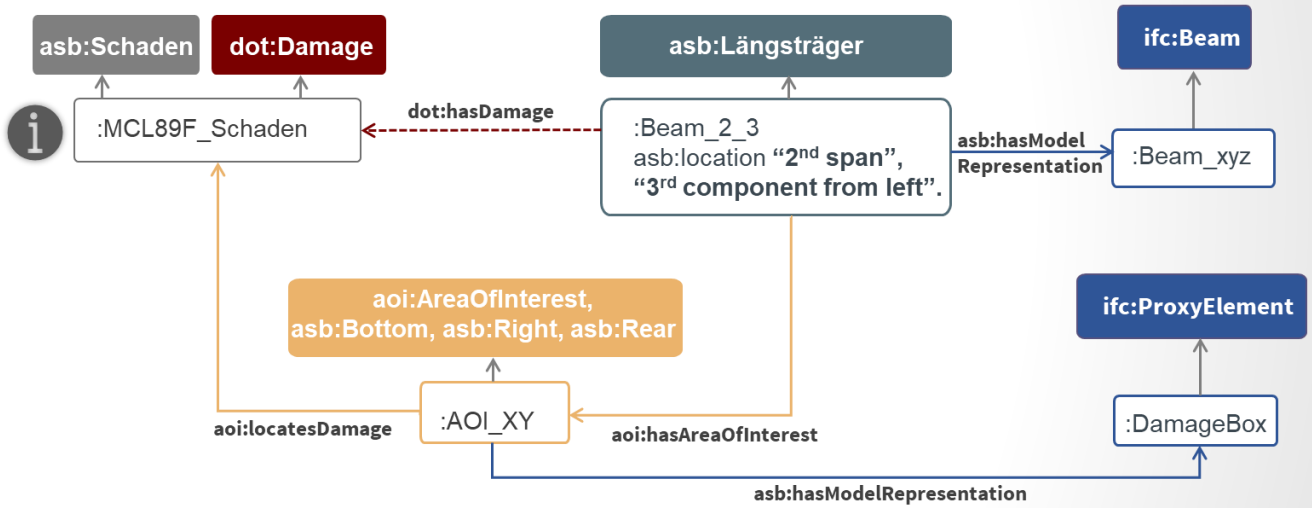


Integrate legacy data with BIM models

Interlinked structure of legacy maintenance and BIM data

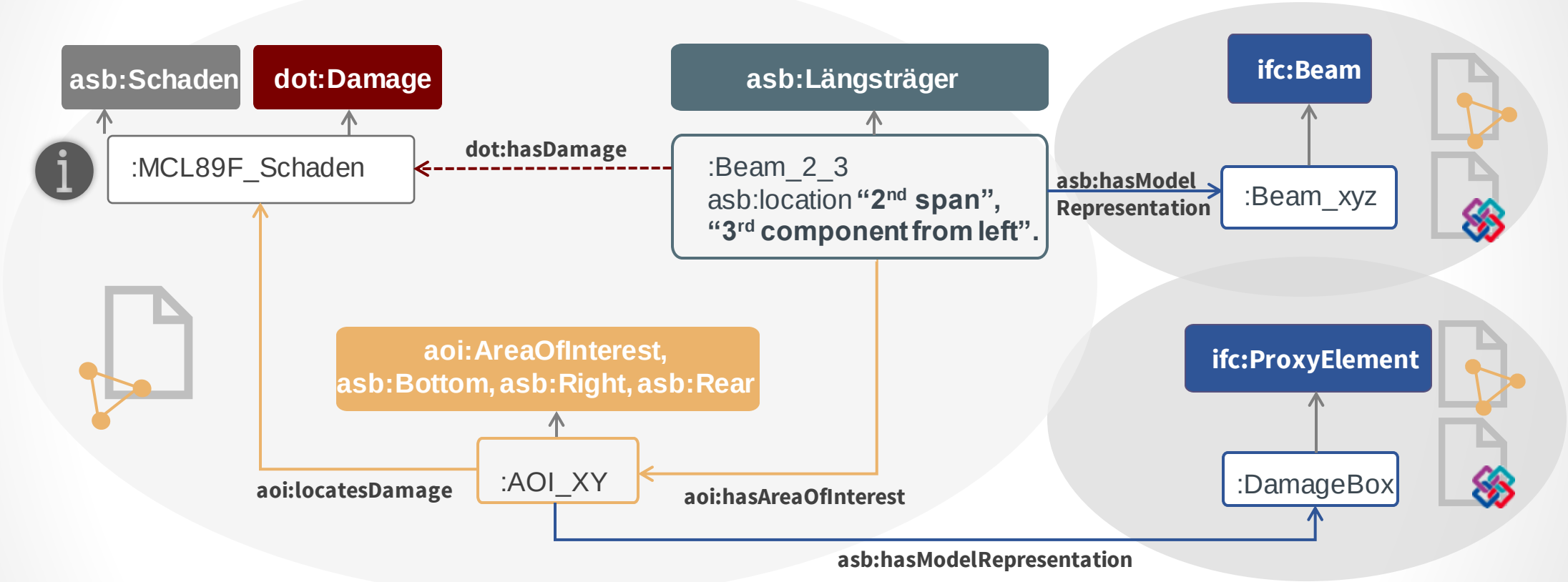
Query interlinked data: Most affected areas per component type

compType	aoiLabel	nrOfAoi
asb:Cap	„top"	"5"^^xsd:integer
asb:Cap	„top side"	"3"^^xsd:integer
asb:Cap	„rear"	"2"^^xsd:integer
asb:Roadway Coating	„longitudinal center“	„8"^^xsd:integer
asb:Roadway Coating	„front and rear“	„1"^^xsd:integer



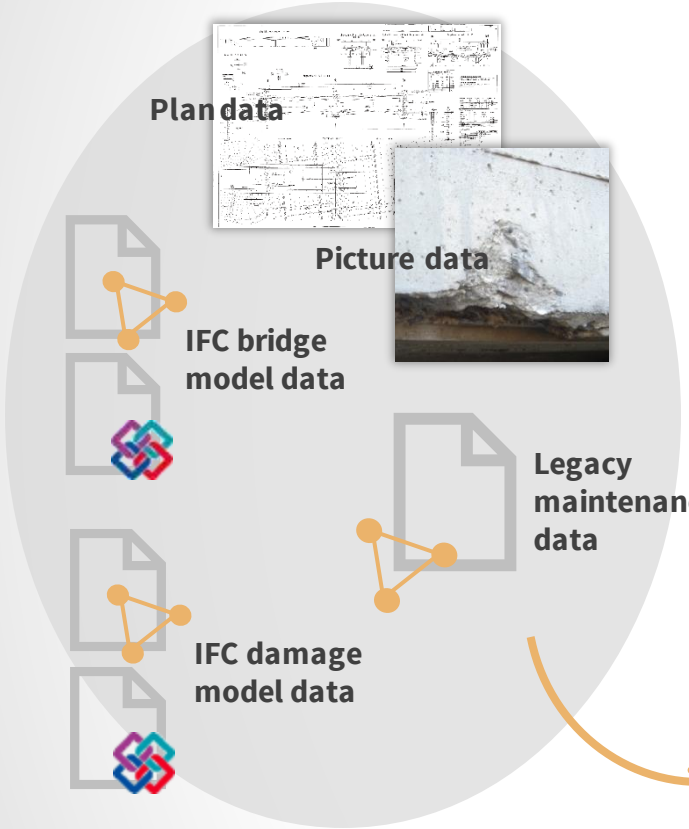
Integrate legacy data with BIM models

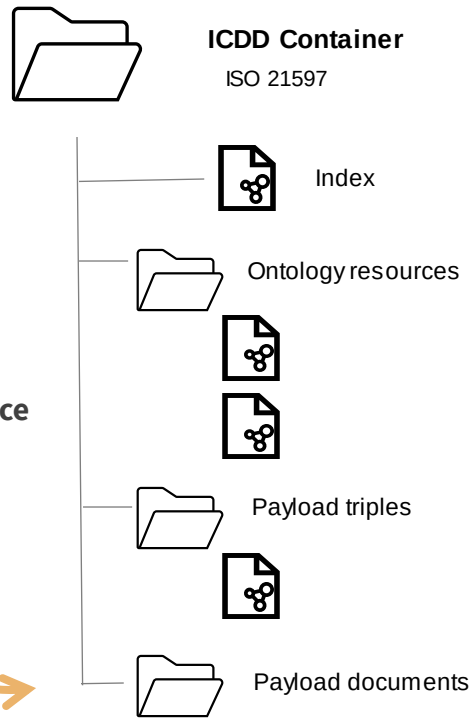
Interlinked structure of legacy maintenance and BIM data

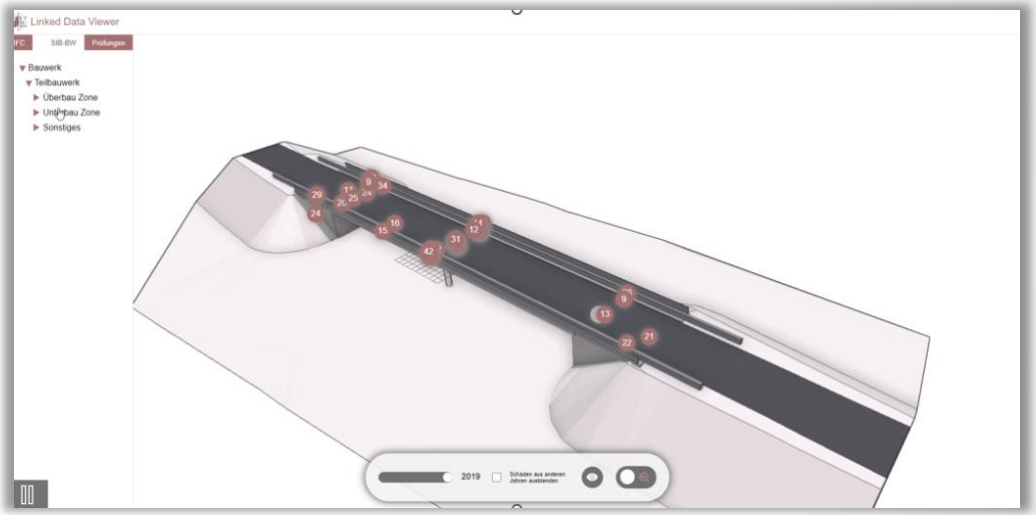


Integrate legacy data with BIM models

Use interlinked data for better visualization and data analysis

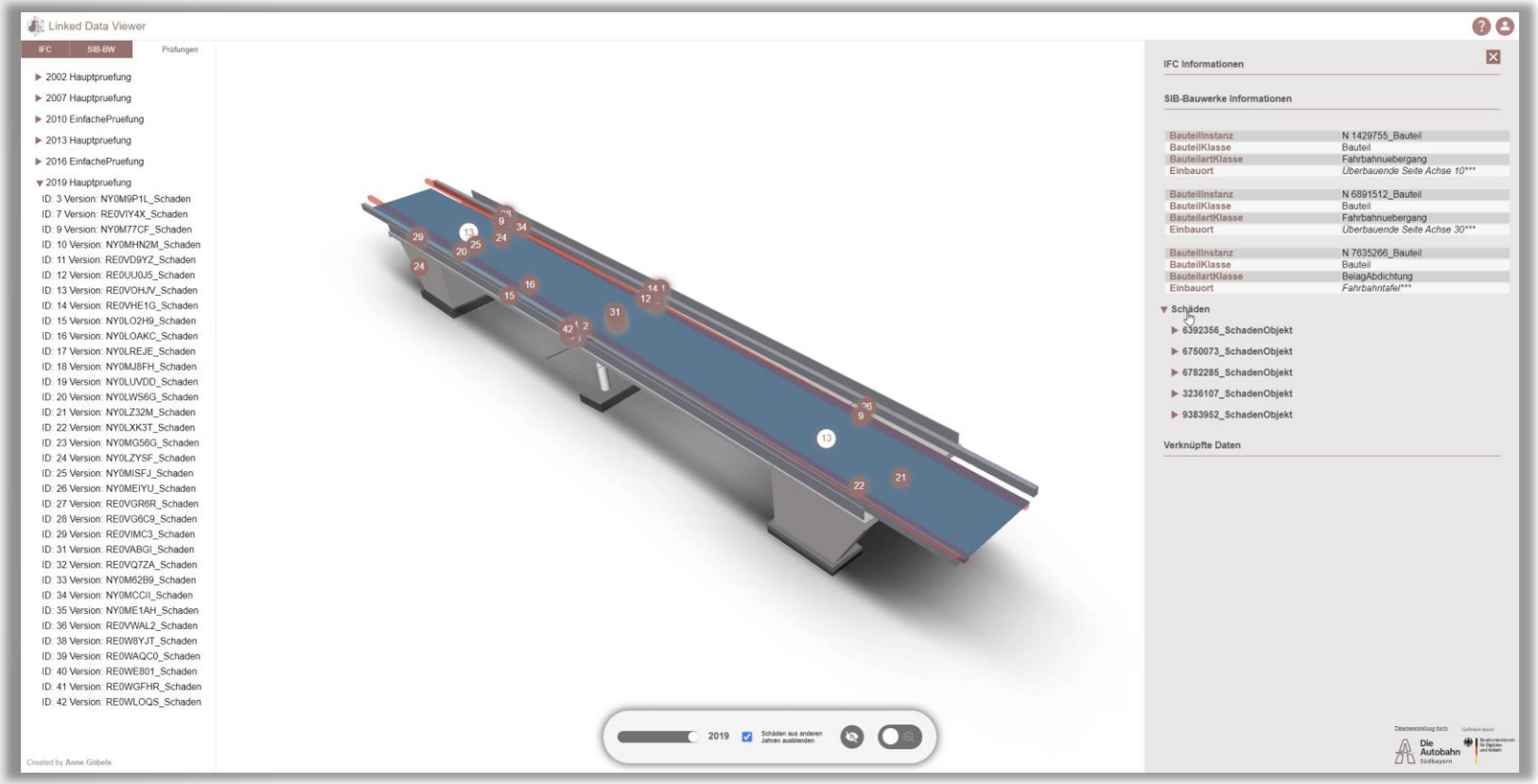






Integrate legacy data with BIM models

Use interlinked data for better visualization and data analysis



LINKED DATA VIEWER

Hands-On
Transfer Inspection Data into RDF

Hands on

Represent inspection report in RDF!

→ Model the information contained in the inspection report as RDF graph

→Transform the table structure

→Use the presented LBD ontologies to semantically enhance the legacy data

Inspection report table

Damage

Id	Component type	Location Component	Vertical Location Damage	Transversal Location Damage	Damage type	Damage Size	Picture Name
21	Abutment	Front	Bottom	Left	Water damage	“one spot”	Picture A
35	Abutment	Front and Rear	-		Crack	“entire component”	-

Hands on – Solution approach

Represent inspection report in RDF!

- **Express table and columns as class and properties**
- **Convert rows into RDF statements**
- **Create abutment components (using bot:Element or brot:Component or own approach)**
- **Use DOT and AOI ontology to organize damage data**

Hands on – Solution approach

Represent inspection report in RDF!

```
@prefix brcomp: <https://w3id.org/brcomp#> .
@prefix dot: <https://w3id.org/dot#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix aoi: <https://w3id.org/aoi#>.

@prefix ex: <http://example.org/myLegacyDataModelOntology#> .
@prefix : <http://example.org/BridgeX/Inspection2024/> .

:AbutmentFront a brcomp:Abutment;
    ex:LocationComponent ex:Front;
    dot:hasDamage :Damage35;
    aoi:hasAreaOfInterest :AreaOfInterest_21.

:AbutmentRear a ex:Abutment, brcomp:Abutment;
    ex:LocationComponent ex:Rear;
    dot:hasDamage :Damage35.
```

```
:Damage35 a ex:Damage, dot:Damage;
    ex:Id 35;
    ex:ComponentType ex:Abutment;
    ex:LocationComponent ex:Front, ex:Rear;
    ex:DamageType ex:Crack;
    ex:DamageSize "affects entire component".
```

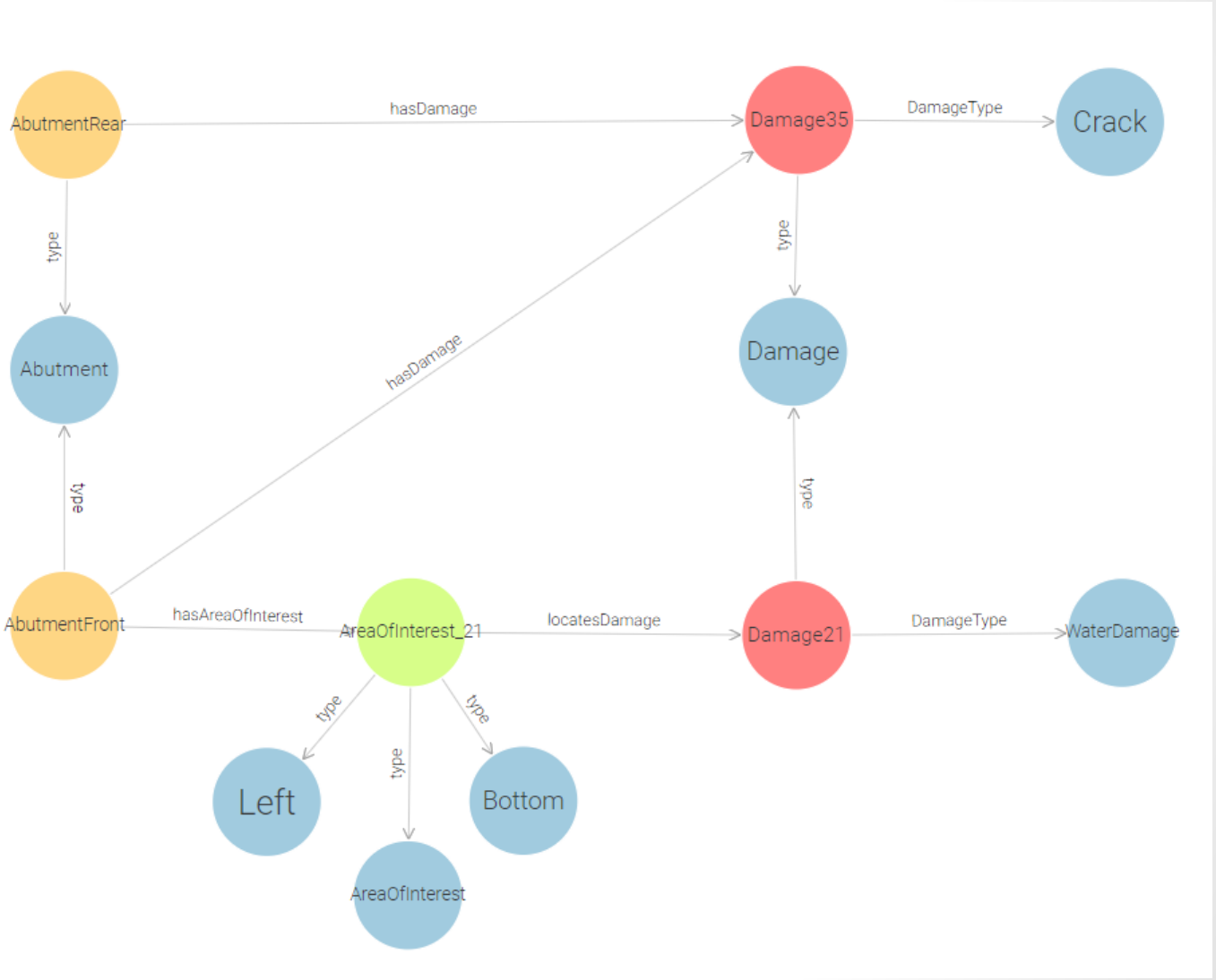
```
:Damage21 a ex:Damage, dot:Damage;
    ex:Id 21;
    ex:ComponentType ex:Abutment;
    ex:LocationComponent ex:Front;
    ex:VerticalDamageLocation ex:Bottom;
    ex:TransversalDamageLocation ex:Left;
    ex:DamageType ex:WaterDamage;
    ex:DamageSize "one spot";
    ex:PictureName "PictureA".
```

```
:AreaOfInterest_21
    a      aoi:AreaOfInterest,
           ex:Bottom, ex:Left;
    aoi:locatesDamage :Damage21.
```

Hands on – Solution approach

Represent inspection report in RDF!

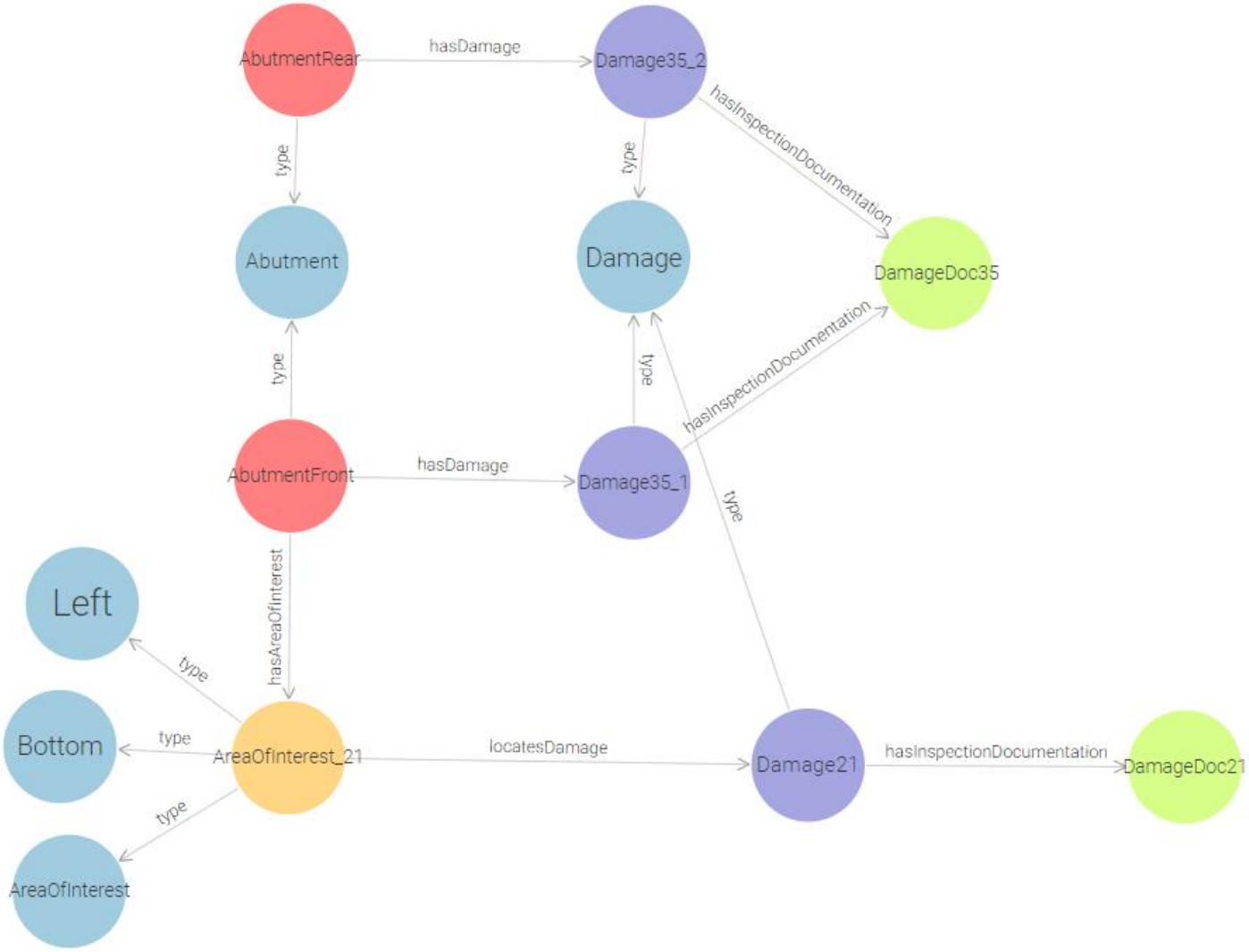
- **One Damage is related to two components?**
  - Realistic?
  - Consider use case / intention of your data model
  - Add constraints / rules to your data model /ontology to check data quality



Hands on – Solution approach

Represent inspection report in RDF!

- **Alternative solution**
  - Keep maintenance data as it is
  - Define dot:Damage objects separately -> link them to original damage object



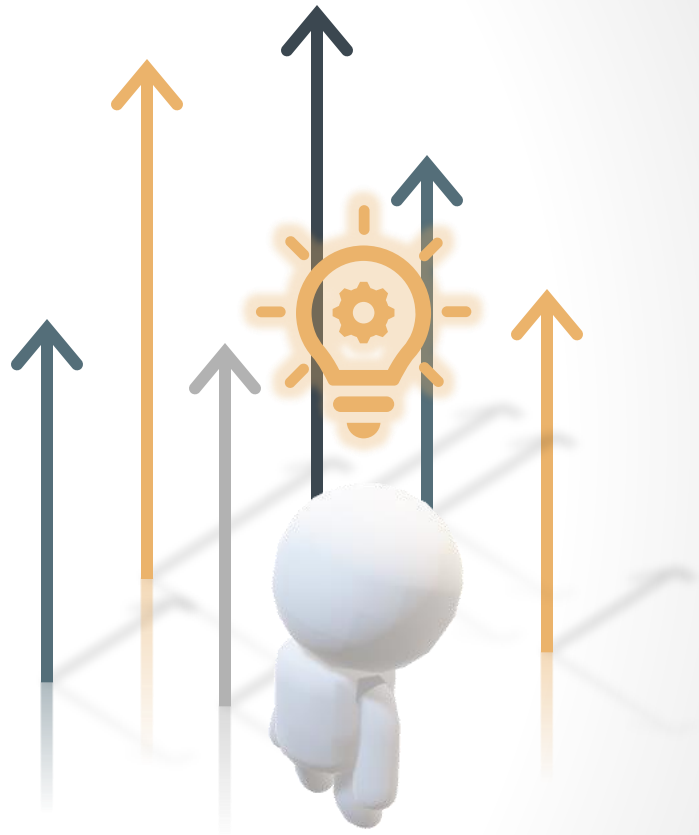
Now you know..

→that Linked Data approaches can lift legacy data!

→how to integrate LBD ontologies in domain-specific legacy data models

→how to represent maintenance data in RDF

→the potential of linking legacy maintenance data with modern model-based approaches



LBD and Maintenance Data Transformations

Semantic Lifting of Legacy Data

Summer School of LDAC 2024

Anne Göbels