

EXCHANGE INFORMATION REQUIREMENTS FOR ICDD CONTAINERS USING SHACL

Philipp Hagedorn



Computing in Engineering | Ruhr-Universität Bochum

Head of Research Group

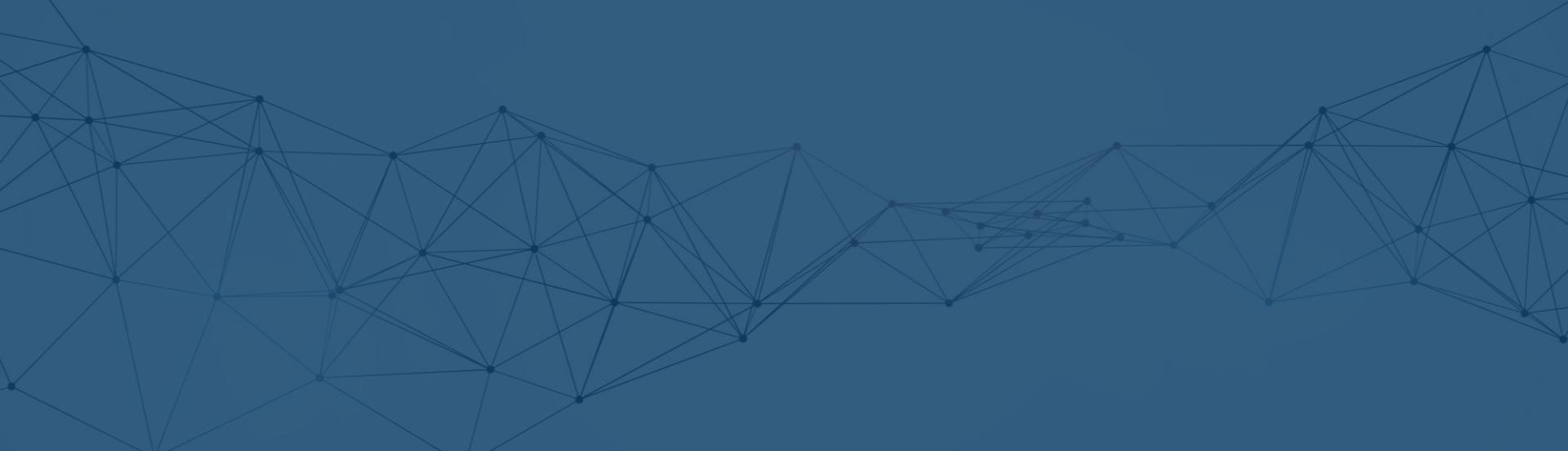
- Prof. Dr. Markus König

Research activities

- 20 research assistants in three research areas
 - **Data Management**
 - Group Leader: Philipp Hagedorn
 - Artificial Intelligence
 - Sensoring and Visualization



Introduction



Information in an asset's life

- is **heterogeneous**
(multiple formats or schemas)
- is **distributed**
(multiple stakeholders or sources)
- is **exchanged**
among stakeholders
- requires **context**
to be interpreted
- must be **valid**
to be reliable



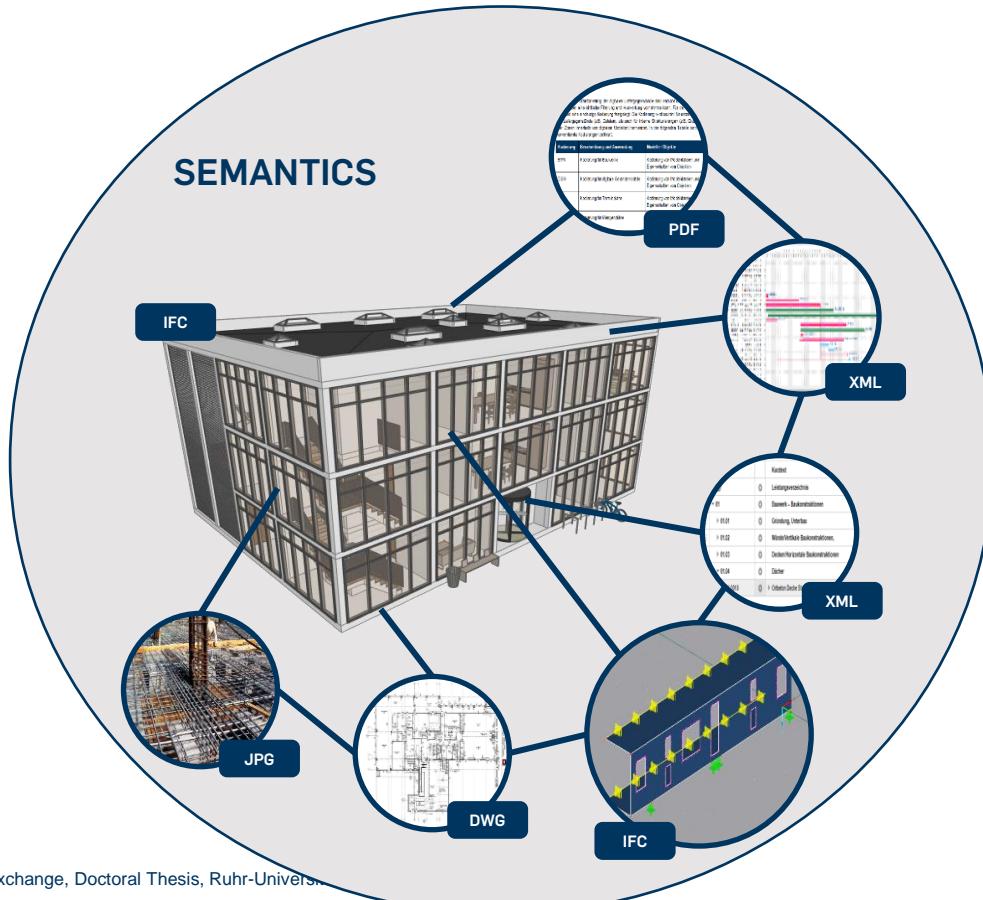
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Information in an asset's life

Knowledge and semantics

- project information composed of multiple interconnected building models, documents and data
- interpreting information is often depending on human knowledge
- information enriched with semantics transforms to knowledge
- semantics are the meaning, interpretation, and reasoning of information in each context

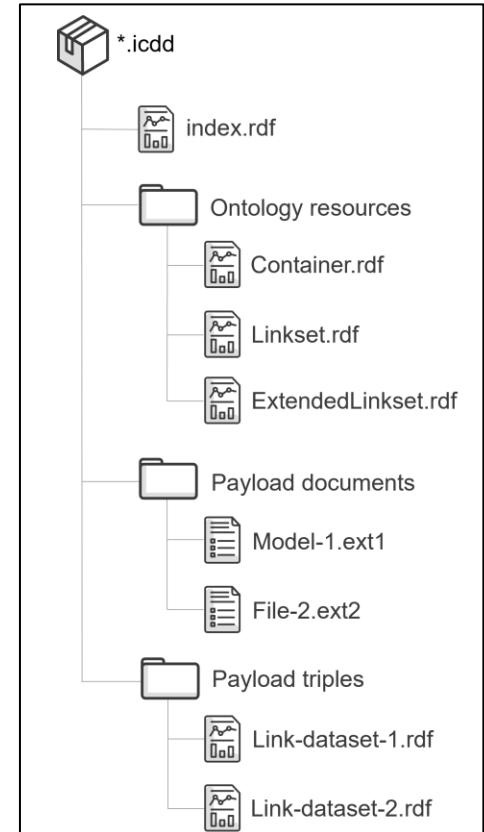
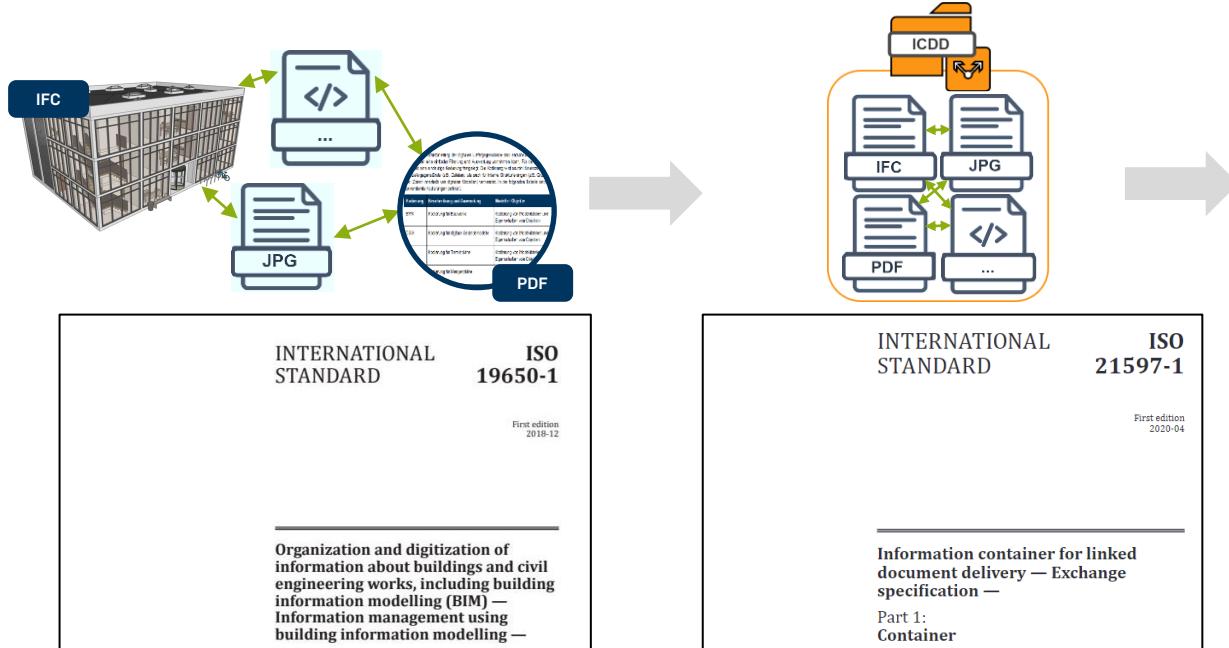


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Information in an asset's life

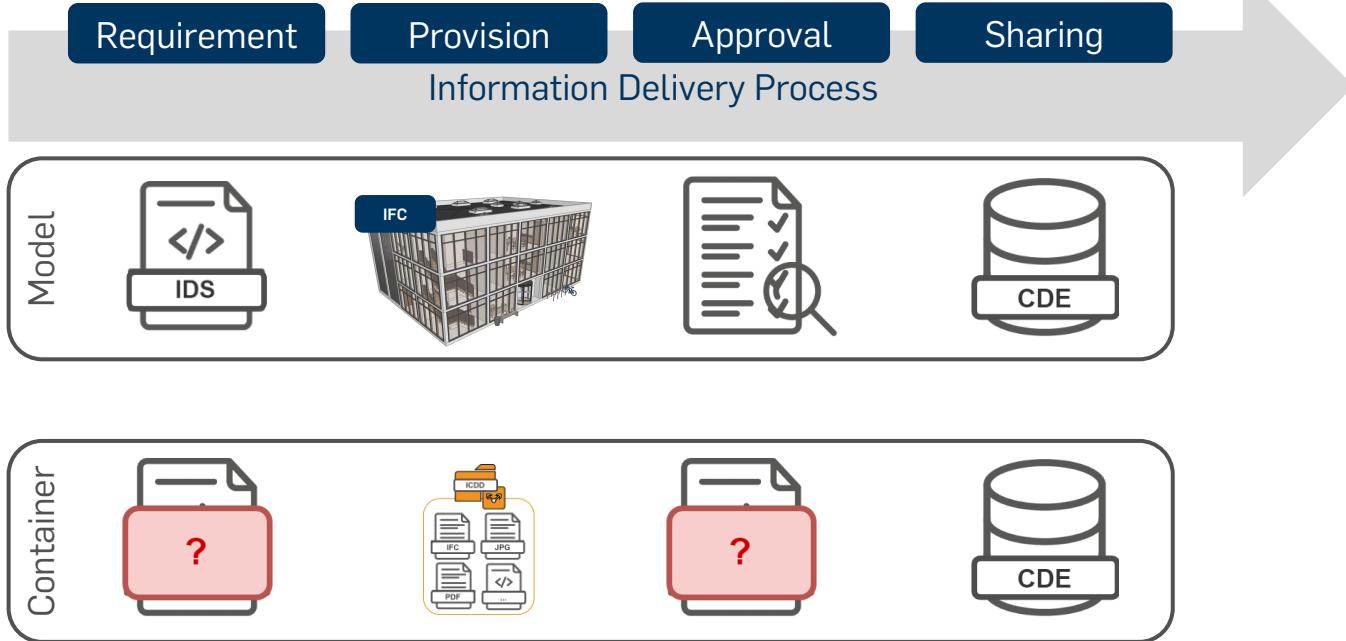
Information Container for linked Document Delivery



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Exchange Information Requirements for ICDD Containers using SHACL



RQ

How can ICDD information containers be exchanged and validated to achieve a reliable BIM information exchange?

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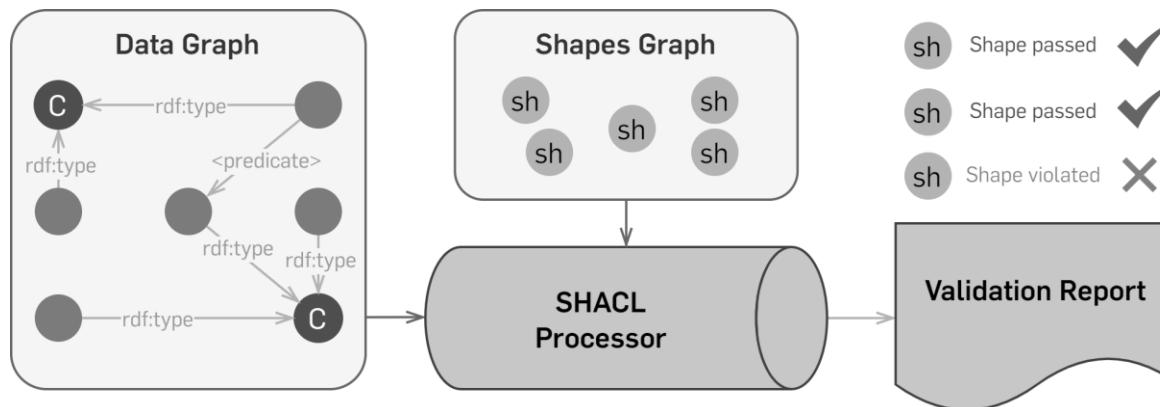


Exchange Information Requirements for ICDD Containers using SHACL

Requirements checking in the Semantic Web

Shapes Constraint Language (SHACL)

- specifying the expected structure, constraints, and rules for RDF data



Shapes Constraint Language (SHACL)
W3C Recommendation 20 July 2017



SHACL Advanced Features 1.1
Draft Community Group Report 02 December 2021

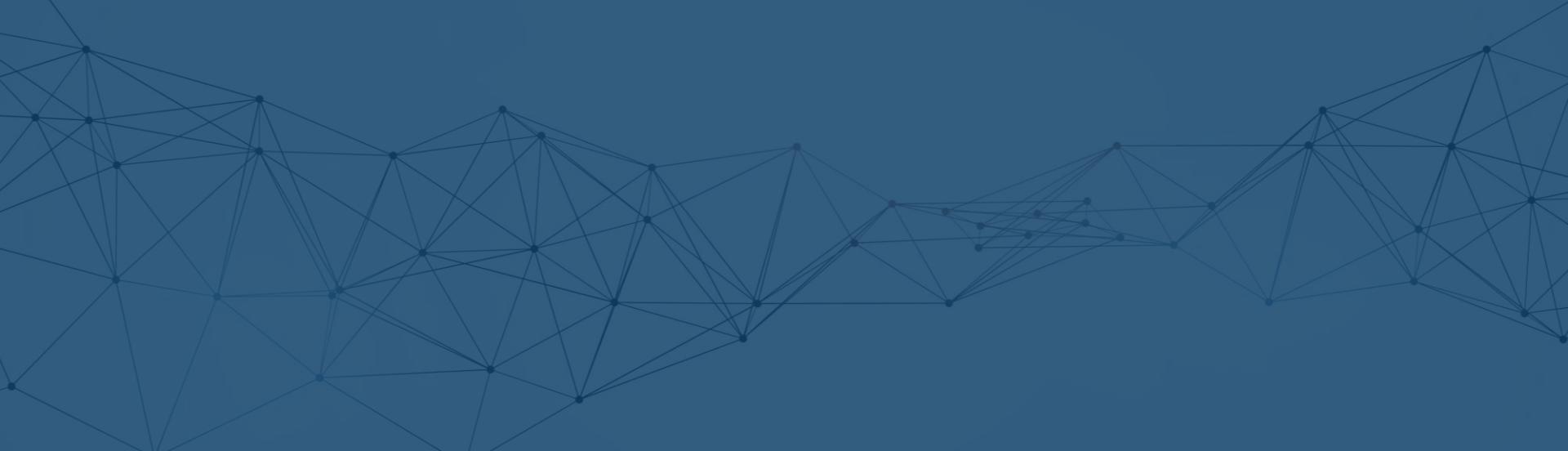


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Exchange Information Requirements for ICDD Containers using SHACL

Concept



Information Delivery Processes Ontology (IDPO)

Requirements

- created Terminology Map (TM)
- extracted terminology from
 - ISO 19650 (**BIM – IM**),
 - ISO 29481 (**IDM**),
 - ISO 21597 (**ICDD**),
 - ISO 19510 (**BPMN**),
 - **PROV** ontology
- defined 18 competency questions

No.	ISO 19650-1,4 [124, 125] Information Management	ISO 29481-1 [130] IDM	ISO 21597-1 [126] ICDD	ISO/IEC 19510 [132] BPMN	PROV [149]
TM1	Information container (3.3.12)		Container (3.1.1)	Data object (Table 7.1)	Entity
TM2	Information exchange (3.3.7)	Transaction (3.20)		Activity / Message Event (Table 7.1)	Activity
TM3	Information Verification	Information Receipt		Activity (Table 7.1)	Activity / Usage
TM4	Information Delivery	Information Delivery		Activity (Table 7.1)	Activity / Generation
TM5	Actor (3.2.1)	Actor (3.1)	Party (Table 4)	Participant (Table 7.1)	Agent
TM6	Appointed party [124, 3.2.3] Information provider [125, 3.2.1]	Executor		Participant (Table 7.1)	Agent
TM7	Appointing party [124, 3.2.4] Information receiver [125, 3.2.2]	Initiator		Participant (Table 7.1)	Agent
TM8	Information (3.3.1)	Information unit (3.12)	Payload (3.1.2)		
TM9	Exchange information requirement (3.3.6)	Exchange requirement (3.9)			
TM10	Project / Asset	Project		Collaboration (Table 9.1)	
TM11	Status (3.3.13)				
TM12		Information constraint (3.5)			

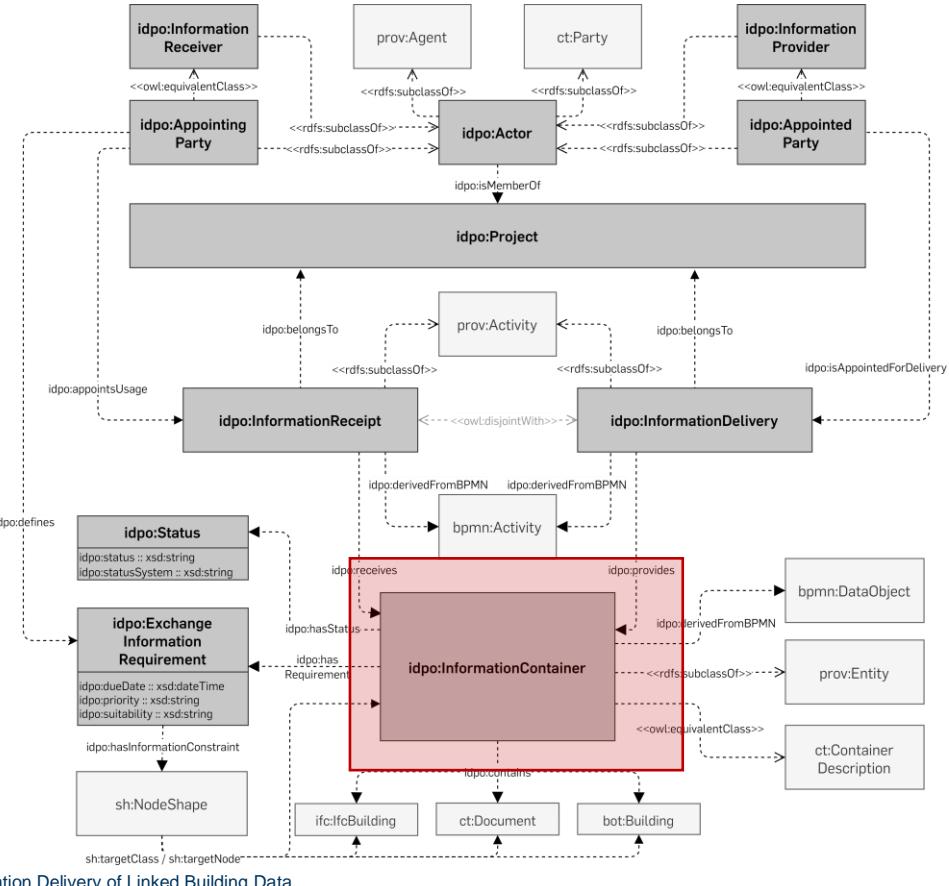
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Exchange Information Requirements for ICDD Containers using SHACL

Information Delivery Processes Ontology (IDPO)

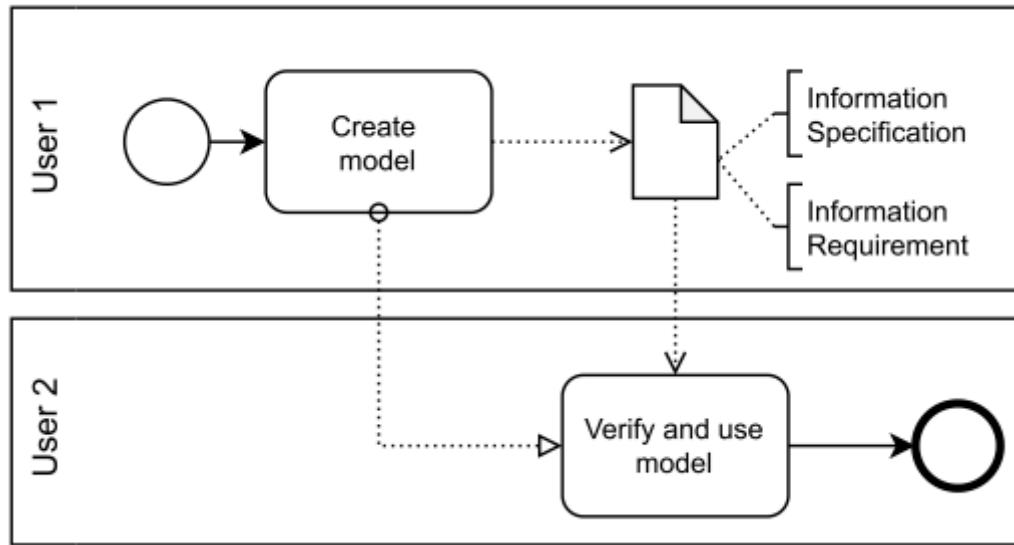
- developed according Linked Open Terms
- prefix: *idpo*
- URI: <<https://w3id.org/idpo#>>
- published with CC-BY-40 license
- interfaces to *prov*, *bpmn*, *sh*, *ifc*, *ct*, *bot*



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BPMN to IDPO

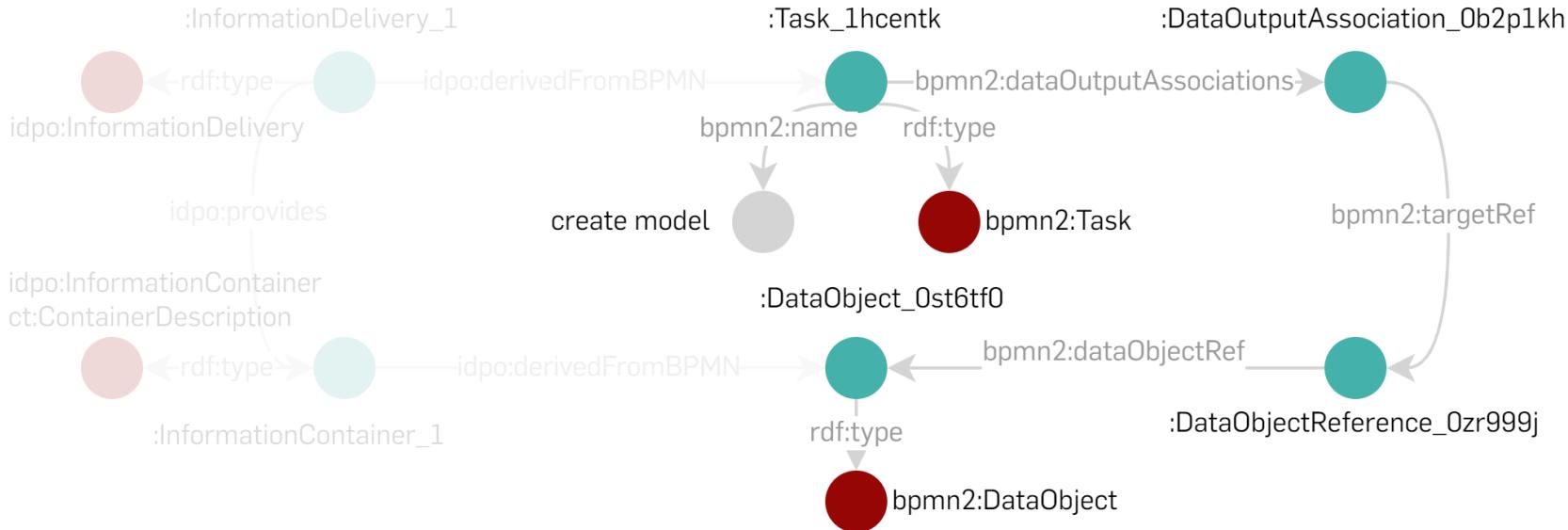
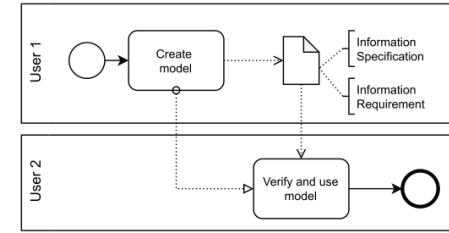


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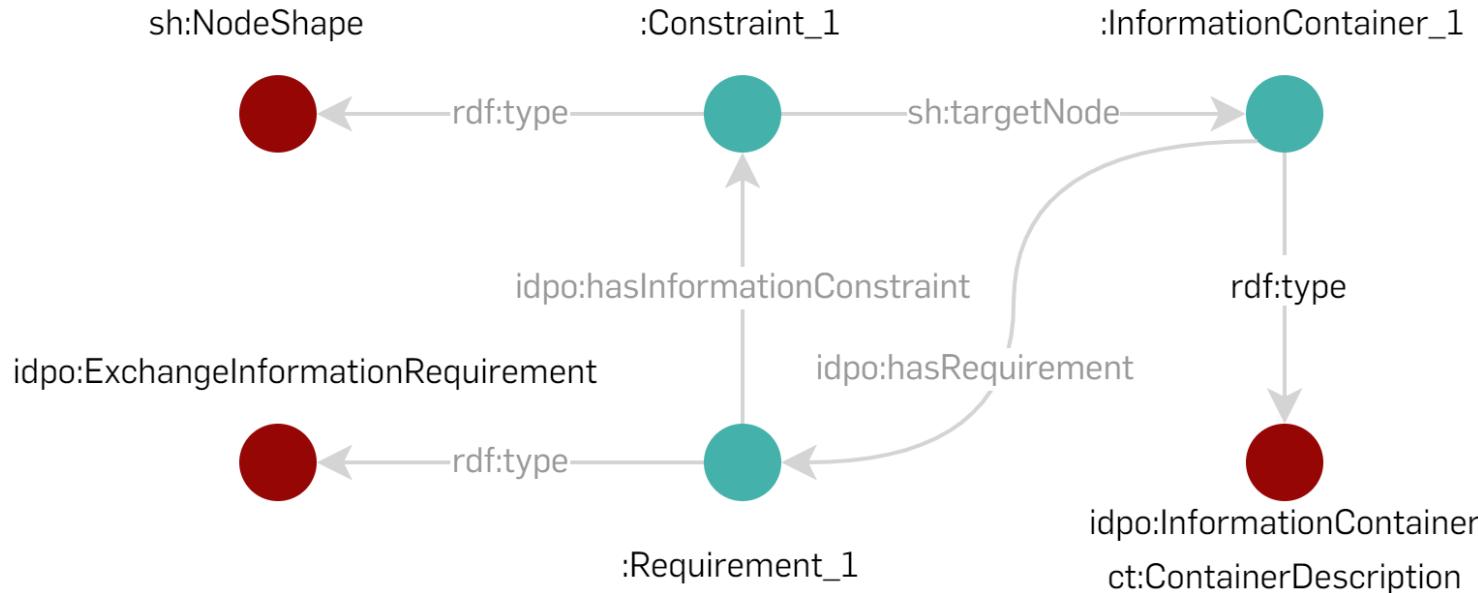
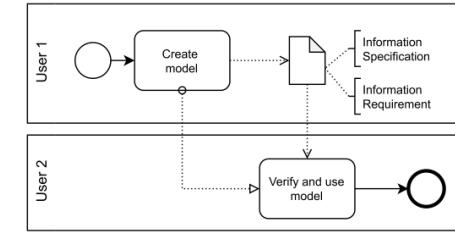
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BPMN to IDPO



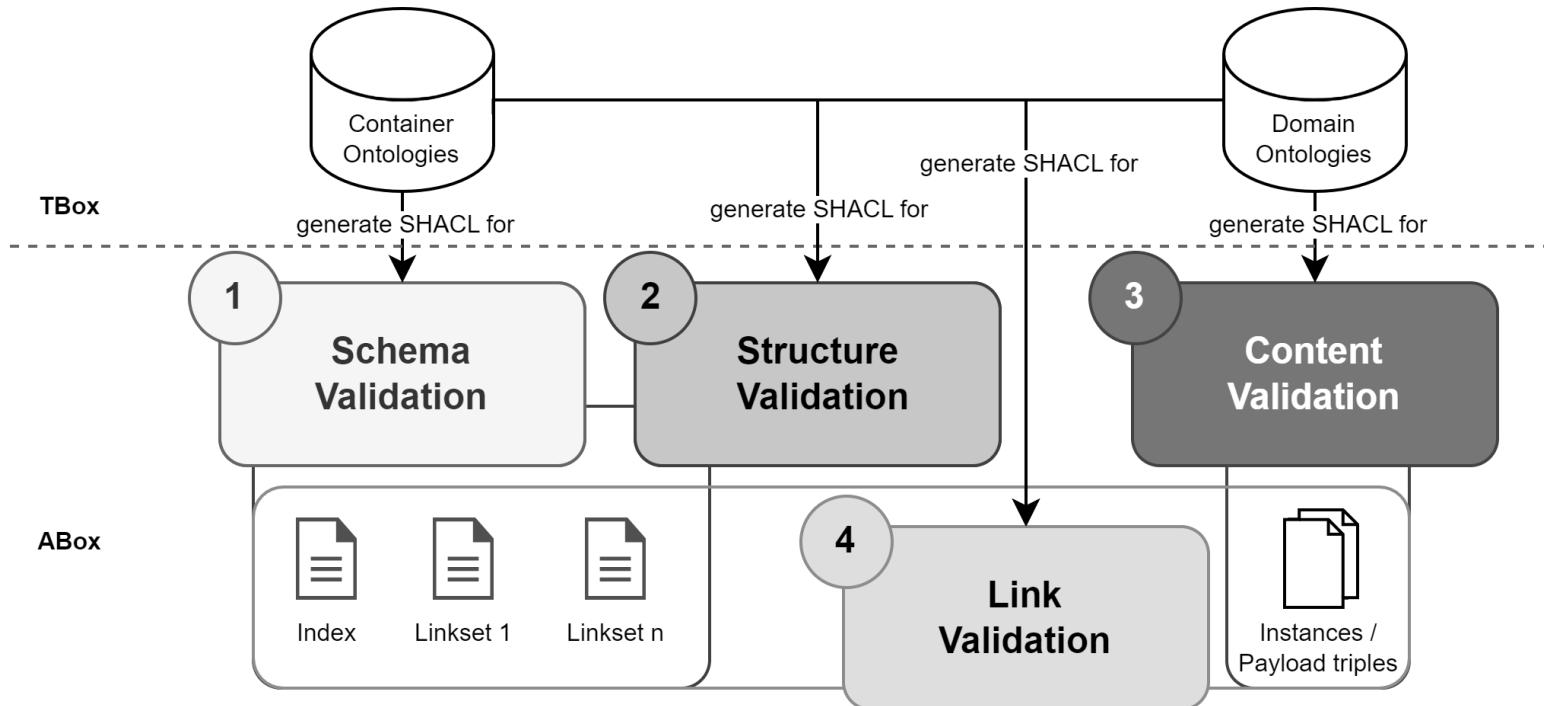
Hagedorn, P., & König, M. (2021). BPMN-related Ontology for Modeling the Construction Information Delivery of Linked Building Data

BPMN to IDPO



Hagedorn, P., & König, M. (2021). BPMN-related Ontology for Modeling the Construction Information Delivery of Linked Building Data

Validation Framework



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① Schema Validation

- provided through ISO 21597-1 and -2
 - extension → checks whether classes of the standardized ontologies are extended
 - dataset validation → checks whether present data complies to the standardized ontologies
- shapes are defined in the appendices of the standard

```
<https://standards.iso.org/iso/21597/-1/ed-1/en/Container#Linkset>
  a sh:NodeShape ;
  sh:closed true ;
  sh:ignoredProperties (
    rdf:type
    rdfs:label
  ) ;
  sh:property <https://standards.iso.org/iso/21597/-1/ed-1/en/Container#Linkset-filename> ;
  sh:property <https://standards.iso.org/iso/21597/-1/ed-1/en/Container#Linkset-priorVersion> ;
  .
```

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Exchange Information Requirements for ICDD Containers using SHACL

② Structure Validation

Natural language requirement:

The information provider must deliver an XML file within an ICDD container by 2023-02-12.

```
ex:EIR_Example a sh:NodeShape ;  
    sh:targetClass ct:ContainerDescription;  
    sh:property [  
        sh:path ct:containsDocument ;  
        sh:class ct:InternalDocument;  
        sh:qualifiedMaxCount 1;  
        sh:qualifiedMinCount 1;  
        sh:qualifiedValueShape ex:xmlDocumentRequired ,  
    ] ;  
.
```

③ Content Validation

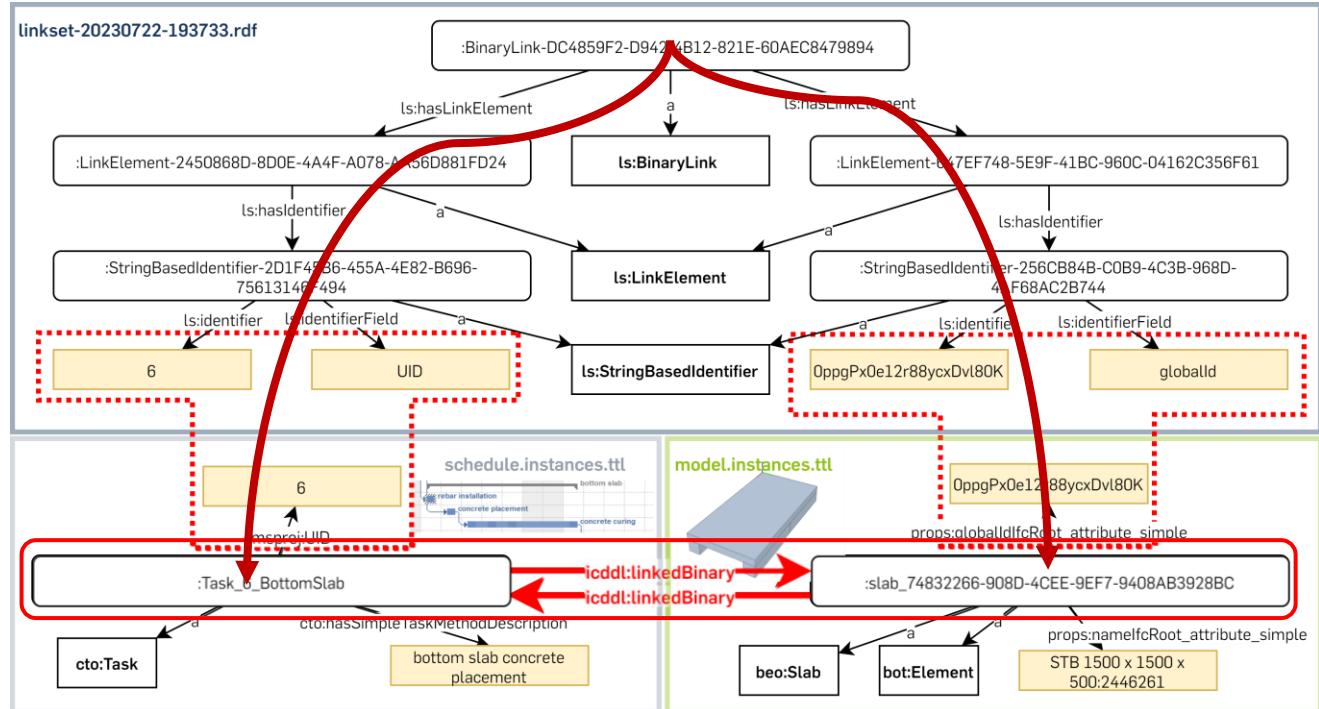
Natural language requirement:

(1) *Each space in a building must have at least one door (2) that must have a width and a fire rating value attached for determining escape routes inside the building in the planning process.*

```
ex:spaceShape a sh:NodeShape ;  
    sh:closed false ;  
    sh:targetClass bot:Space ;  
    sh:property 1  
        sh:minCount 1 ;  
        sh:path bot:containsElement ;  
        sh:class beo:Door ;  
        sh:node ex:doorShape ;  
    ] ;  
.  
.
```

④ Link Validation

Natural language requirement:
Each building element must be linked to at least one task from the schedule.



Hagedorn, P., Pauwels, P., & König, M. (2023). Semantic Rule Checking of Cross-Domain Building Data in Information Containers for Linked Document Delivery using the Shapes Constraint Language

Link Validation

Natural language requirement:

Each building element must be linked to at least one task from the schedule.

```
1 icddshacl:ElementShape a sh:NodeShape ;
2 sh:property [
3   sh:path props:globalIdIfcRoot_attribute_simple ; #applying property shape
4   to the IFC GUID property of each element
5   sh:node icddshacl:IcddLinkingShape; #applying the linking shape to each GUID
6   property value
7 ]
8 sh:targetClass bot:Element . #targeting all BOT elements
9
10 icddshacl:IcddLinkingShape a sh:PropertyShape ;
11 sh:path [sh:inversePath ls:identifier] ;
12 sh:class ls:StringBasedIdentifier;
13 sh:node [ #validating along the path from the IFC GUID to the Task UID through
14   the linking mechanism of ICDD
15   sh:property [
16     sh:path [sh:inversePath ls:hasIdentifier];
17     sh:class ls:LinkElement;
18     sh:node [
19       sh:property [
```

Too complex for plain SHACL rules

```
32 ] ]
33   [ sh:property [
34     sh:path ls:identifierField;
35     sh:hasValue "UID"; ];
36   sh:property [
37     sh:path ls:identifier;
38     sh:node [
39       sh:property [
40         sh:path [sh:inversePath msproj:UID];
41         sh:class cto:Task;
42         sh:message "The linked entity is not a Task";
43       ]; ]; ]; ] ).
```

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Exchange Information Requirements for ICDD Containers using SHACL

Link Validation

Natural language requirement:
Each building element must be linked to at least one task from the schedule.

```
1 icddshacl:ElementLinkedToMinOneTask a sh:NodeShape ;
2 sh:targetClass bot:Element ;
3 sh:sparql [
4 a sh:SPARQLConstraint ;
5 sh:message "Each building element must be linked to at least one task." ;
6 sh:select """
7     PREFIX ls: <https://standards.iso.org/iso/21597/-1/ed-1/en/Linkset#>
8     PREFIX props: <https://w3id.org/props#>
9     PREFIX msproj: <http://schemas.microsoft.com/project#>
10    PREFIX cto: <https://w3id.org/cto#>
11    SELECT DISTINCT $this
12    WHERE {
13        $this props:globalIdIfcRoot_attribute_simple ?elementGuid .
14        OPTIONAL{
15            ?link1 ?linking1 [ls:hasIdentifier/ls:identifier ?elementGuid] .
16            ?link1 ?linking2 [ls:hasIdentifier/ls:identifier ?taskUid] .
17            ?task msproj:UID ?taskUid.
18            ?task a cto:Task.
19        }
20        FILTER(!bound(?task))
21    }"""
22 ] .
```

Hagedorn, P., Pauwels, P., & König, M. (2023). Semantic Rule Checking of Cross-Domain Building Data in Information Containers for Linked Document Delivery using the Shapes Constraint Language



Exchange Information Requirements for ICDD Containers using SHACL

ICDD Link Properties

ICDDL Ontology

- an ontology to provide link properties between RDF entities
- based of the ICDD ontology schemes for links and extended links
- infers ICDD Link predicates based on the link class instances
- uses SHACL inference (Advanced Features)
- <https://w3id.org/icddl#>

<u>linked binary</u> ^{op}	
<u>IRI</u>	https://w3id.org/icddl#linked
<u>Description</u>	An ls:Link comprising exactly 2 individuals of class ls:LinkElement
<u>Sub Property Of</u>	linked binary ^{op}
<u>Super Property Of</u>	<ul style="list-style-type: none">linked binary ^{op}linked binary ^{op}linked directed ^{op}linked directed inverse ^{op}
<u>Rule</u>	<p><u>type</u> ^p SPARQL CONSTRUCT rule <u>label</u> ^{ap} sh:rule for icddl:linked <u>comment</u> ^{ap} Infers ICDD Link predicates for instances of ls:Link as icddl:linked and inverse as icddl:linked. <u>construct</u> ^p ▶ SPARQL</p>
<u>Target Class</u>	ls:Link
<u>Seealso</u>	ls:BinaryLink

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Exchange Information Requirements for ICDD Containers using SHACL

ICDDL Ontology

- defines properties that are sh:NodeShapes at the same time
- targeting the link classes
- inferring using sh:SPARQLRule
CONSTRUCT
- Union over possible graph pattern of the linking mechanism and identifiers

```
icddl:linkedBinary
  rdf:type owl:ObjectProperty ;
  rdf:type sh:NodeShape ;
  rdfs:label "linked binary"@en ;
  rdfs:seeAlso ls:BinaryLink ;
  rdfs:subPropertyOf icddl:linked ;
  sh:rule [
    rdf:type sh:SPARQLRule ;
    sh:construct """
PREFIX ls: <https://standards.iso.org/iso/21597/-1/ed-1/en/Linkset#>
PREFIX icddl: <https://w3id.org/icddl#>
CONSTRUCT {
  ?rdfEntity1 icddl:linkedBinary ?rdfEntity2 .
  ?rdfEntity2 icddl:linkedBinary ?rdfEntity1 .
}
WHERE {
  $this ls:hasLinkElement ?elem1 .
  $this ls:hasLinkElement ?elem2 .
```

Constructed triples

Hagedorn, P., Pauwels, P., & König, M. (2023). Semantic Rule Checking of Cross-Domain Building Data in Information Containers for Linked Document Delivery using the Shapes Constraint Language

④ Link Validation

Natural language requirement:

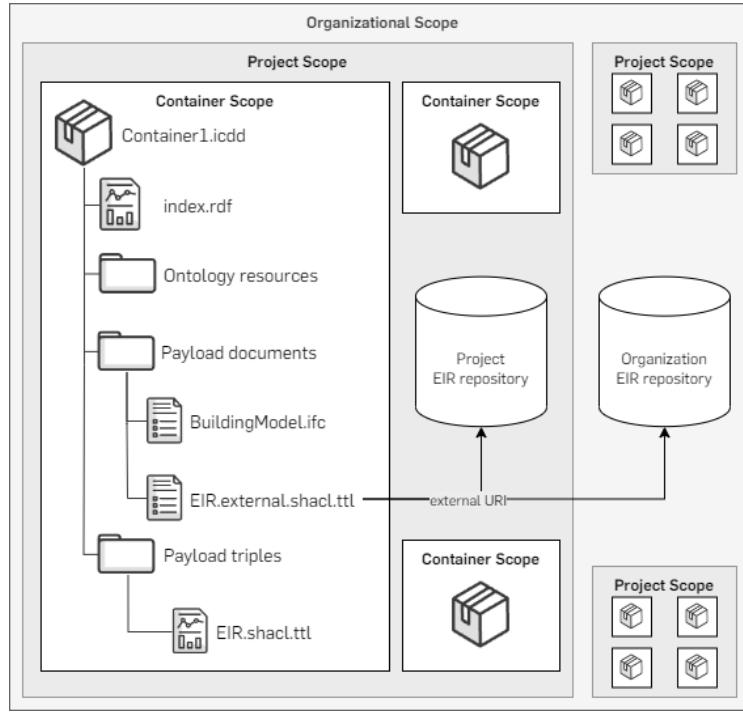
Each building element must be linked to at least one task from the schedule.



```
ex:elementShape a sh:NodeShape ;  
    sh:closed false ;  
    sh:targetClass bot:Element ;  
    sh:property [  
        sh:minCount 1 ;  
        sh:path icddl:linkedBinary ;  
        sh:class cto:Task ;  
    ] .
```

Hagedorn, P., Pauwels, P., & König, M. (2023). Semantic Rule Checking of Cross-Domain Building Data in Information Containers for Linked Document Delivery using the Shapes Constraint Language

SHACL Shapes Management



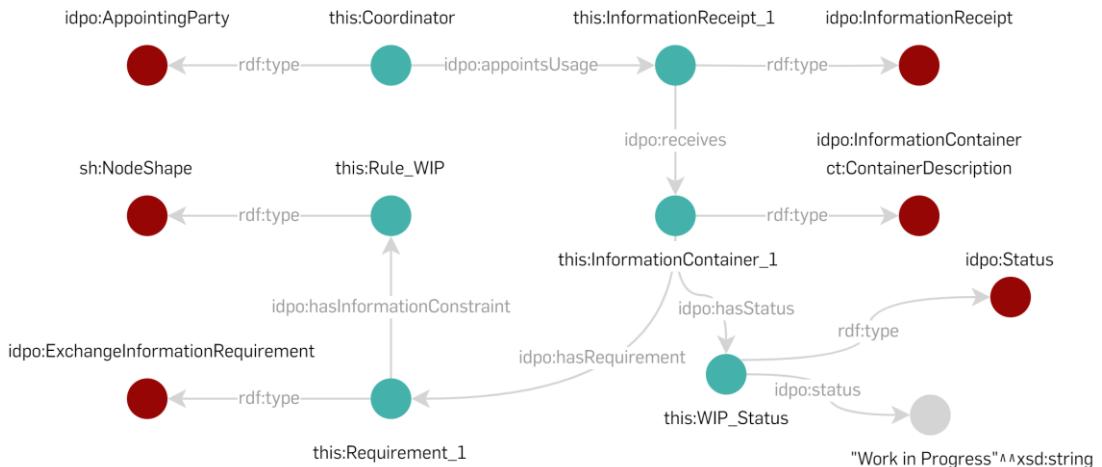
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Exchange Information Requirements for ICDD Containers using SHACL

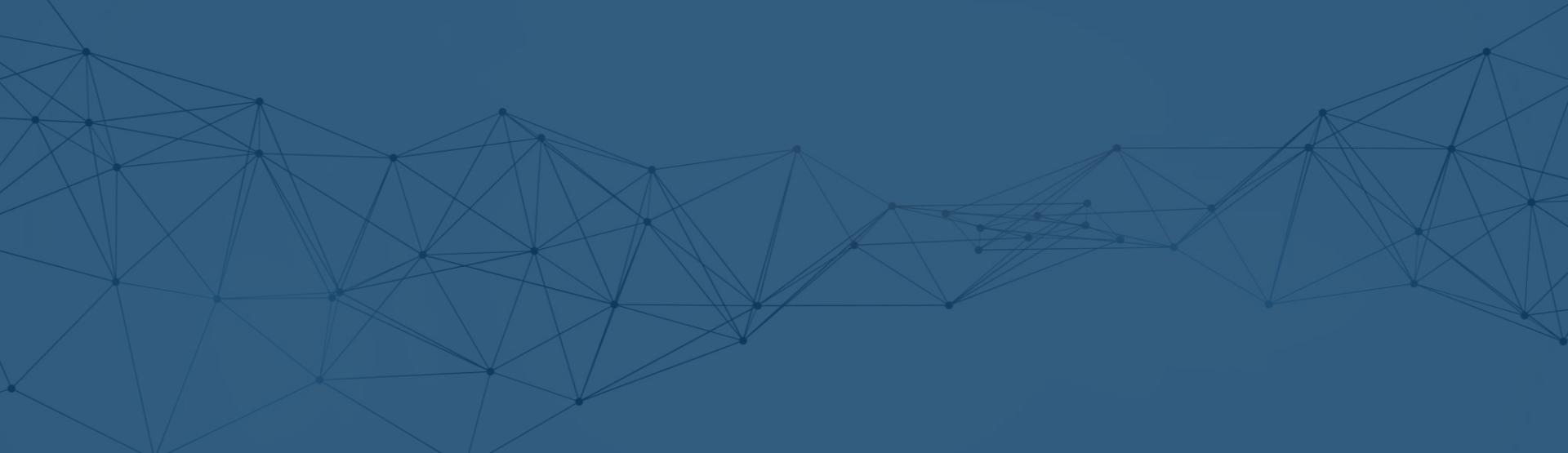
SHACL Conditional Shapes

```
this:Rule_WIP
a sh:NodeShape ;
sh:target [
  a sh:SPARQLTarget ;
  sh:prefixes idpo: ;
  sh:prefixes this: ;
  sh:select """
    SELECT ?this
    WHERE {
      ?this a idpo:InformationContainer .
      ?this idpo:hasRequirement [ idpo:hasInformationConstraint this:Rule_WIP] .
      ?this idpo:hasStatus this:WIP_Status . }"""
  ] ;
```



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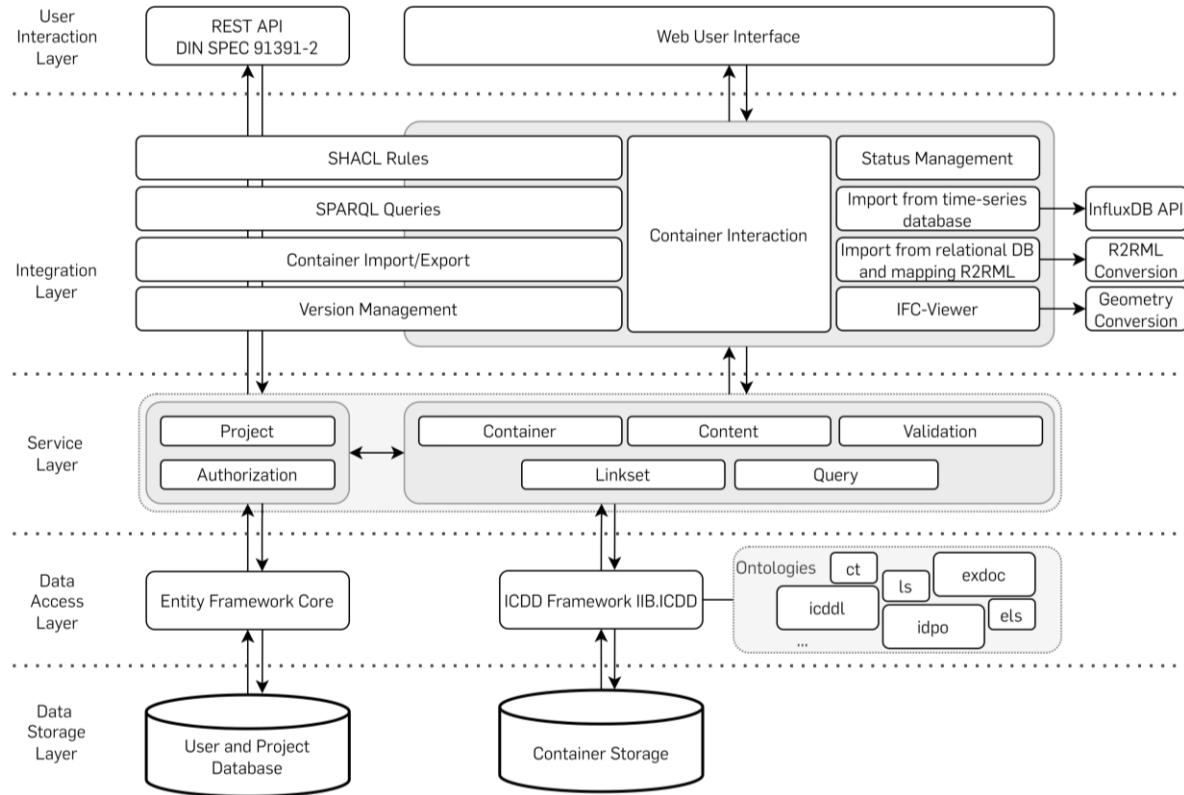
Implementation



Software prototype

Architecture

- five-layer architecture
- satisfies functional and non functional requirements
- uses components
 - IIB.ICDD
 - openICDD REST API
 - dotNetRDF
 - other open source packages



Hagedorn, P., Liu, L., König, M., Hajdin, R., Blumenfeld, T., Stöckner, M., Billmaier, M., Grossauer, K., & Gavin, K. (2023). BIM-enabled Infrastructure Asset Management using Information Containers and Semantic Web

Software prototype

The screenshot shows the RUB ICDD Platform development instance at <https://icdd.vm.rub.de/dev01/>. The page title is "RUB ICDD Platform". The top navigation bar includes links for "HOME", "PROJECTS", "DOCUMENTATION", "API", "CONTACT", "REGISTER", and "LOGIN". The RUB logo is in the top right corner.

The main content area features a heading "DEVELOPMENT INSTANCE" and a note: "This is not a production environment!". Below this, a text block explains the platform's purpose: "This is a toolkit for working with Information Container for linked Document Delivery (ICDD) according to ISO 21597-1:2020. The platform offers several functions for uploading, validating, editing, and exporting ICDD containers. The platform supports the information management according ISO 19650 and provides a DIN SPEC 91391 conform REST API for accessing information containers in external clients."

On the right side, there is a "Quick start:" section with three buttons: "Register a new user", "Log in as a registered user", and "Open or create a project".

The main interface is divided into four sections, each featuring a building icon:

- Upload**: An arrow pointing up to a building icon. Description: "You can upload your *.icdd files right now by clicking the link below and start a new session."
- Validate**: A checkmark icon inside a building icon. Description: "Your file will be checked against conformance criteria delivered by the standard for the container in the active
- View and Edit**: A magnifying glass icon inside a building icon. Description: "Explore the contents of your file and manipulate meta data online for the container in the active session. Viewer
- Export**: A wrench icon inside a building icon. Description: "Export the container back into standardized container format."

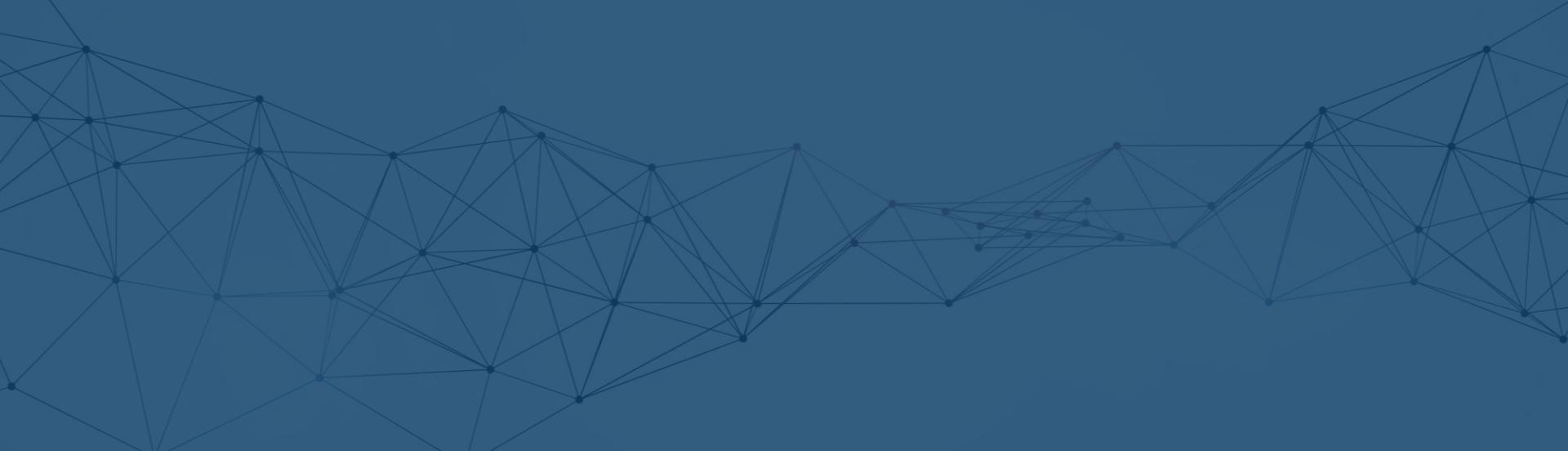
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Exchange Information Requirements for ICDD Containers using SHACL

Case Studies



Case Studies

1) BIM-based Construction Scheduling



2) BIM-based Infrastructure Management



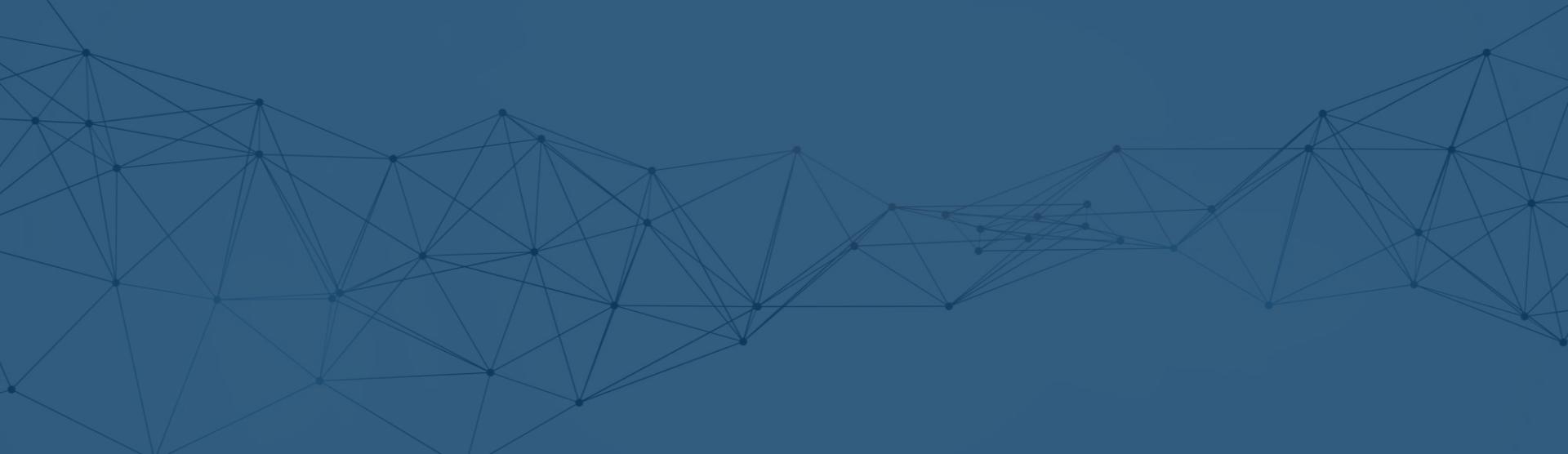
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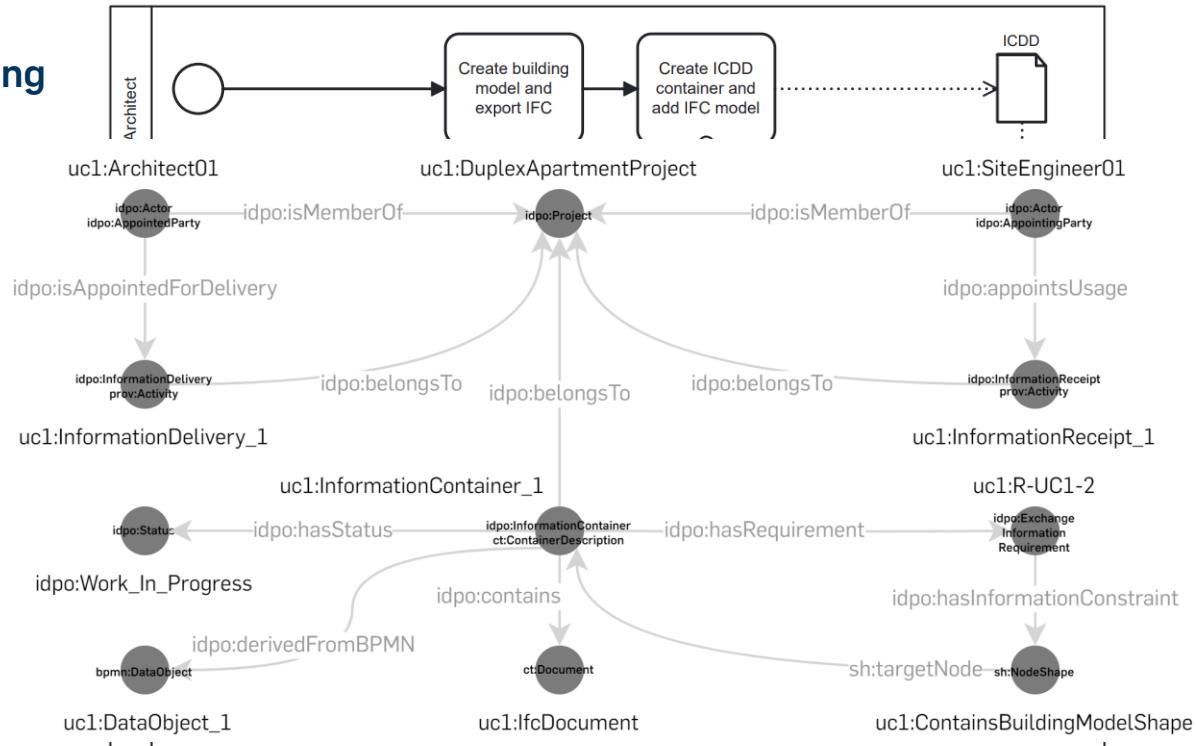
Case Study 1

Building Construction



Case Study 1

BIM-based Construction Scheduling

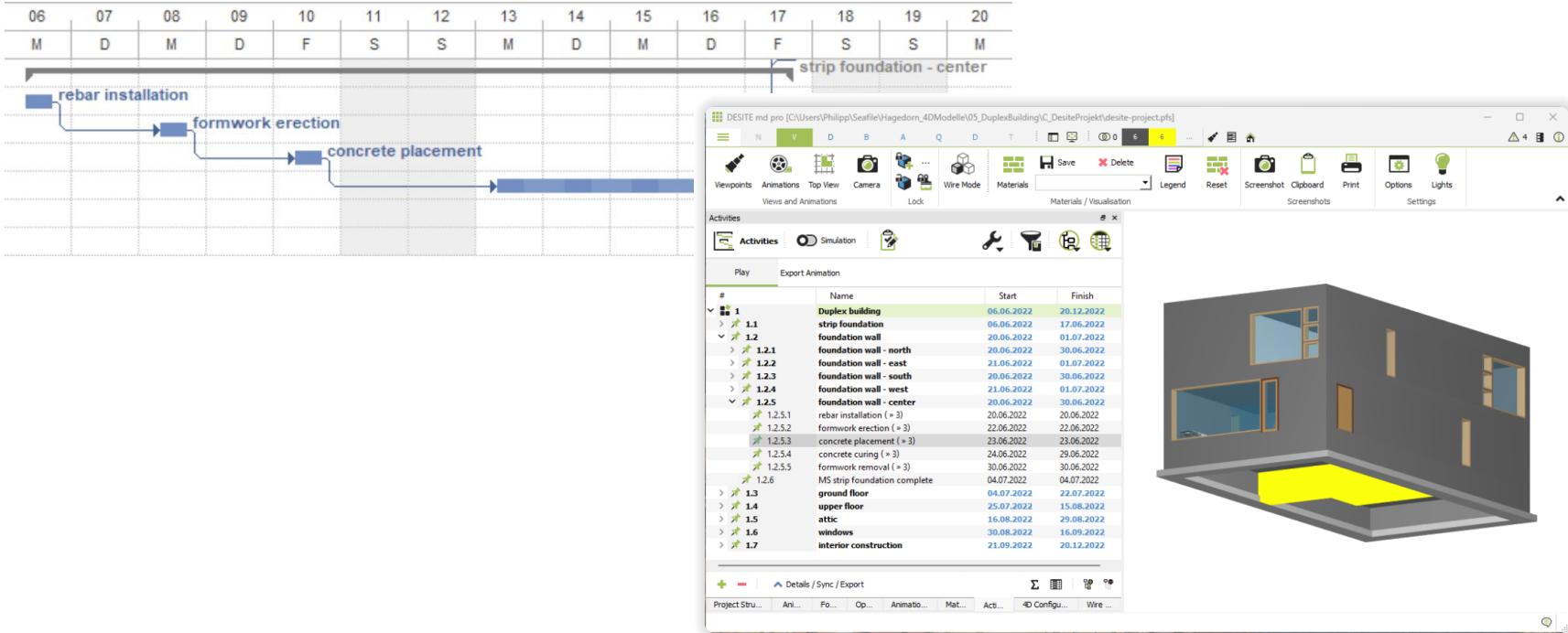


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Exchange Information Requirements for ICDD Containers using SHACL



BIM-based Construction Scheduling



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Exchange Information Requirements for ICDD Containers using SHACL

Delivery Plan

Reviewing the Delivery Plan in the ICDD Platform

RUB ICDD PLATFORM HOME PROJECTS SHAPES MANAGEMENT DOCUMENTATION API CONTACT ADMIN AREA Messages philippagedorn LOGOUT RUB

Start / Projects / PhD_Thesis_Hagedorn / Containers / UC1_design_duplex_building.icdd

EXPLORER

- PhD_Thesis_Hagedorn
 - UC1_design_duplex_building.icdd [version 1 of this document]
 - UC1_design_duplex_building.icdd
 - index.rdf
 - Ontology Resources
 - Container.rdf
 - Linkset.rdf
 - ExtendedLinkset.rdf
 - ExtendedDocument.rdf
 - Payload documents
 - model.ifc
 - schedule.xml
 - Payload triples
 - bim-based-schedule.rdf
 - delivery-plan.ttl
 - UC2_operation_bridge.icdd (change container)

CONTENT

uc1:EachElementLinkedToMinOneTaskShape

uc1:EachTaskHasUidShape

uc1:fcDocument

uc1:InformationContainer_1

uc1:InformationContainer_1_1

rdf:type	idpo:InformationContainer
rdf:type	ct:ContainerDescription
idpo:belongsTo	uc1:DuplexApartment
idpo:contains	uc1:fcDocument
idpo:contains	uc1:XmlSchedule
idpo:derivedFromBPMN	uc1:DataObject_2
idpo:hasRequirement	uc1-R-UC1-10
idpo:hasRequirement	uc1-R-UC1-4
idpo:hasRequirement	uc1-R-UC1-5
idpo:hasRequirement	uc1-R-UC1-6
idpo:hasRequirement	uc1-R-UC1-7
idpo:hasRequirement	uc1-R-UC1-8
idpo:hasRequirement	uc1-R-UC1-9
idpo:hasStatus	idpo:Shared
idpo:isProvidedBy	uc1:InformationDelivery_2
idpo:isReceivedBy	uc1:InformationReceipt_2
rdfs:label	Information container 1.1

uc1:InformationDelivery_1

uc1:InformationDelivery_2

PROPERTIES

XBM Ifc.js

Transparency mode Orbit Reset viewer

Model model.ifc Visibility

Selected elements:

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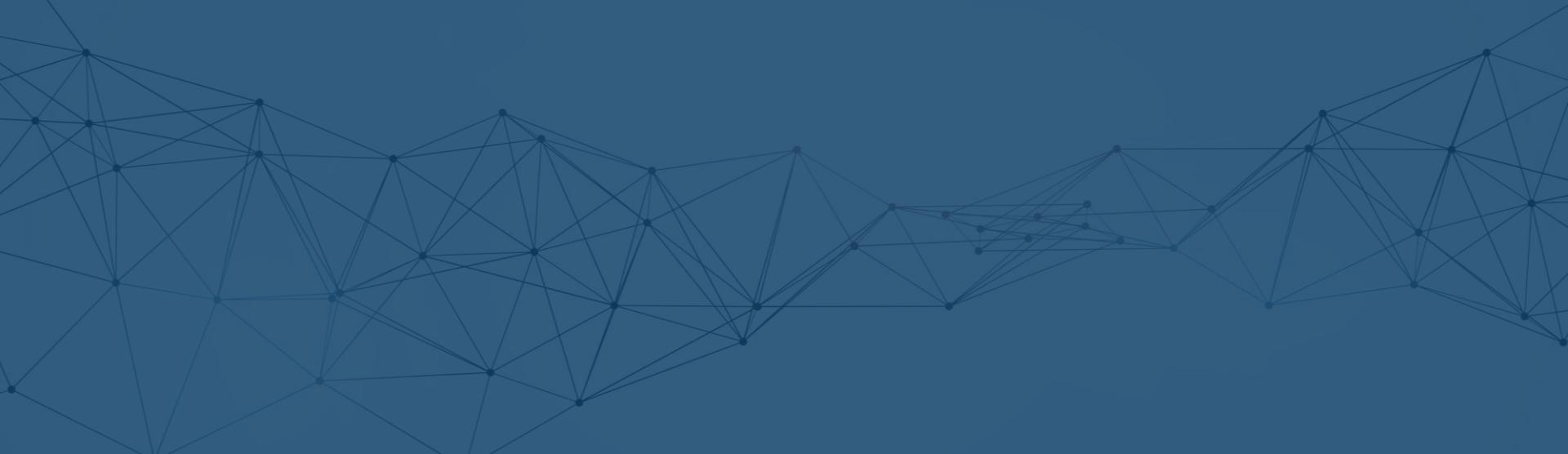
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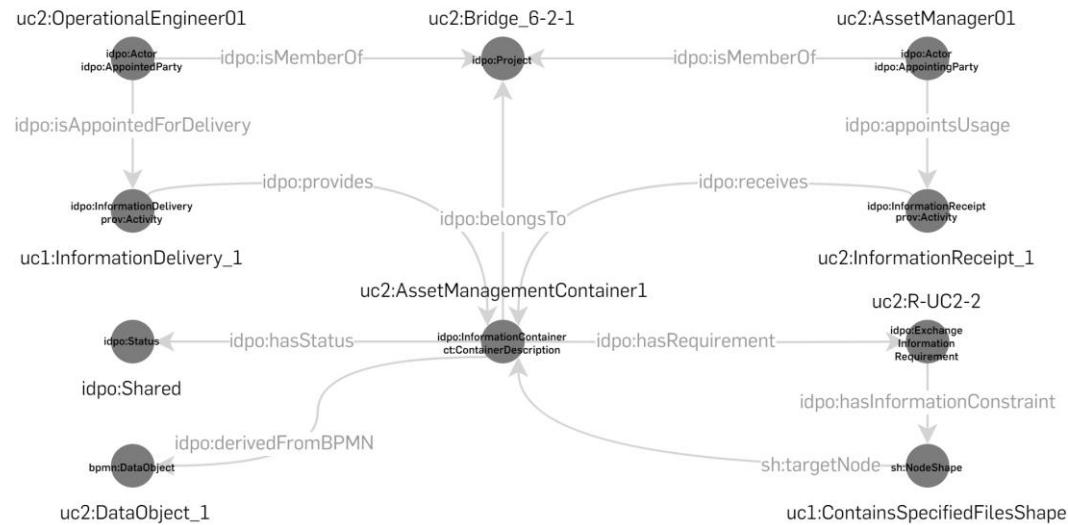
Case Study 2

Infrastructure Management



Case Study 2: BIM-based Infrastructure Management

Bridge Condition Assessment



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Exchange Information Requirements for ICDD Containers using SHACL

Case Study 2: BIM-based Infrastructure Management

Bridge Condition Assessment

Defined Requirements

Conformance **R-UC2-1** The container must be compliant with ISO 21597 [127, 129] except for the employed *exdoc:ExternalRelationalDatabase* instance.

Structure **R-UC2-2** The container must have all specified files registered.

Domain **R-UC2-3** Each RDF *Component* converted from the database must sustain the interrelation to an RDF *Structure* entity.

Domain **R-UC2-4** Each RDF *Inspection* converted from the database must sustain the interrelation to an RDF *Structure* entity

Domain **R-UC2-5** Each RDF *Condition* converted from the database must sustain the interrelation to an RDF *Component* and an RDF *Inspection* entity

Link **R-UC2-6** Each element in the model.ifc must be linked to an RDF *Component* converted from the database.

Link **R-UC2-7** Each element in the model.ifc must not exceed a condition grade of 2.4 in the latest inspection record.

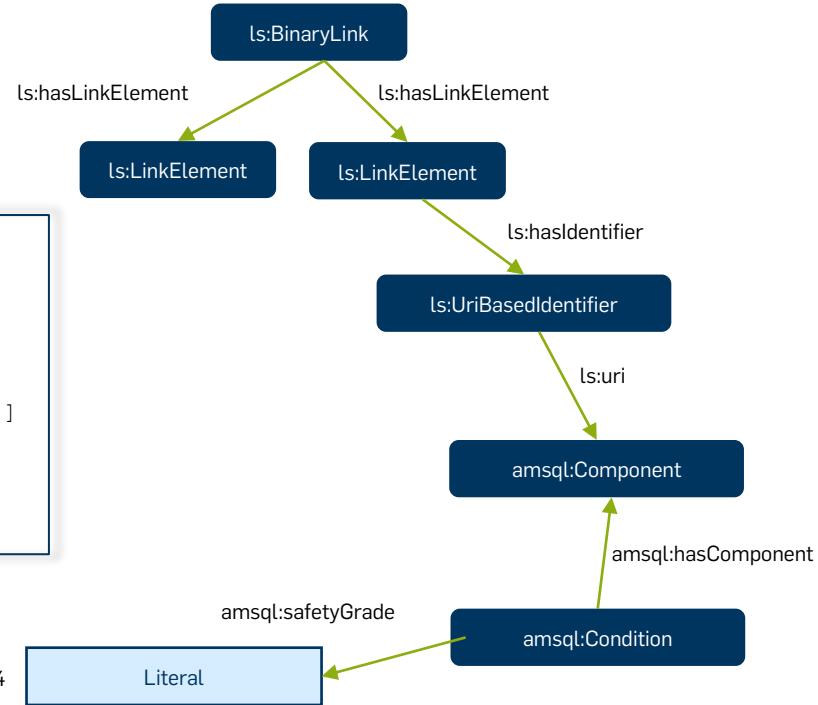
Case Study 2

Bridge Condition Assessment

Link

R-UC2-7 Each element in the model.ifc must not exceed a condition grade of 2.4 in the latest inspection record.

```
[ ] rdf:type sh:PropertyShape ;
  sh:path (
    ls:hasLinkElement
    ls:hasIdentifier
    ls:uri
    [ sh:inversePath
      <http://icdd.vm.rub.de/ontology/amsql#hasComponent> ;
      <http://icdd.vm.rub.de/ontology/amsql#safetyGrade>
    ) ;
  sh:maxInclusive 2.4 ;
  sh:message "has safety grade worse than 2.4" .
```



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EXPLORER

- PhD_Thesis_Hagedorn
 - UC2_operation_bridge.icdd
 - index.rdf
 - Ontology Resources
 - Container.rdf
 - Linkset.rdf
 - ExtendedLinkset.rdf
 - ExtendedDocument.rdf
 - Payload documents
 - 6-2-1_bridge_model.ifc
 - 6-2-1_Plan_01_Overview.pdf
 - 6-2-1_Plan_02_Abutment.pdf
 - 6-2-1_Plan_03_Column.pdf
 - DatabaseMapping.ttl
 - InspectionDatabase
 - Payload triples
 - links-model-database.rdf
 - delivery-plan.ttl
 - InspectionDatabase.inst.ttl
 - UC1_design_duplex_building.icdd (change container)
 - UC1_design_duplex_building.icdd (change container)

CONTENT

Container
Linked Data

```

40 sh:property [
41   rdf:type sh:PropertyShape ;
42   sh:path (
43     ls:hasLinkElement
44     ls:hasIdentifier
45     ls:uri
46     [
47       sh:inversePath
48       <http://icdd.vm.rub.de/ontology/amsql#hasComponent> ;
49       <http://icdd.vm.rub.de/ontology/amsql#stabilityGrade>
50     )
51     sh:maxInclusive "2.4" ;
52     sh:message "has stability grade worse than 2.4" ;
53   ];
54   sh:targetClass ls:BinaryLink ;
55

```

Apply RDFS Inference Execute

Result	Node	Validated Path	Found Value	Message	Affected IFC Objects
sh:Violation of Shape	ns0:Binary Link- _-:8304043 62- 15301527	_-:5610267 91- MEQx1t4Zck eKe8nM4aeS tA	2.7	has safety grade worse than 2.4	0EA6U3GuX 43hBMVUl DQFm

PROPERTIES

Properties
Status & Review
Issues
IFC-Viewer

Transparency mode

Orbit

Reset viewer

Model

Visibility

6-2-1_bridge_model.ifc

Selected elements:

0EA6U3GuX43hBMVUlDQFm

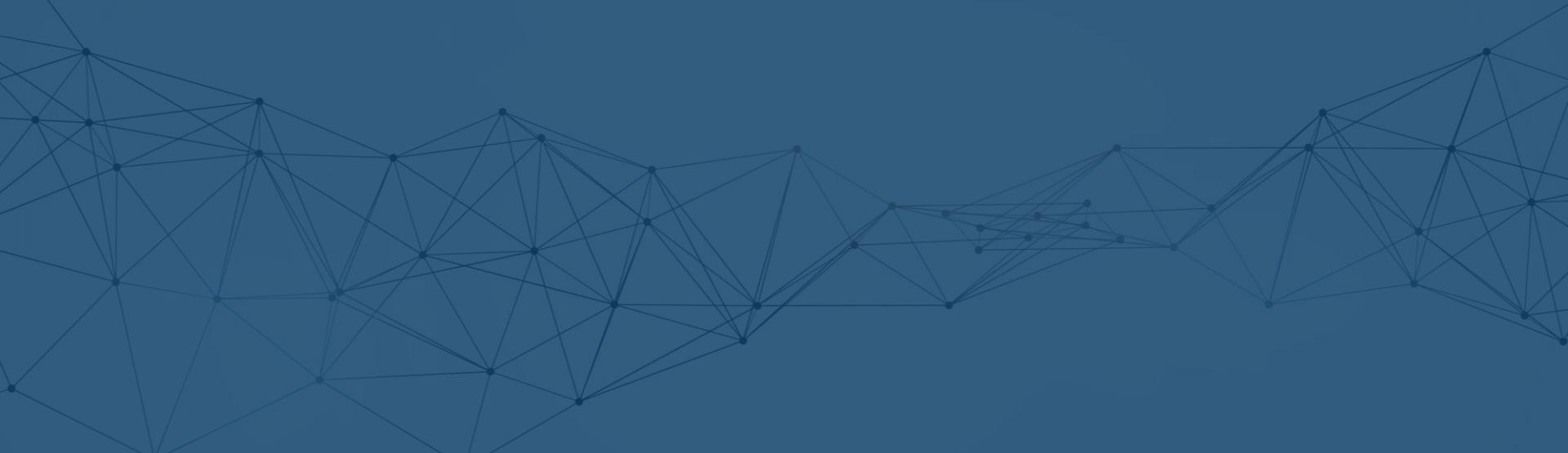
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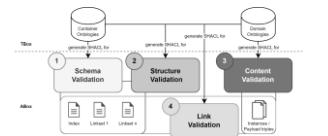
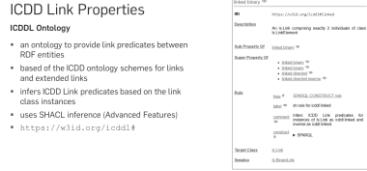
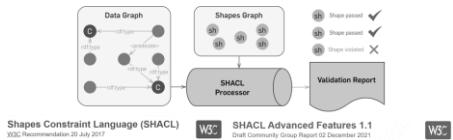


Exchange Information Requirements for ICDD Containers using SHACL

Conclusion



Conclusion



jyrkioraskari / IFCtoLBD



r



r2rml4net



philhag



msproj-xml-to-lbd

R2RML: RDB to RDF Mapping Language



synthesize the extension approaches and EIR
→ propose a revision of the ICDD standard

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Exchange Information Requirements for ICDD Containers using SHACL

LDAC 2024 in Bochum

LDAC2024 - Linked Data in Architecture and Construction Week

Summer School (10-12 June 2024)

+

12th Linked Data in Architecture and Construction Workshop
(13 - 14 June 2024)



Exchange Information Requirements for ICDD Containers using SHACL



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