

A shared construction resource ontology for semantically aligning cost and time domains in construction projects

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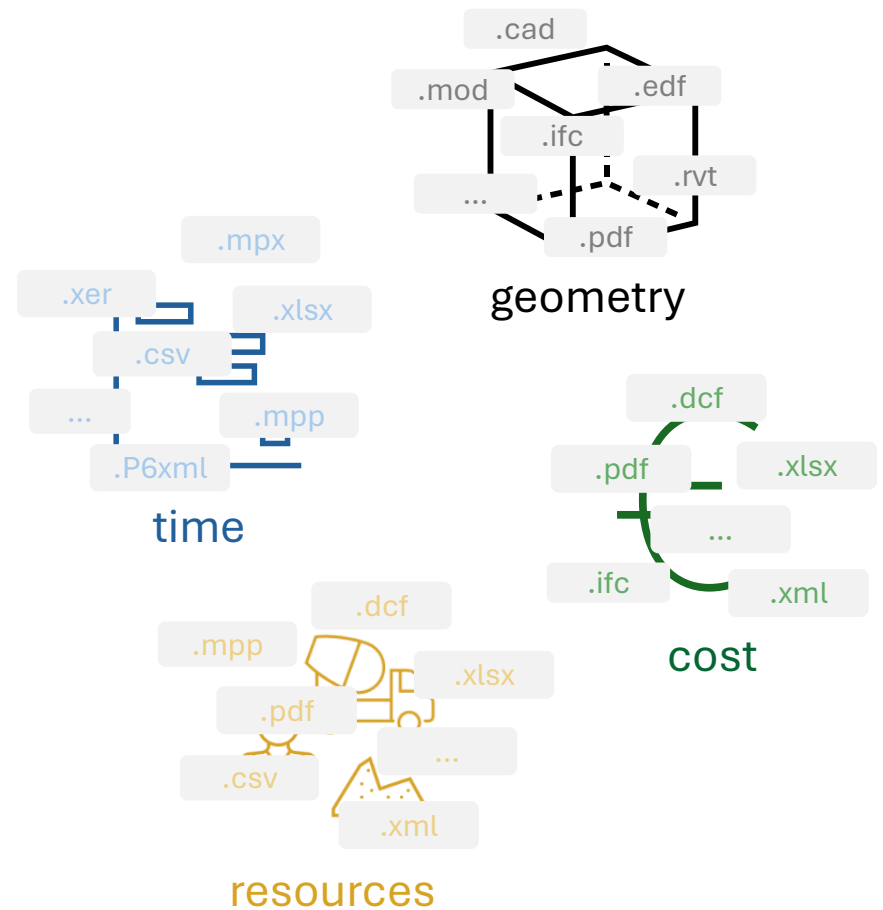
Introduction

- **Costing and scheduling** are critical, **interdependent** processes
- Both processes must be **continuously balanced**
- Construction documents are often managed separately, leading to **fragmented workflows** and inefficiencies
- A **lack of integration** between time and cost causes misaligned planning, resource conflicts, and redundant data handling



Problem Statement

- **Mismatch in resource definitions** in time schedule vs cost documents
- **Resources** are **rarely modeled** explicitly and **aligned** across scheduling and costing
- **Duplicate and implicit resource modeling**, same resource may appear **multiple times** with inconsistent usage
- This **fragmentation** hampers control, causes cost overruns, and limits traceability

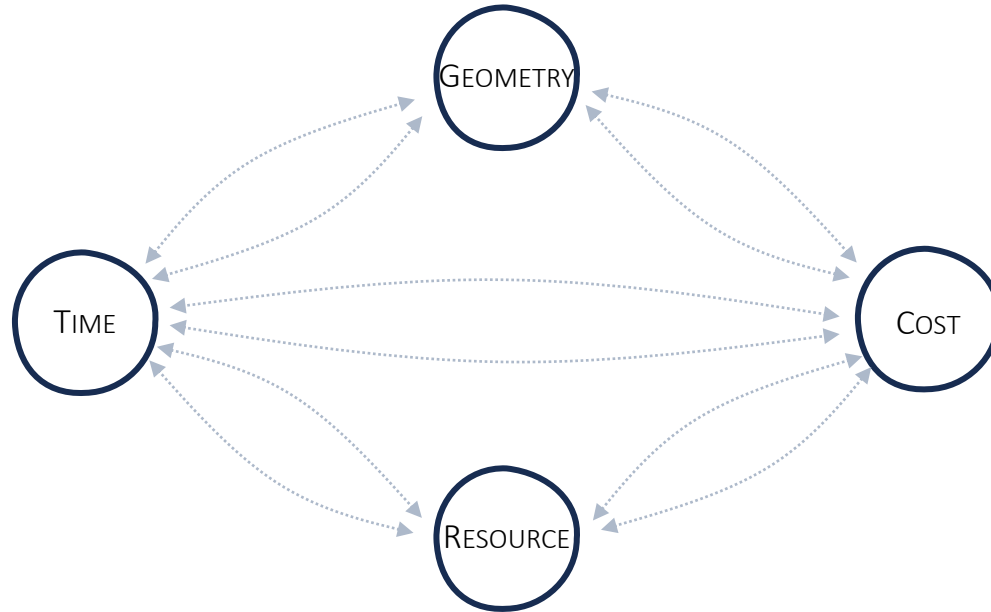


Research Gap

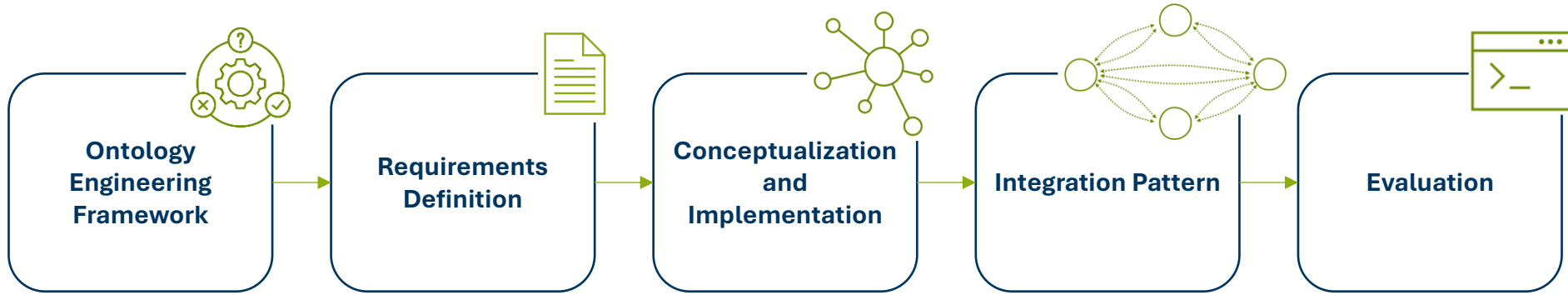
- **ifcOWL**
 - Supports **basic links between geometry-cost and geometry-tasks**, but **lacks granular representation** for cost and time data
 - Entities like **IfcCostItem** and **IfcTask** are **underspecified** (absence of detail properties)
- **Domain fragmentation**
 - **Existing ontologies** often **focus on a single domain** (cost or time)
 - **Lack of a unified**, resource-centered representation across domains

Research Aim

- Develop a **shared ontology to align cost, time, resource, and geometry domains**
- Enable traceable, interoperable, reusable and machine-interpretable project data



Methodology



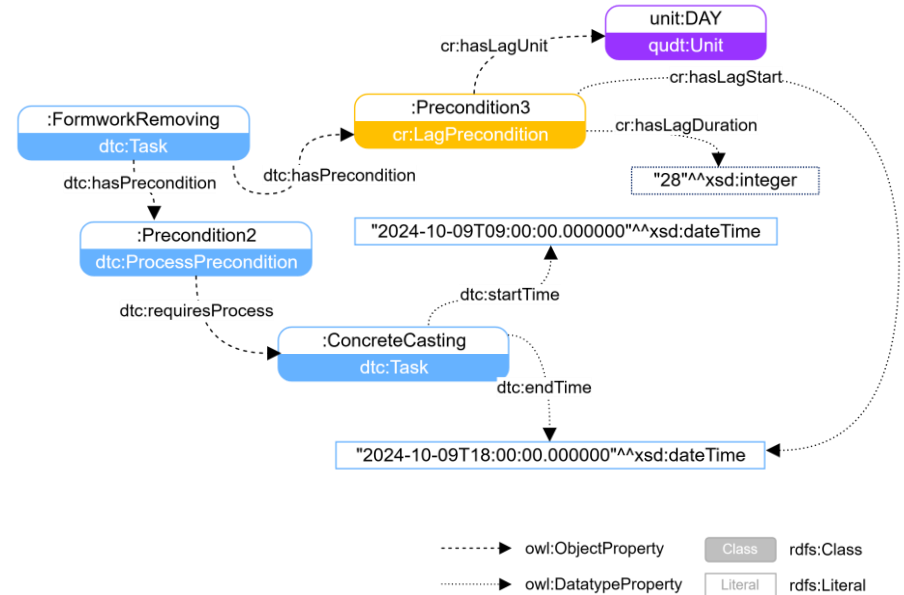
Requirements Definition

Cost	Time	Resource
C1: How is a cost item defined?	T1: How is a task defined?	R1: How is resource defined?
C2: Which types of cost components constitute a cost item?	T2: How is a task connected to a cost item?	R2: Which type of resources exist?
C3: How is the cost item connected to the building product in the IFC model?	T3: How is the task connected to the building product in the IFC model?	R3: How is a resource connected to a cost item?
C4: How is the quantity of the building product used for the cost estimation?		R4: How is a resource with a specific utilization rate connected to a task?

Conceptualization and Implementation - Time

■ Digital Twin Construction (DTC) Ontology

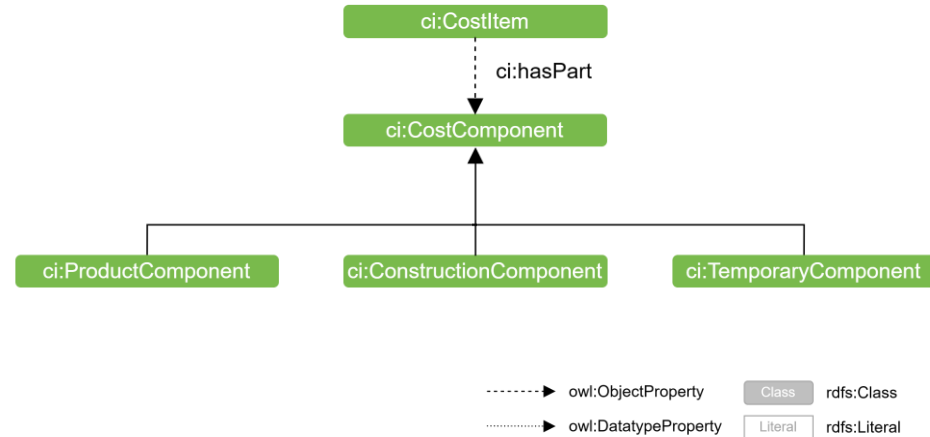
- **dtc:Task**: core class representing a construction activity
- **Preconditions** allow representation of logical and temporal dependencies (e.g. dtc:ProcessPrecondition)



Conceptualization and Implementation - Cost

■ Cost Item (CI) Ontology

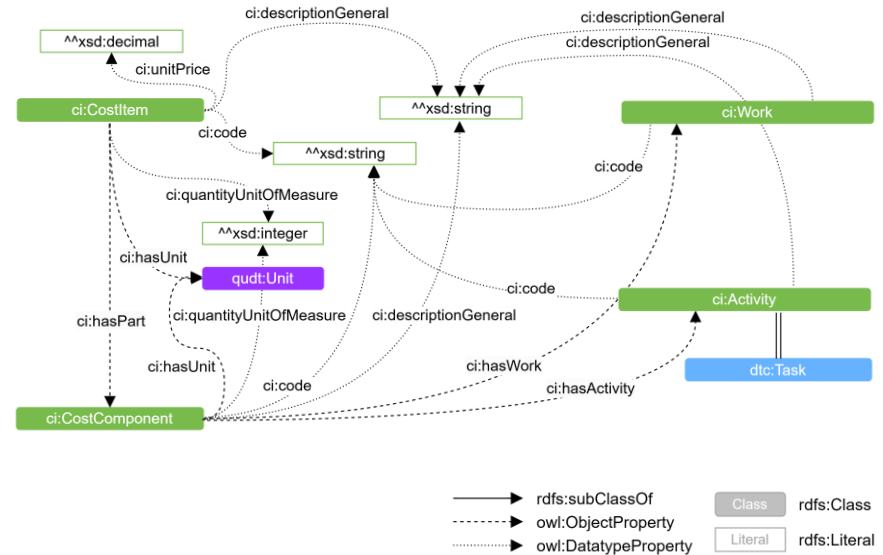
- **ci:CostItem**: core class representing a unit cost
- **Aggregation pattern** via **ci:hasPart** to **ci:CostComponent** entities
- **3 subclasses**:
 - ci:ConstructionComponent
 - ci:ProductComponent
 - ci:TemporaryComponent



Conceptualization and Implementation - Cost

■ Cost Item (CI) Ontology

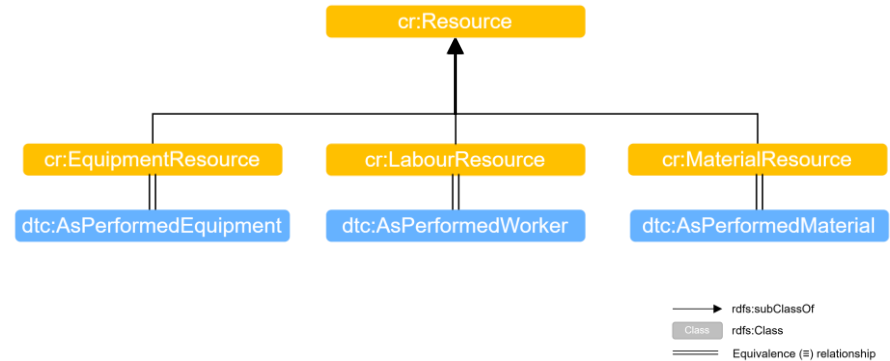
- **ci:Work**: class representing the physical part of the construction work (“wall”)
- **ci:Activity**: class representing the action that must be performed to carry out the construction work (“creation” or “demolition” of the wall)
- **Properties**: ci:code, ci:unitPrice, ci:description, ci:hasUnit, etc.
- **Units** reused from **QUDT ontology**
- **Multilingual classification**: via the CTERM ontology (cterm:Function, etc.)



Conceptualization and Implementation - Resource

■ Construction Resource (CR) Ontology

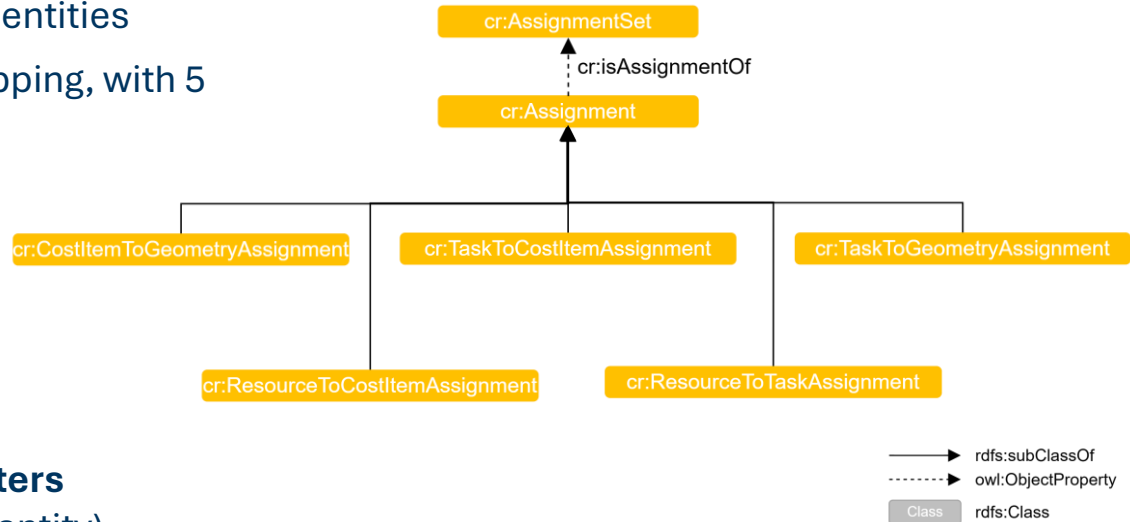
- **cr:Resource**: core class representing all resource entities (labor, materials, equipment)
- **3 subclasses**: cr:EquipmentResource, cr:MaterialResource, cr:LabourResource
- **Semantic Equivalency** between CR and DTC ontology:
 - cr:LabourResource \equiv dtc:AsPerformedWorker
 - cr:MaterialResource \equiv dtc:AsPerformedMaterial
 - cr:EquipmentResource \equiv dtc:AsPerformedEquipment



Conceptualization and Implementation - Assignment

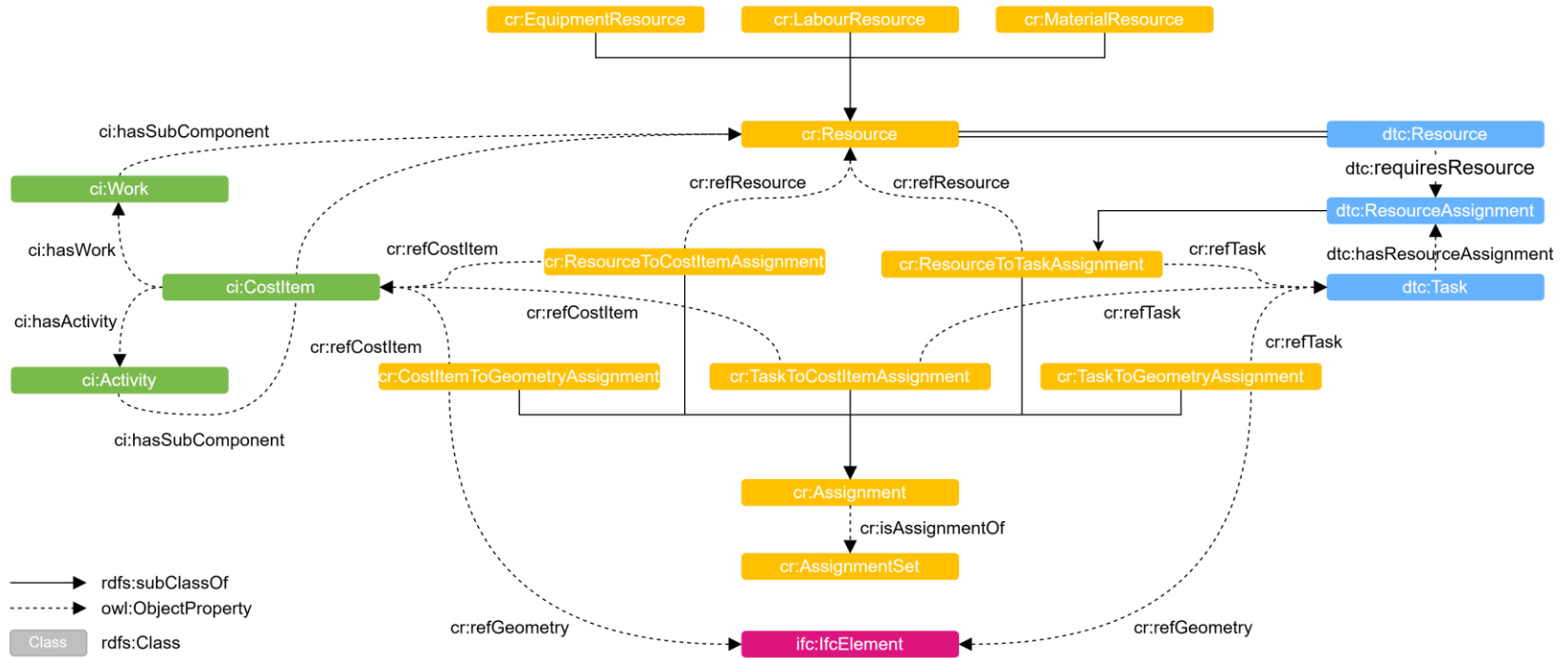
- **Assignment across domains**

- **cr:AssignmentSet**: container for multiple **1-to-1 mappings** between domain entities
- **cr:Assignment** single 1-to-1 mapping, with 5 subclasses:
 - cr:CostItemToGeometryAssignment
 - cr:TaskToCostItemAssignment
 - cr:TaskToGeometryAssignment
 - cr:ResourceToCostItemAssignment
 - cr:ResourceToTaskAssignment



- Assignments may **carry parameters** (e.g., utilization rate, formula, quantity)

Conceptualization and Implementation



Conceptualization and Implementation - Terminology

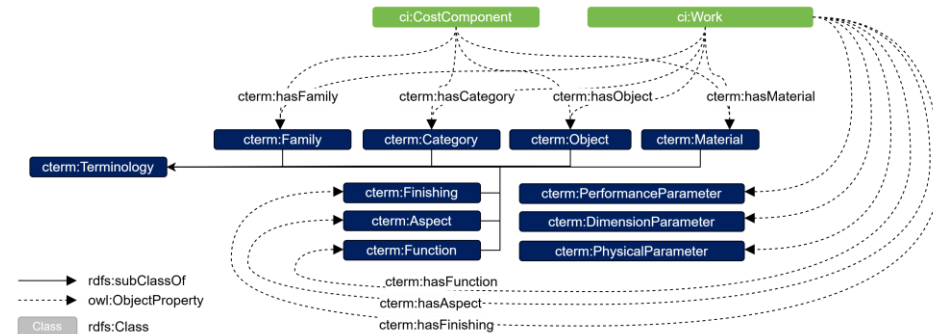
- **Construction Terminology (CTERM) Ontology**

- **Core terminology classes:** cterm:Object, cterm:Material, cterm:Function, etc.

- **Vocabulary terms** can be:

- **Reused** across ontologies
- **Specialized by semantic role** (e.g., cterm:Reinforcement used as cterm:Function)
- **Labeled in multiple languages** (@en, @de, @it)

- The CTERM ontology will also be made available as SKOS vocabulary in future work.

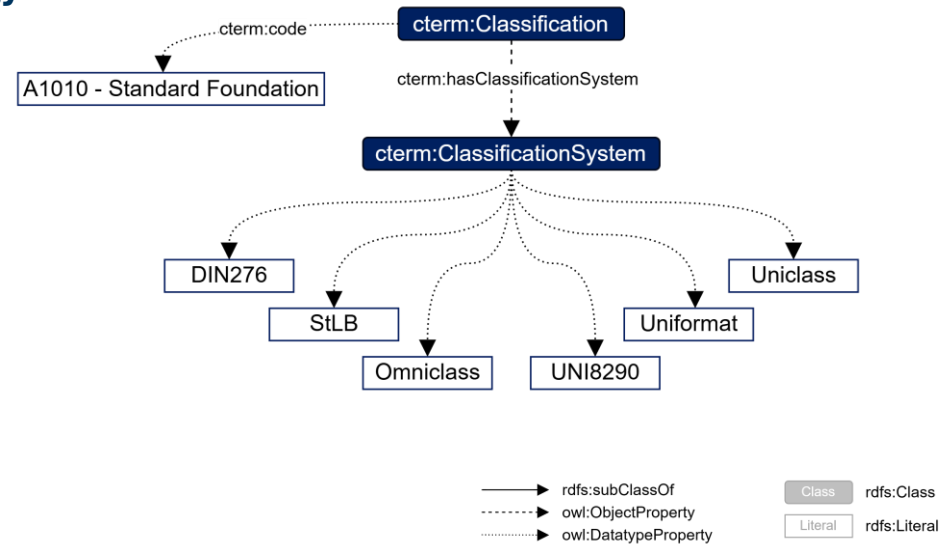


Conceptualization and Implementation - Classification

■ Construction Terminology (CTERM) Ontology

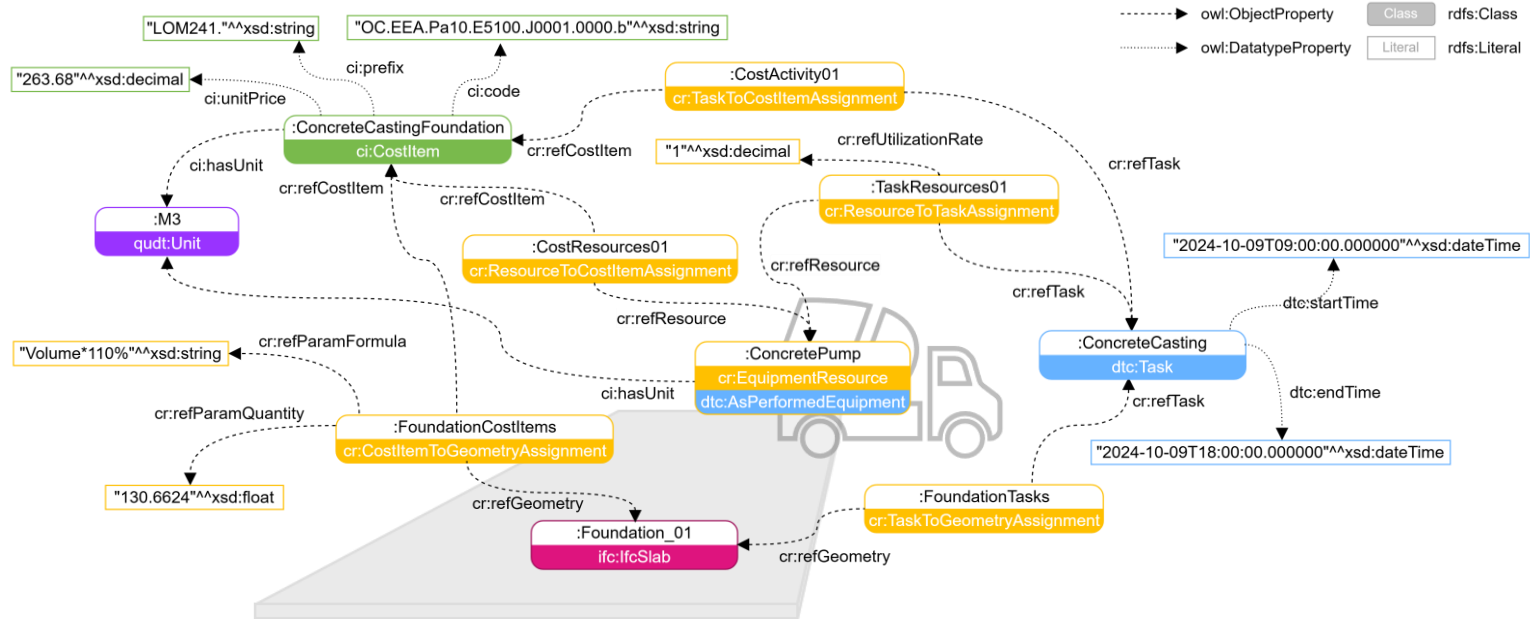
■ 6 classification systems referenced:

- cterm:DIN276 (German)
- cterm:StLB (German)
- cterm:UNI8290 (Italian)
- cterm:Omniclass
- cterm:Uniclass
- cterm:Uniformat



Evaluation

- The **evaluation** of the conceptualized and implemented **resource-centric ontology network for construction project management** is based on a **sample dataset**



Evaluation – CQs C1-C4

```
1 PREFIX cr: <https://w3id.org/cr#>
2 PREFIX ci: <https://w3id.org/ci#>
3 PREFIX dtc: <https://dtc-ontology.cms.ed.tum.de/ontology#>
4 SELECT ?item ?component ?type ?product ?qty ?formula
5 WHERE {
6   ?item a ci:CostItem .
7   ?item ci:hasPart ?component .
8   ?component a ?type .
9   ?assignment cr:refCostItem ?item .
10  ?assignment cr:refGeometry ?product .
11  ?assignment cr:refParamQuantity ?qty .
12  ?assignment cr:refParamFormula ?formula .
13 } LIMIT 1
```

Listing 1: SPARQL Code for CQs C1–C4

Results of the query for CQs C1–C4

item	component	type	product	qty	formula
:Foundation_LOM241. OC.EEA.Pa10.E5100. J0001.0000.b	:ConstructionComponent_OC.EEA. Pa10.E5100. J0001.0000.b	ci:ConstructionComponent	geometry:lfc-Slab_905	130.6624	Volume*1.1

Evaluation – CQs T1-T3

```
1 SELECT ?task ?ci ?product
2 WHERE {
3   ?task a dtc:Task.
4   ?assignment1 cr:refTask ?task.
5   ?assignment1 cr:refCostItem ?ci.
6   ?assignment2 cr:refTask ?task.
7   ?assignment2 cr:refGeometry ?product.
8 } LIMIT 1
```

Listing 2: SPARQL Code for CQs T1–T3

Results of the query for CQs T1–T3

task	ci	product
scheduling:Task_LEANCONCRETECAST- ING_4152F6CF-A19D-EF11-A011-A059508B7099	:SubFoundation_LOM241.OC.EEA.Pa10. A6415.J0001.0025.-	geometry:lfcSlab_2649

Evaluation – CQs R1-R4

```
1 SELECT ?res ?type ?ci ?task
2 WHERE {
3   ?res a ?type .
4   { ?assignment1 cr:refResource ?res .
5     ?assignment1 cr:refCostItem ?ci. }
6 UNION
7   { ?assignment2 cr:refResource ?res .
8     ?assignment2 cr:refTask ?task. }
9 }
```

Listing 3: SPARQL Code for CQs R1–R4

Results of the query for CQs R1–R4

res	type	ci	task
:LabourResource_RU.00.00.00.0005.-	cr:LabourResource	:Reinforcement- Bar_LOM241.OC.EEA. Pa02.E9700.Sb017.0255.-	
scheduling:Resource_WORKER1_6A52F6CF-A19D-EF11-A011-A059508B7099	cr:LabourResource		scheduling:Task_RE- BARS_4952F6CF-A19D-EF11- A011-A059508B7099

Conclusion

■ Benefits

- Developed a **shared construction resource ontology** aligning cost, time, and geometry domains
- Improved **traceability** and **coordination** in BIM-based project planning
- Basis for **automated validation** of cost/schedule coherence

■ Limitations

- Requires **consistent modeling** of shared resources in both domains
- Manual intervention still needed when **resource definitions diverge**
- Generalizability across **diverse regulatory and project contexts** remains to be validated

■ Future Work

- Validation on **real project data**
- Analysis of **different scenarios** (e.g. weekly resource usage, comparing cost-schedule resource planning)

Thank you

RUB

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