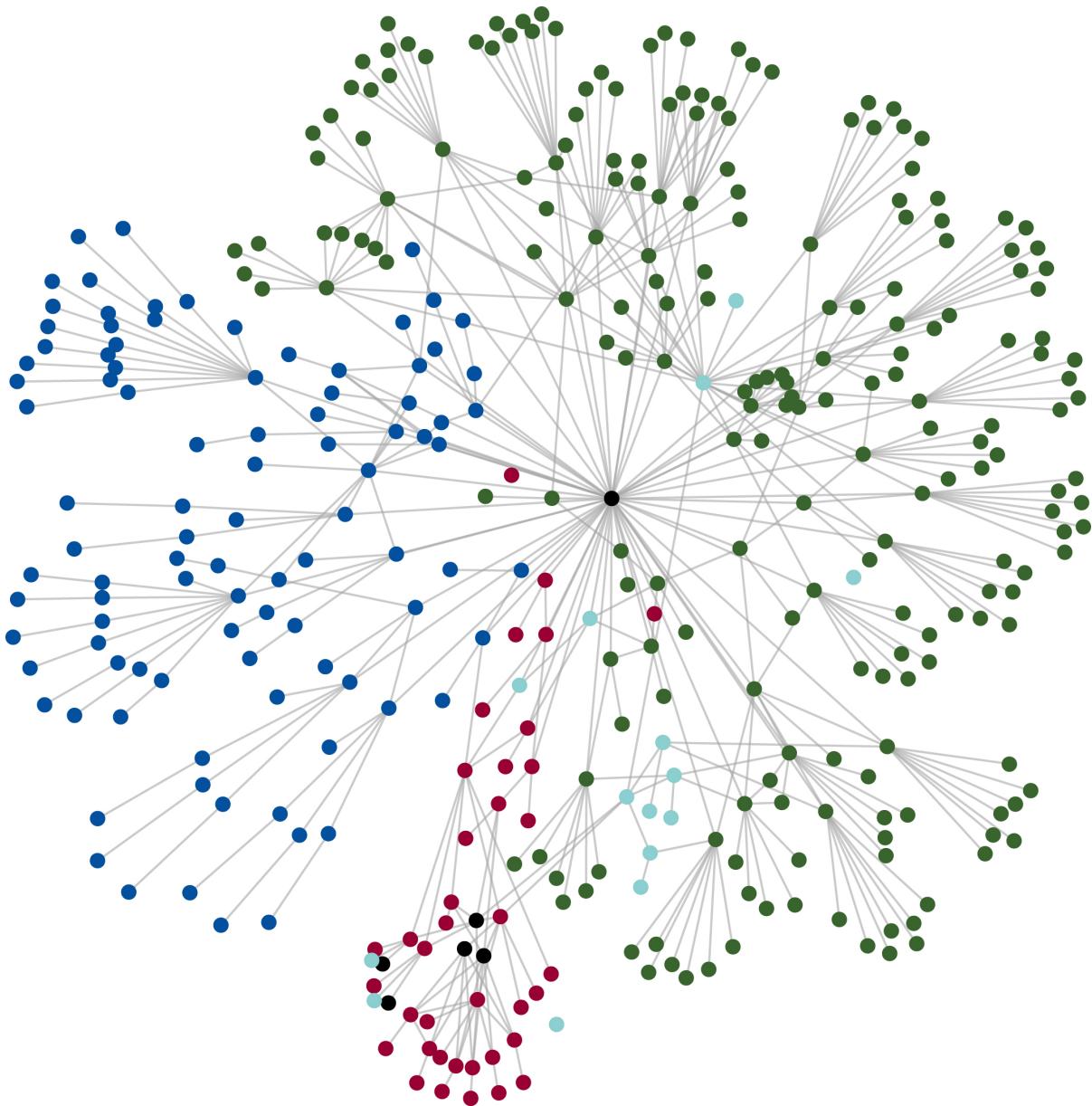


Semantic Web for Linked Data in Construction

Connecting LCA-Database to IFC-Model

Bachelor Thesis | Isabelle Seifert | July 05, 2024



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1 Abstract

New challenges arise every day in the construction industry, and international organisations are working hard to mitigate them by conducting research and creating new databases and tools to evaluate a construction project most efficiently. However, most databases are created independently from the BIM software used to manage and display construction projects, which makes it difficult to use them in any process during the different project phases. This brings up the challenge of connecting both and enriching the BIM-model with relevant data. The heterogeneity of data structure and a missing conventional naming and classification scheme make it especially hard to find a linkage.

The aim of this thesis is to explore a way to bridge the gap between BIM software and relevant datasets. The overall strategy used is to create a semantic web using the Resource Description Framework (RDF). The dataset that has been chosen for this work is the German environmental dataset named Ökobaudat. To allow interoperability with any BIM-model, buildingSMART Data Dictionary (bSDD) is used as a universal naming scheme because it includes the IFC schema. Additionally, the product classification database Freeclass has been added to the semantic network to showcase the simple mapping of products to the respective environmental data.



Figure 1: buildingSMART Germany Logo (BuildingSMART, 2024)

2 Introduction

The Architecture, Engineering and Construction (AEC) industry is a big contributor to global resource depletion and other environmental impacts. It accounts for 40% of Greenhouse Gas Emissions (GHG) worldwide, generates 35% of the total waste in the EU and uses up to 50% of all extracted raw materials globally (Dervishaj & Gudmundsson, 2024) (see fig.2). Consequently, todays approach on planning and constructing a project needs to be reconfigured to reduce the construction industry's impact on climate change. To align with the goals of the Paris Agreement, the UN Environment Programme suggests adopting a life cycle approach in construction project planning (United Nations Environment Programme, 2022). This requires a multifaceted approach incorporating all aspects and phases of a construction project.



Figure 2: Environmental Impact Construction Industry

At the same time, the AEC industry is undergoing a big shift towards a more technological approach using Building Information Modelling (BIM) for an efficient workflow. This offers the opportunity to create tools to quickly include important environmental impact data into the project workflow and assess a design regarding its carbon footprint. The objective of this thesis is to explore a way to connect environmental databases containing Life Cycle Assessment (LCA) data to the respective design or evaluation software. The goal is to identify an approach that is holistic and can be used by all stakeholders involved in a project. Therefore, it should be usable with as many different software as possible to create efficient data exchange and communication.

3 Background

3.1 Life Cycle Assessment

LCA is a method of calculating the environmental impact of a construction project throughout its entire lifecycle. Each phase is assessed individually, helping to identify opportunities for reducing energy consumption, greenhouse gas emissions, and other negative environmental impacts (Finnveden et al., 2009). Figure 2 displays an entire lifecycle of a construction project. It shows the different phases from raw material extraction through material processing, manufacturing, distribution, use, repair, maintenance and disposal or recycling. The recommended whole lifecycle approach suggests calculating environmental impacts for all phases shown to compare and assess them holistically.

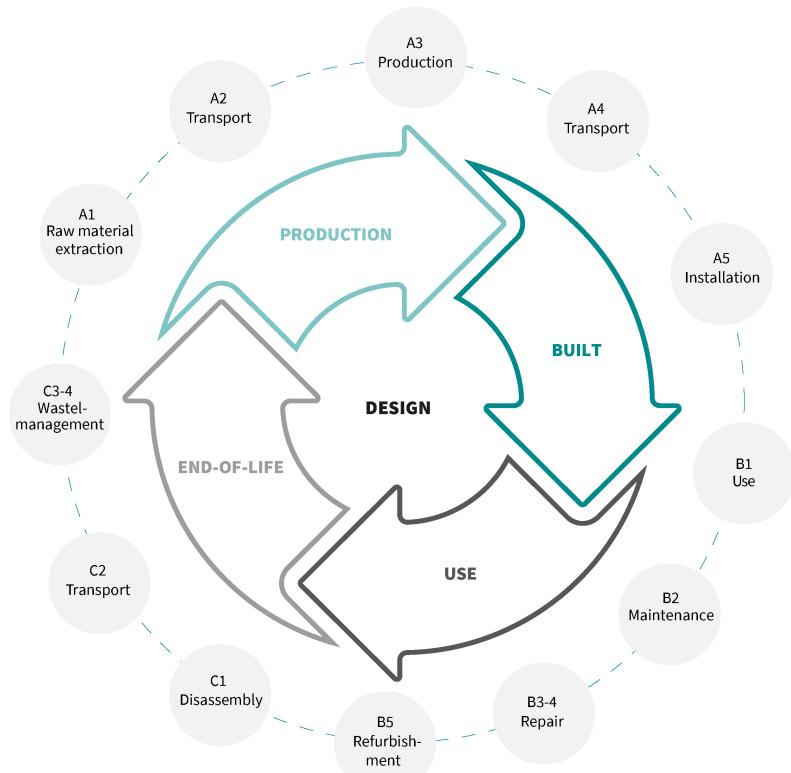


Figure 3: Life cycle of a construction project

LCA is a rather complex process, but it helps improve the environmental performance of construction projects and assists governments to establish guidelines and standards for sustainable construction (Barbhuiya & Das, 2023). Especially when conducted in early phases of a project, LCA can have a big impact, as the influenceability of a design outcome is highest in the early project phases (fig. 4).

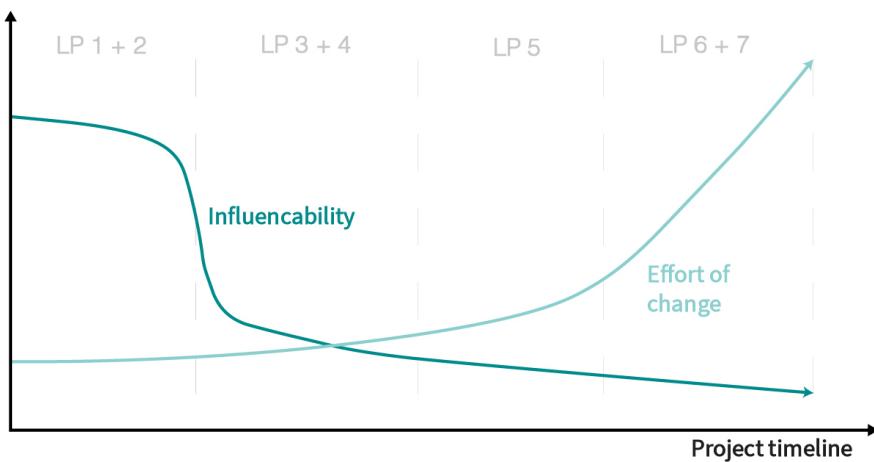


Figure 4: Project Influencability

3.2 BIM and LCA

BIM is an object-oriented database, utilized to represent the physical and functional characteristics of a construction project. It improves interdisciplinary work and supports visualization, coordination, simulation, and optimization (Lu et al., 2017). According to Sous-Verdaguer, Llatas and García-Martínes, several studies have shown that BIM can significantly improve a project workflow and help with early decision making by incorporating information into the model (Soust-Verdaguer et al., 2017).

The individual components of the model can be enriched with information used for efficient evaluation of different aspects like environmental impact or cost of a design. This presents a great opportunity for integrating environmental impact data into the BIM-model and evaluating it using LCA in the early stages of a project.

Sous-Verdaguer, Llatas, and García-Martínes also describe several studies with different approaches on LCA Data and BIM-model integration. Most of the case studies analysed used an automatic material quantification in the BIM environment to extract the bill of quantities in the form of an excel spreadsheet. Afterwards, the materials were manually organized and enriched before transferring them to the LCA application. These steps require expertise, are time-consuming and error-prone, which makes this method not proficient for exact analysis. Especially in early stages of design, BIM-based LCA needs significant manual input because the exact material quantities and details still need to be distinguished. This presents a big challenge for efficient early design decisions.

In every software integration or BIM tools analysed by Sous-Verdaguer, Llatas and García-Martínes, there was no tool without manual mapping of the data. This suggests that a new and different approach needs to be developed to mitigate these mapping issues (Soust-Verdaguer et al., 2017).

“The main problem is that most of the simulation tools and CAD are not linked together. The time-consuming manual data input and the additional expenditure to the normal planning work is economically not bearable, particularly if different scenarios have to be compared.”

— Neuberg et al., 2002

A much faster and direct evaluation within the BIM environment would be possible if the LCA-data was integrated directly into the BIM software and mapped to the building elements automatically. There have been approaches to automatically map the relevant data to the respective building components, but unconventional naming schemes and classification systems make it difficult to automatically allocate the data to the respective building elements. Therefore, early-stage decision making based on the relevant data is not possible, as there is no way of comparing design options without knowing the impact of changes in a design.

3.3 buildingSMART Data Dictionary as a Common Naming Scheme

In order to increase efficiency by doing the evaluation process directly within the BIM software and to allow for automatic mapping, Dervishaj and Gudmundsson suggest to find a common taxonomy for building components and LCA properties (Dervishaj & Gudmundsson, 2024). This would eliminate the need for dedicated LCA software. An efficient way to find common framework is the buildingSMART Data Dictionary (bSDD) developed by buildingSMART. It provides classification systems, definitions, properties and their allowed values, units, and translations for better interoperability between different software and matching data. It can help produce more reliable models for environmental assessment and collaborative work (Dervishaj & Gudmundsson, 2024).

3.4 Semantic Web as Solution

A semantic web is a way of creating a machine-readable format that contains information that can be accessed based on meaning rather than syntax. It can carry not only entities but also semantic information like relationships and dependencies between them. This holds great potential for displaying information from different databases and mapping them simultaneously to the respective values or entities of a BIM-model. There are several studies suggesting a semantic web as an approach to

improve data enrichment and interoperability in the construction industry. Especially for LCA analysis with its complex nature, it has been recommended for the mitigation of data distribution issues.

“LCA is an analysis that requires the integration of large complex heterogeneous databases with utmost accuracy. The semantic web is the only logical choice of technology for managing such a large-scale metadata-intensive problem.”

— Sobkhiz et al., 2021

Dervishaj and Gudmundsson also suggest knowledge management using a semantic web as key for multidisciplinary collaboration, since it improves interoperability between data sources when conducting LCA and accelerates decision-making during the design phases(Dervishaj & Gudmundsson, 2024).

3.5 Resource Description Framework (RDF)

RDF is the foundation of a semantic web structure. It is a machine-readable standard model consisting of a graph network made up of nodes and edges. Nodes being the entities described and edges the relation between them. (see fig.5)



Figure 5: RDF as Nodes and Edges

It is used for data exchange and has been developed to represent general relationships between multiple resources in the web. It facilitates the merging and connecting of data even if the underlying sources and schemes differ. RDF uses triples, which consist of a subject, predicate, and object, to represent data. This structure allows for the creation of a flexible and extensible model that can be used to describe relationships between different data points, each defined by an Universal Resource Identifier (URI).

Using URIs creates universal identities for data that remains consistent across databases. This allows for linking everything on the web and provides flexibility to the RDF schema. RDF's flexibility makes it well-suited for establishing a semantic network that connects multiple databases to classification systems. One example is the connection of the structure of a BIM-model, an ecological database, and a product classification database.

3.6 Ontology Languages

When creating a semantic web using RDF, ontology languages like RDFS, SKOS or OWL are being used to enrich the RDF structure with semantic information. As shown in the following illustration the ontology languages are used to add metadata to the nodes of the RDF model using URIs. (see fig.6)

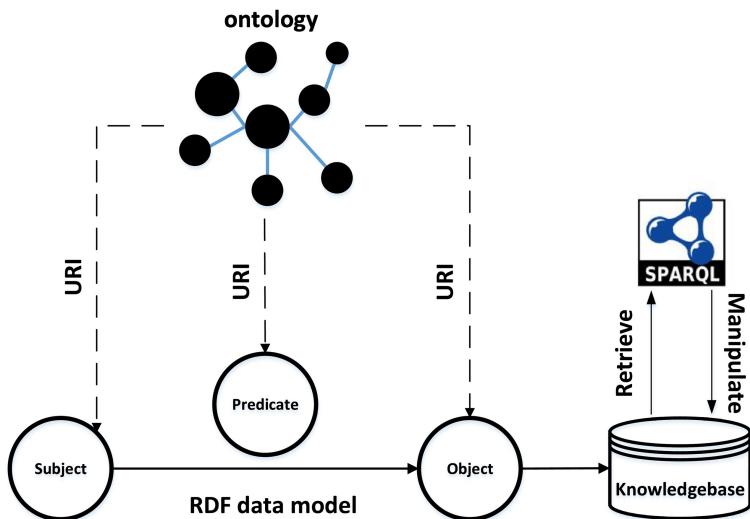


Figure 6: RDF model(Sobhkhiz et al., 2021)

3.7 SparQL Query Language

After the creation of the graph structure information can be retrieved using SPARQL Protocol and RDF Query Language (SparQL)(see fig.6). SparQL is a query language protocol to retrieve and manipulate data stored in the RDF format. It allows to extract, manipulate and even add data to a semantic web. Data can be filtered based on specific criteria, compared and evaluated based on semantic patterns. The use of SparQL presents the opportunity of creating an ever-growing semantic web, that can be queried for relevant data. It could enable the comparison of many data points across multiple databases that are connected semantically.

Example SparQL query:

```

1 SELECT ?subject ?predicate ?object
2 WHERE {
3   ?subject ?predicate ?object .
4 }
```

4 Methodology

This thesis aims to bridge the gap between environmental impact datasets and BIM-models, enabling a more efficient workflow when enriching the model with information. By constructing a semantic web using RDF, the objective is to illustrate the connections between material classifications in the BIM-model and the data of a database.

Creating these semantic connections, helps overcome the issues of non-identical naming conventions and ensure smooth cooperation between all stakeholders of a project using various software and datasets. LCA and the integration of respective datasets to the BIM-model is a current challenge in the construction industry. Therefore, the primary focus is on connecting environmental impact values to the materials of building components within the BIM-model. Connecting LCA databases to BIM-models would aid in making early design decisions based on LCA data, with the aim of creating designs that have minimal greenhouse gas emissions. It would facilitate easier material and supplier selection to reduce carbon emissions from production, transportation, installation, and other factors. Throughout the iterative design process, materials and manufacturers could be compared and assessed until the final design is achieved. Furthermore, an integrated workflow of LCA and BIM-model would streamline complex decision-making throughout the entire life cycle of a project. In short, the scope was defined first, then the classification schemes were analysed, and correspondences were identified and matched using ontology languages. Then mappings were made, creating semantic links between similar data in the different datasets. All information was translated into RDF and written in Turtle format. The resulting semantic web can be queried using the query language SparQL to extract information for different use cases. Additionally, for better illustration the semantic web graph has been visualized in the software Gephi.

The goal is to showcase the potential of integrating the semantic web in the design process using BIM and enriching a 3D model with environmental impact information. This web presents the opportunity to expand it to facilitate more semantic information as the industry evolves.

4.1 Limitations

The Industry Foundation Classes (IFC) format has been selected as the foundation of this work due to its widespread use in BIM software. To describe the IFC structure the bsDD, developed by buildingSMART, has been used. To narrow the scope of this thesis, Ökobaudat has been selected as an exemplary database for connection with the IFC structure. Since concrete is the most used material in construction and contributes over 7% of global greenhouse gas emissions annually (Springer Nature Limited, 2021), it has been chosen as the example material for creating the semantic web in this thesis. With 14 billion cubic meters annually, it is the most used human-made material on earth (Global Cement and Concrete

Association, 2021), which is why in future use cases a whole life cycle approach is very important to ensure proactive decision making. To make the semantic web as extensible as possible the knowledge graph DBpedia has been incorporated in the web by using the included definition for concrete.

Finally, the product classification database Freeclass has been selected to showcase how the semantic relation of a product to its environmental footprint can be displayed. This supports the comparability of different manufacturers and undermines decision-making. As ontology languages RDFS, OWL and SKOS were used to describe the semantic relationships between the different entities (see fig. 7).

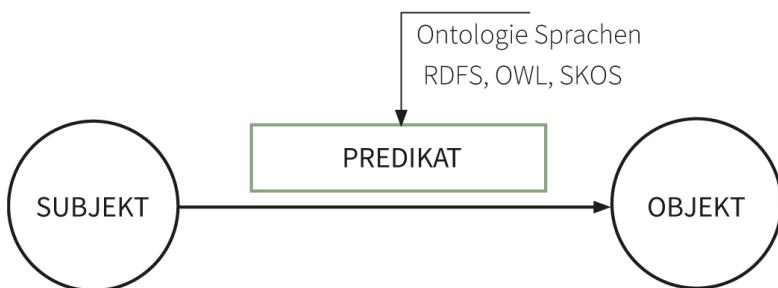


Figure 7: Ontology Languages Used

4.1.1 RDF Schema (RDFS)

RDF Schema (RDFS) provides a data-modelling vocabulary for RDF data and is a semantic extension of the basic RDF vocabulary. It is used to define the terms for RDF data and provide basic ontology capabilities for structuring and organizing this data (W3C, 2024).

The following key features have been used in this thesis:

Description of class hierarchies using *rdfs:Class* and *rdfs:subClassOf*

Domain and range using *rdfs:domain* and *rdfs:range*

Label and comments using *rdfs:label* and *rdfs:comment*

4.1.2 Web Ontology Language (OWL)

The Web Ontology Language (OWL) is a more expressive ontology language built upon RDF and RDFS, designed to represent complex information and relationships in a domain. OWL is used for creating ontologies, which define the structure of knowledge for various domains, enabling advanced reasoning about the entities within those domains (W3C, 2012).

The following key features have been used in this thesis:

Description of class hierarchies using *owl:Class* and *owl:subClassOf*

Property hierarchies using *owl:Property* and *owl:subPropertyOf*

Definition of values using *owl:hasValue*

Definition of data types using *owl:DatatypeProperty*

4.1.3 Simple Knowledge Organization System (SKOS)

The ontology language Simple Knowledge Organization System (SKOS) provides a standard way to describe concepts, their labels, definitions, relationships, and mappings between different schemes. This makes SKOS particularly valuable for integrating and linking knowledge from diverse sources, facilitating better data interoperability and retrieval in the semantic web. It can be used for creating mappings between entities and organizing them into groups(W3C, 2004).

The following key features have been used in this thesis:

Creating semantic relations using *skos:narrower* and *skos:broader*

Mapping entities using *skos:sameAs* , *skos:narrowMatch*,*skos:broadMatch* and *skos:closeMatch*

4.1.4 Example Application

Every instance of the datasets has been defined as *owl:Class* while given an *rdfs:label* for better readability. Within the different classification schemes *rdfs:subClassOf* has been used to describe class subclass relationships. The relation between the environmental impact values from Ökobaudat and the different material classes in the Freeclass classification database has been displayed using *skos:narrowMatch*. These mappings were done manually and with the respective accuracy. Entities representing the same type of material in the different databases were connected using *skos:sameAs*.

4.2 Analysis of Data Structures

4.2.1 DBpedia

DBpedia is the strongest worldwide available knowledge graph on the web.(DBpedia, 2024) It has been used in this thesis to serve as a base and define the material concrete in a very general and wholistic way. The DBpedia concrete is defined as a subclass of the DBpedia material and translated into triples as shown below.

```

1 # DBpedia Material Definition
2
3 dbp:Material a owl:Class .
4 dbp:Concrete a owl:Class ;
5     rdfs:subClassOf dbp:Material

```



Figure 8: DBpedia Logo (DBpedia, 2024)

For better illustration, the resulting nodes and edges of the semantic web are displayed as well. (see fig.9)

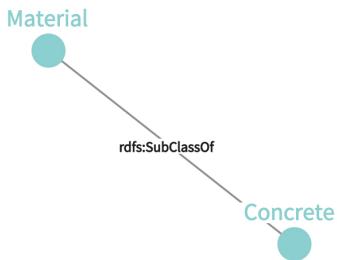


Figure 9: DBpedia Nodes and Edges

A second use case of DBpedia in this thesis has been the definition of the units for the Global Warming Potential (GWP). When comparing environmental impact values, the unit compared is very important to consider. In the Ökobaudat not all materials and elements have the same units. "kg CO₂/m²", "kg CO₂/kg", "kg CO₂/pcs" and "kg CO₂/m³" were defined in the RDF as units using the DBpedia unit definition as shown in the following triples.

```

1 # Define Units for GWP
2 dbpp:unit a owl:Property ;
3     rdfs:domain bSDD:uri/LCA/LCA/3.0/prop/GWP_total .
4 dbp:kg_CO2_m2 a dbpp:unit ;
5     rdfs:label "kg_CO2/m2" .
6 dbp:kg_CO2_kg a dbpp:unit ;
7     rdfs:label "kg_CO2/kg" .
8 dbp:kg_CO2_pcs a dbpp:unit ;
9     rdfs:label "kg_CO2/pcs" .
10 dbp:kg_CO2_m3 a dbpp:unit ;
11     rdfs:label "kg_CO2/m3" .
  
```

4.2.2 bSDD and IFC

The bSDD is a comprehensive and standardized database that provides a common language for defining and describing construction industry terms and concepts. It contains metadata of different concepts, properties, units, values, classifications, languages, and relations. It is a library for containing shared definitions in IDS specifications and IFC data and can be referenced by using the URI of each instance (BuildingSMART, 2024). The bSDD contains several dictionaries with distinct data in different languages and for various use cases. In this thesis the focus has been on the IFC and the LCA dictionary.

IFC is a data model standard for representing building information. It can be enriched with the templates provided by bSDD like templates for building components and material properties. It is structured in a class, subclass and properties system. Classes represent entities within the data model. They describe different building elements, systems and other entities relevant to their domain. Each class usually has a set of



Figure 10: bSDD Logo
(BuildingSMART, 2024)

properties describing different characteristics, behaviours, and relationships with other entities.

The IFC Schema contains already some semantic information about hierarchical relationships, but it is only a schema that does not contain actual values for different properties. Since the focal point of this thesis is the material concrete and its environmental impact values, the chosen scope is the “IfcMaterial” class and its subclass “Pset_MaterialConcrete”, which are included in the IFC 4.3 dictionary.

In the IFC dictionary there are no properties included concerning the environmental impact of a material included. Therefore, relevant properties from the LCA dictionary have been included like the global warming potential for every life cycle stage of a project. These properties are individually defined for different stage of the whole project life cycle for example “cPset_Environmental-ImpactValues_A1” and “cPset_EnvironmentalImpactValues_D”. As part of this thesis, the IFC dictionary and the LCA dictionary have been connected semantically to display their relationship and to add properties like the global warming potential to any material in an IFC based BIM-model. The hierarchical structure and the connection between the two dictionaries are displayed in the following illustration (see fig.11).

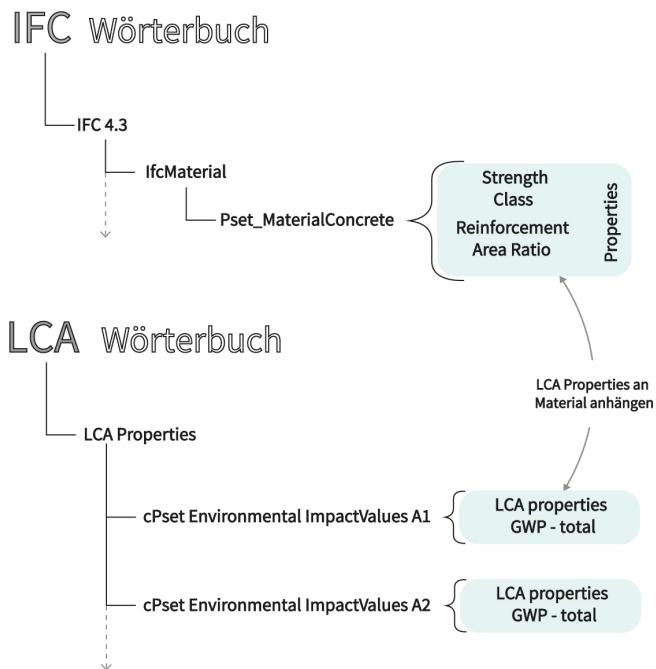


Figure 11: bSDD Structure

The structure of the two dictionaries has been translated manually into RDF triples in Turtle format. Shown below is a snippet of the RDF triples. Displayed is the incorporation of the properties “GWP_total” and “Strength-Class” of the respective material, in this case concrete.

“Pset_MaterialConcrete” was defined as the domain of the properties. The range of “GWP_total” has been defined as `xsd:double` and of `Strength-Class` as `xsd:string`, respectively. For better visualization, the main RDF strand of the hierarchical structure of the IFC and LCA dictionary is displayed as well, (see fig.12)

```

1 # Define IFC structure
2
3 bSDD:uri/buildingsmart/ifc a owl:Class ;
4   rdfs:label IFC    ^^xsd:string .
5
6 bSDD:uri/buildingsmart/ifc/4.3 a owl:Class ;
7   rdfs:subClassOf bSDD:uri/buildingsmart/ifc ;
8   rdfs:label IFC 4.3  ^^xsd:string .
9
10 # IfcMaterial as a class
11 bSDD:uri/buildingsmart/ifc/4.3/class/IfcMaterial a owl:Class ;
12   rdfs:label IFC Material^^xsd:string ;
13   rdfs:subClassOf bSDD:uri/buildingsmart/ifc/4.3.
14
15 # Pset_MaterialConcrete as an individual of IfcMaterial
16 bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral a
17   bSDD:uri/buildingsmart/ifc/4.3/class/IfcMaterial ;
18   rdfs:label Pset_MaterialConcrete  ^^xsd:string .
19
20 #Strengthclass as Property of Pset_MaterialConcrete
21 bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/prop
22   /Pset_ConcreteElementGeneral/StrengthClass a owl:Property ;
23   rdfs:domain bSDD:uri/buildingsmart/ifc/4.3/class/
24     Pset_ConcreteElementGeneral ;
25   rdfs:range xsd:string ;
26   rdfs:label Strength Class  ^^xsd:string .
27
28 #GWP as Property of Pset_MaterialConcrete
29 bSDD:uri/LCA/LCA/3.0/prop/GWP_total a owl:Property ;
30   rdfs:domain bSDD:uri/buildingsmart/ifc/4.3/class/
31     Pset_ConcreteElementGeneral ;
32   rdfs:range xsd:double ;
33   rdfs:label GWP total .

```

To access the entire RDF Triple structure please refer to A Appendix Section.

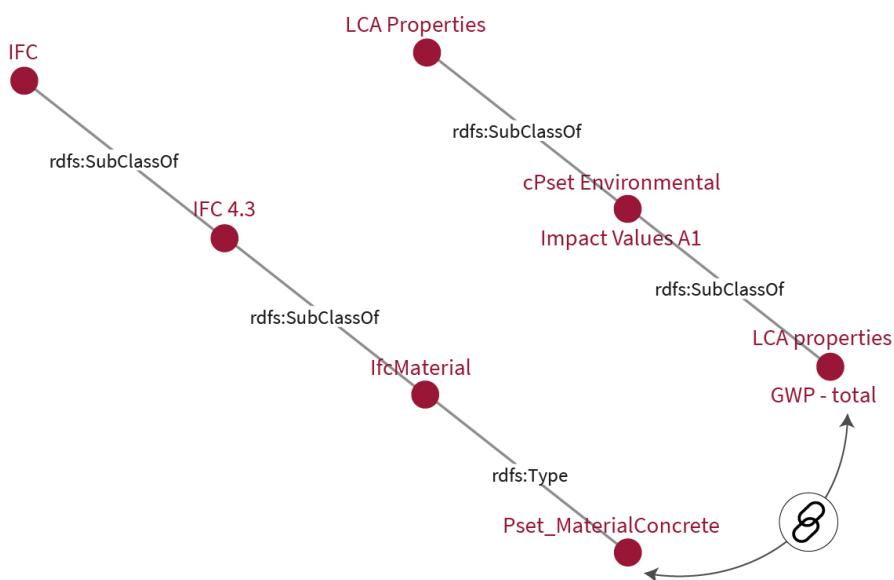


Figure 12: bSDD Structure as Nodes and Edges

4.2.3 Ökobaudat

Ökobaudat is the German database for ecological evaluation, providing standardized, comprehensive environmental data on commonly used construction materials, and is managed by the German Federal Ministry for Housing, Urban Development and Building. It contains datasets about the environmental impact of commonly used materials in construction in compliance with DIN EN 15804. The dataset is based on manufacturer-specific Environmental Product Declarations (EPDs), which each manufacturer can obtain for their product after meeting the ISO 14025 standard and getting confirmation from a third-party verifier (German Federal Ministry for Housing, U. D., 2024).

Ökobaudat includes generic datasets and specific environmental declaration datasets from multiple companies and associations. In this thesis, the focus has been the generic datasets to make a generic approach for early design decisions possible. Within the environmental datasets, the data is split into several categories for different stages of the life cycle of a material. Since the total global warming potential (GWP) is usually the factor used for comparison and evaluation in LCA, it has been chosen as most relevant constituent. The values for the different stages A1 until D of a life cycle have been used as data points in this thesis. As concrete is the material of choice in this thesis, only the data related to concrete has been added to the semantic web. Additionally, the data regarding steel reinforcement was included to be able to assess the environmental impact of reinforced concrete. The structure of the Ökobaudat is a subclass structure with properties and values included. It is displayed exemplary in the following illustration how the hierarchical structure was organised, and the property values were attached to the lowest class (see fig.14).

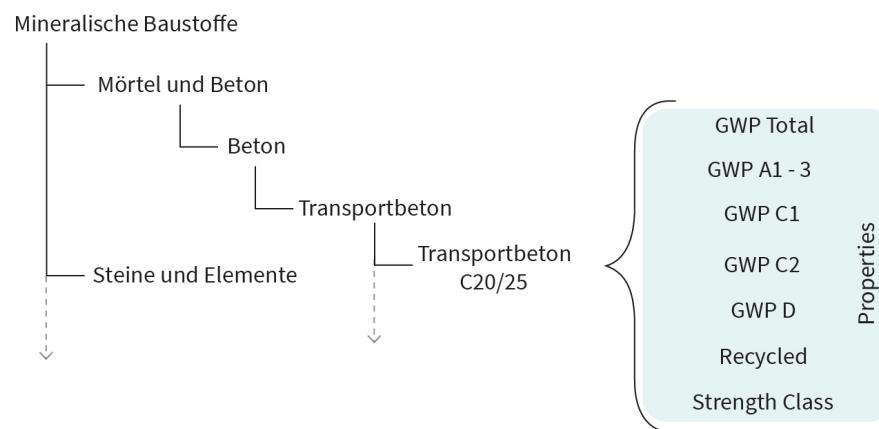


Figure 14: Ökobaudat Structure

The structure has been translated manually into RDF triples using *owl:Class* and *rdfs:subClassOf*. Shown below is the main branch of the structure and one example of how the relevant properties have been included to the most specific material class in the hierarchy. The main strand of the RDF representing the Ökobaudat structure has been displayed visually as nodes and edges (see fig.19).



Figure 13: Ökobaudat Logo
(German Federal Ministry for Housing, U. D., 2024)

```

1 #Oekobaudat Structure
2
3 #Mineralische_Baustoffe + connection bSDD IfcMaterial
4 obd:Mineralische_Baustoffe a owl:Class ;
5   rdfs:label Mineralische Baustoffe ^^^xsd:string ;
6   rdfs:subClassOf bSDD:IfcMaterial .
7
8 #Moertel_und_Beton
9 obd:Moertel_und_Beton a owl:Class ;
10   rdfs:label Moertel und Beton ^^^xsd:string ;
11   rdfs:subClassOf obd:Mineralische_Baustoffe .
12
13 #Beton
14 obd:Beton a owl:Class ;
15   rdfs:label Beton ^^^xsd:string ;
16   rdfs:subClassOf obd:Moertel_und_Beton .
17
18 #Transportbeton
19 obd:Transportbeton a owl:Class ;
20   rdfs:label Transportbeton ^^^xsd:string ;
21   rdfs:subClassOf obd:Beton .
22
23 #Transportbeton_C20/25
24 obd:9702d9ab-2af2-4fdc-9d99-225583a9ffb7?version=20.20.020 a owl:
25   Class ;
26   rdfs:label Transportbeton_C20 /25 ^^^xsd:string ;
27   rdfs:subClassOf obd:Transportbeton ;
28   bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
29     prop/Pset_ConcreteElementGeneral/StrengthClass C20 /25 ;
30   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 248.9199851 ;
31   dbp:unit dbp:kg_CO2_m3 ;
32   bSDD:cPset_EnvironmentalImpactValues_A1_A3 228.6183481 ;
33   dbp:unit dbp:kg_CO2_m3 ;
34   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
35     cPset_EnvironmentalImpactValues_C1 1.696008299 ;
36   dbp:unit dbp:kg_CO2_m3 ;
37

```

To access the entire RDF Triple structure please refer to [A Appendix Section](#).

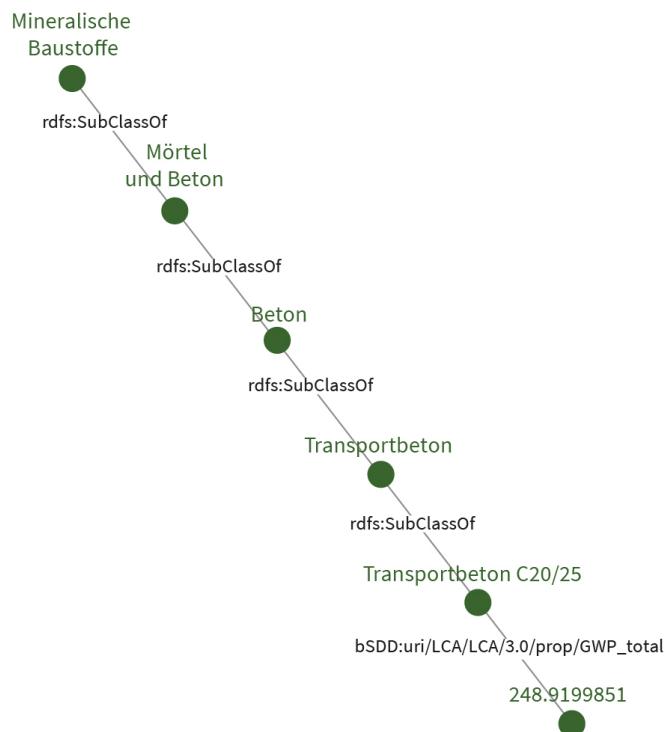


Figure 15: Ökobaudat Structure as Nodes and Edges

4.2.4 Freeclass

Freeclass product classification is a system used to categorize products into various predefined classes or categories. By grouping products with similar characteristics, it aims to streamline product identification. (Freeclass, 2024)

It has a hierarchical structure with top-level categories that are broad and general to encompass a wide range of products. Each top-level category is divided into more specific subcategories that specify the products further. Within each subcategory, products are classified into types. These product types include even more specifications and attributes (see fig.17). At the most specified level, products are added including the manufacturer and a data sheet.



Figure 16: Freeclass Logo
(Freeclass, 2024)

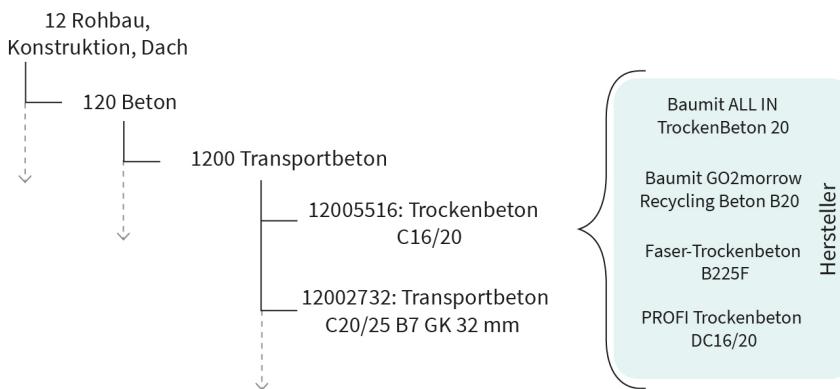


Figure 17: Freeclass Structure

After analysing the Freeclass structure, it has been translated into RDF triples manually using *owl:Class* and *rdfs:subClassOf*. Shown below is one of the strands as an example of how the classification structure has been written in Turtle format and all the individual products were added as instances. The main strand of the Freeclass structure has been displayed as nodes and edges. (see fig.18)

```

1 # FreeClass Class Structure
2
3 fcl:eurobau_artikelstamm/12#trv a owl:Class ;
4   rdfs:label 12 Rohbau Konstruktion^^xsd:string .
5
6 fcl:eurobau_artikelstamm/120#trv a owl:Class ;
7   rdfs:label 120 Beton^^xsd:string ;
8   rdfs:subClassOf fcl:eurobau_artikelstamm/12#trv .
9
10 fcl:eurobau_artikelstamm/1200#trv a owl:Class ;
11   rdfs:label 1200 Transportbeton^^xsd:string ;
12   rdfs:subClassOf fcl:eurobau_artikelstamm/120#trv .
13
14 #Trockenbeton C16/20 + Manufacturers (as instances)
15 fcl:eurobau_artikelstamm/12005516#trv a owl:Class ;
16   rdfs:label Trockenbeton C16/20 ^^xsd:string ;
17   rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv .
18
19 fcl:produkt_info/556/AT0076 a fcl:eurobau_artikelstamm/12005516#trv ;
20   rdfs:label Baumit ALL IN TrockenBeton 20 ^^xsd:string .
21
22 fcl:produkt_info/561/AT0076 a fcl:eurobau_artikelstamm/12005516#trv ;
  
```

```

23   rdfs:label Baumit G02morrow Recycling Beton B 2 0 ^^xsd:string
24   .
25   fcl:produkt_info/553/AT0076 a fcl:eurobau_artikelstamm/12005516#trv ;
26     rdfs:label Baumit NixMix Beton 200005516#trv .
27
28   fcl:produkt_info/555/AT0076 a fcl:eurobau_artikelstamm/12005516#trv ;
29     rdfs:label Baumit TrockenBeton 200005516#trv .
30
31   fcl:produkt_info/629/AT0986 a fcl:eurobau_artikelstamm/12005516#trv ;
32     rdfs:label PROFI Trockenbeton DC16/200005516#trv .
33
34   fcl:produkt_info/580/AT1490 a fcl:eurobau_artikelstamm/12005516#trv ;
35     rdfs:label Faser -Trockenbeton B 2 2 5 F 0005516#trv .
36
37   fcl:produkt_info/579/AT1490 a fcl:eurobau_artikelstamm/12005516#trv ;
38     rdfs:label Trockenbeton B 2 2 5 0005516#trv .

```

To access the entire RDF Triple structure please refer to [A Appendix Section](#).

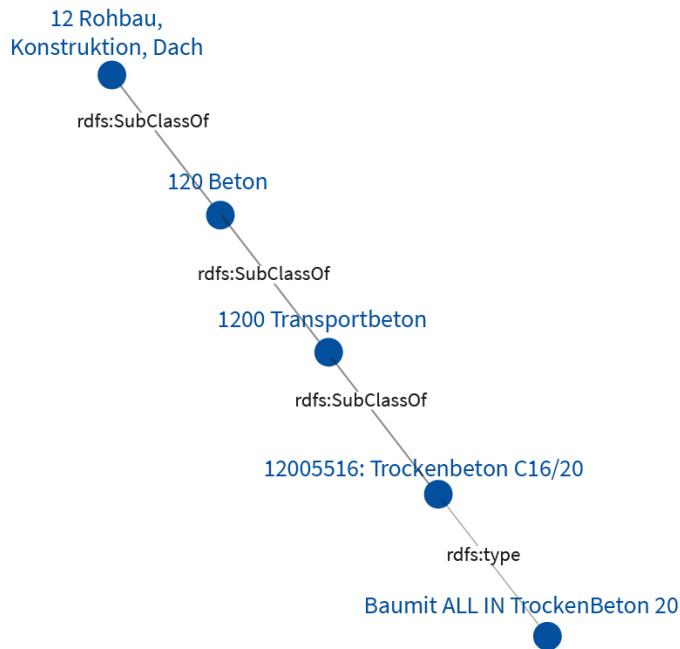


Figure 18: Freeclass Structure as Nodes and Edges

4.2.5 Mappings Between Databases

The datasets have been mapped by connecting the RDF using SKOS. This connection allows for interoperability of the different resources. In the part of the RDF Triple shown below, the definition of concrete in the Ökobaudat (obd:Beton) was connected to the concrete definition in the bSDD (bSDD:Beton) and Freeclass (fcl: eurobau_artikelstamm/120#trv).

```

1 obd:Beton a owl:Class ;
2   rdfs:label "Beton"^^xsd:string ;
3   rdfs:subClassOf obd:Moertel_und_Beton ;
4   skos:sameAs bSDD:Beton ;
5   skos:sameAs fcl:eurobau_artikelstamm/120#trv.

```

The mapping triples have been visualized schematically with nodes and edges in the graphic below. bSDD is depicted red, Ökobaudat is depicted green and Freeclass is depicted blue (see fig. 15).

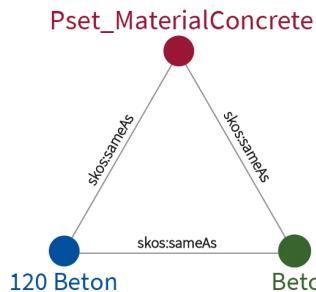


Figure 19: Mapping of Concrete

To showcase a second example, in the part of the RDF Triple shown below the kind of concrete called “Transportbeton C25/30 B1” and has been matched as a narrow match but not exact match to the definition of C20/30 concrete in the Ökobaudat (obd: d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version=20.23.)

```

1 #Transportbeton C20/25 B1
2 fcl:eurobau_artikelstamm/12002501#trv a owl:Class ;
3   rdfs:label "Transportbeton_C20/25_B1"^^xsd:string ;
4   rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv ;
5   skos:narrowMatch obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version
      =20.23.050 .
  
```

Below the mapping between Freeclass in blue and Ökobaudat in green is displayed as nodes and edges (see fig.25)

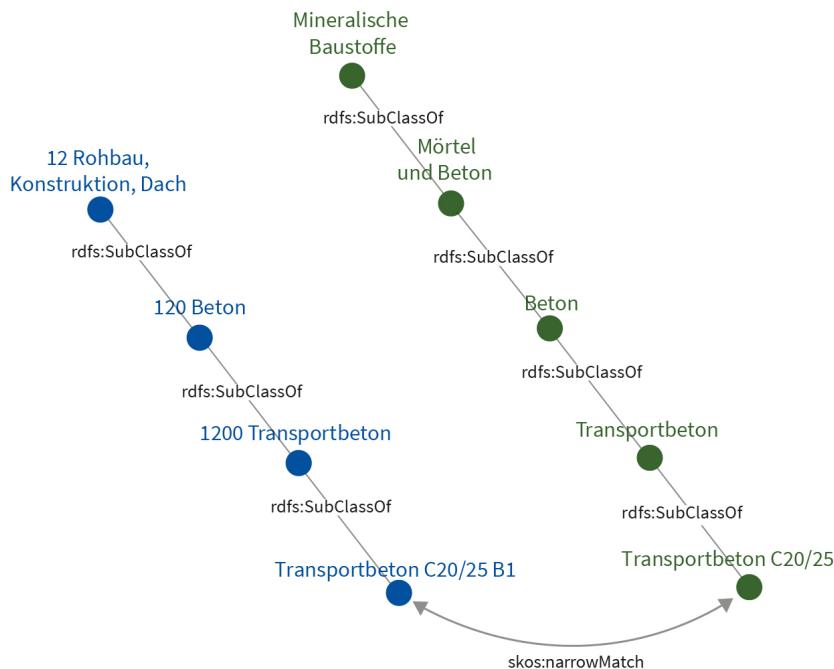


Figure 20: Mapping between Freeclass and Ökobaudat

4.3 Difficulties

A way of automatically extracting information from the mentioned databases through their API has not been possible within the time frame of this thesis. All RDF Triples were written manually in Turtle format after analysis of the classification systems and hierarchies. This has however given a great insight into the database structure and might have been less error-prone than an automated process. Another issue was that Freeclass does not directly indicate the respective URI of the products classified in the database. Therefore, the URIs were identified by extracting them manually from the http protocol.

4.4 Visualization using Gephi

After the RDF file was completed, it has been translated to GraphML using the code attached in the B appendix section. GraphML could then be imported into the software Gephi, where the colours were changed depending on the prefix. This allows the resources to be distinguishable by colour and makes the visualization more comprehensible. Shown below is the bSDD structure in red, the Ökobaudat structure in green, the Freeclass structure in blue and the DBPedia structure in teal (see fig.22).

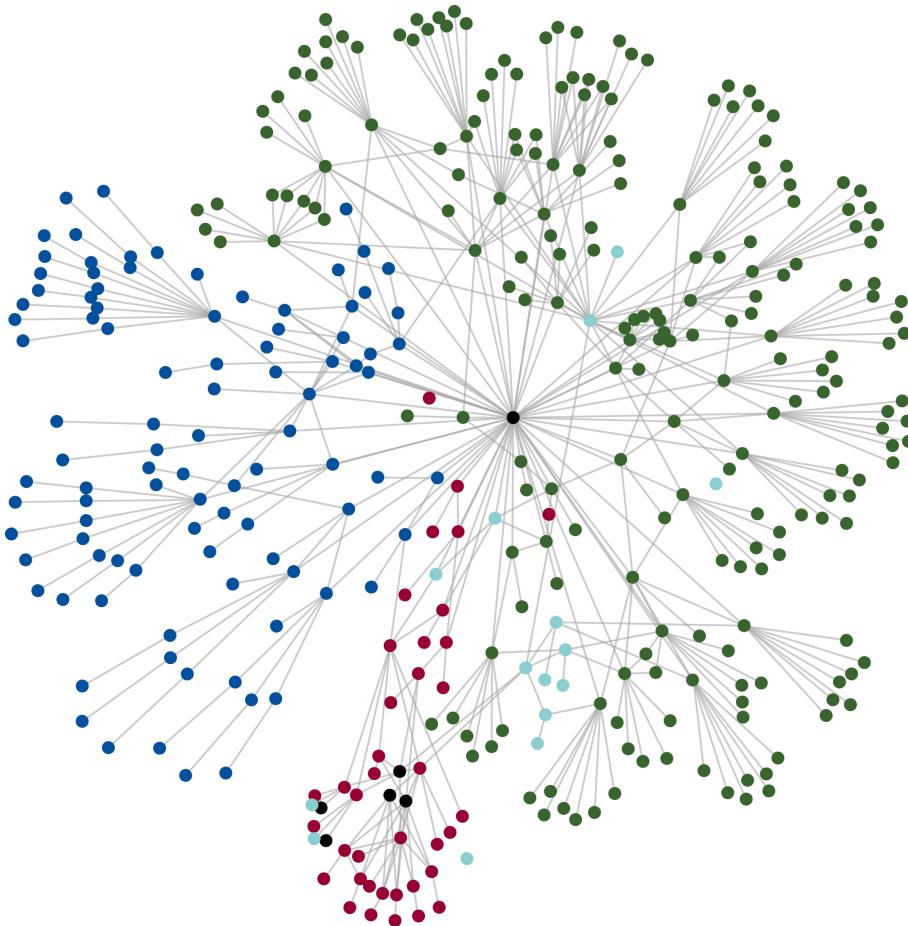


Figure 22: Visual Representation of the Entire RDF Created



Figure 21: Gephi Logo (Gephi, 2024)

5 Results

As a result of this thesis, a semantic web in RDF format has been created that can be used to evaluate a design within a BIM environment, but also to compare materials regarding their specific properties. The evaluation can be done considering LCA values, more specifically the GWP of different kinds of concrete. This semantic web presents the opportunity to streamline a design process and enhance early decision-making in a construction project. It presents the opportunity to allocate environmental impact values to a specific building element depending on properties defined in the property material relationships created in the semantic web. These different values can be queried with the query language SparQL.

5.1 Attaching Environmental Impact Values directly to a BIM-model

Enriching a BIM-model with data requires a lot of expertise and is a very time-consuming process when done manually. With the semantic web created, the data can be transmitted and mapped to the respective building components automatically by using a plugin for the BIM software. The bSDD plugin, developed by buildingSMART is available for software like Blender and Revit and presents the opportunity of connecting the bSDD structure of the semantic web with the relevant software. As illustrated in the following image, the data from the Ökobaudat dataset can be queried from the semantic web and values like the GWP of a material can be transcribed directly into the property sets of building components of a BIM-model. (see fig.23)

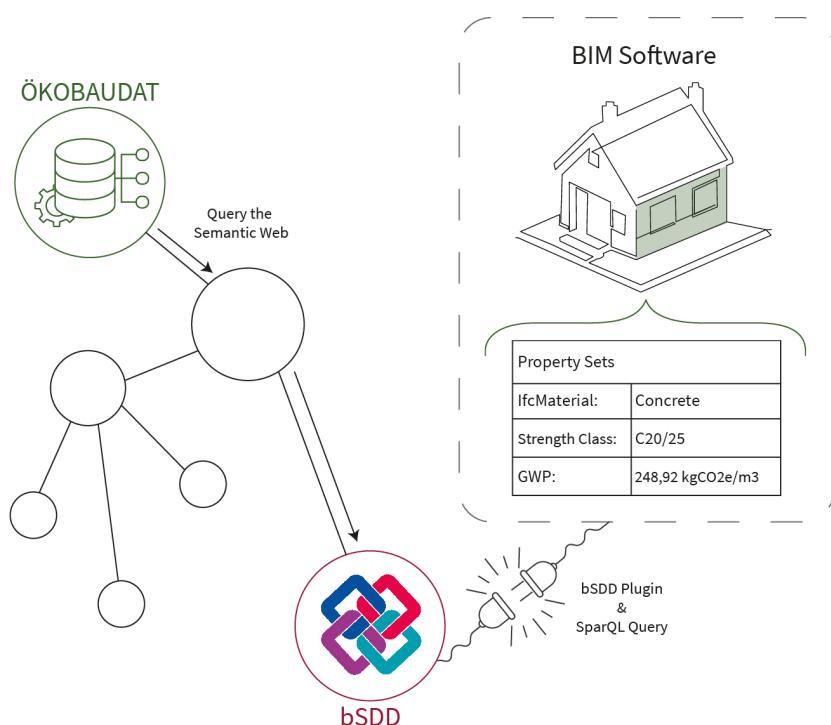


Figure 23: Write data into Property Sets

5.2 Specification of Materials based on LCA Data

While going through different phases of a project, specification of materials is necessary for evaluation of a design given the respective level of detail at that stage. To simplify this process, the data can be queried depending on the level of detail. In the beginning of a project generic data can be extracted by using a query, calculating for example the average GWP for concrete. This provides a generic value to make first estimates of what the GWP of the design might be. In the second stage, the semantic web can be used to display all possible types of the respective material with their GWP. This can be used for making an evaluation of different types of material and a decision based on the different GWP. Since the material classes have been mapped to their respective equals in the Freeclass product classification with *skos:narrowMatch*, these mappings in the semantic web can be used to identify products in that range and finalize the decision of which manufacturer should be used (see fig.24).

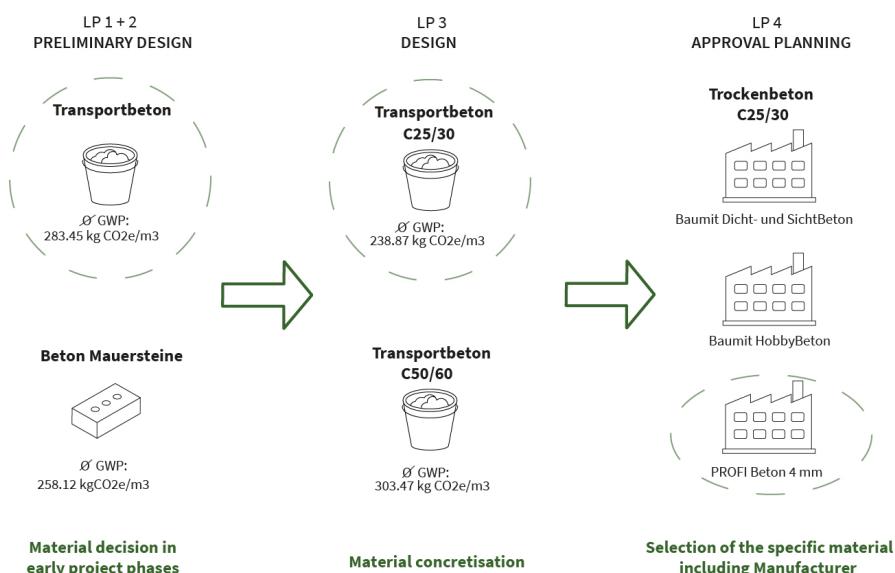


Figure 24: Specification of materials based on LCA data

Below are the three SparQL queries that can be used in the different project phases.

```

1 SELECT (AVG(?gwpTotal) AS ?avgGwpTotal)
2 WHERE {
3   ?concreteType rdfs:subClassOf obd:Transportbeton ;
4     <https://identifier.buildingsmart.org/uri/LCA/LCA
      /3.0/prop/GWP_total> ?gwpTotal .
5 }
6
7 SELECT ?concreteTypeLabel ?gwpTotal ?property ?PropertyValue
8 WHERE {
9   ?concreteType rdfs:subClassOf obd:Transportbeton ;
10    rdfs:label ?concreteTypeLabel ;
11    <https://identifier.buildingsmart.org/uri/
      buildingsmart/ifc/4.3/class/
```

```

12   Pset_ConcreteElementGeneral/prop/
13   Pset_ConcreteElementGeneral/StrengthClass> C25
14   /30 ;
15   <https://identifier.buildingsmart.org/uri/LCA/LCA/3.0/prop/GWP\_total> ?gwpTotal ;
16   ?property ?PropertyValue .
17 }
18
19 SELECT ?classLabel ?instanceLabel ?instanceURI
20 WHERE {
21   ?class skos:narrowMatch <https://www.oekobaudat.de/OEKOBAU.DAT/resource/processes/d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version=20.23.050> ;
22   rdfs:label ?classLabel .
23   ?instance a ?class ;
24   rdfs:label ?instanceLabel ;
25   <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> ?
26   instanceURI .
27 }
```

5.3 Material Comparison based on Properties

Since properties like “recycled” and “reinforced” have been added to the semantic web, the materials can be evaluated based on these properties. By querying the same material with and without the property “recycled”, both can be displayed together with their GWP and thereby be compared and evaluated. It is also possible to query the GWP of reinforced and non-reinforced concrete, as the GWP of reinforcement steel has been added to the semantic web. By inserting the reinforcement ratio to the query and the density of the concrete, the respective amount of steel can be taken into account and added to the GWP of the concrete itself. Thereby reinforced concrete can be compared to the non-reinforced counterpart (see fig.20).

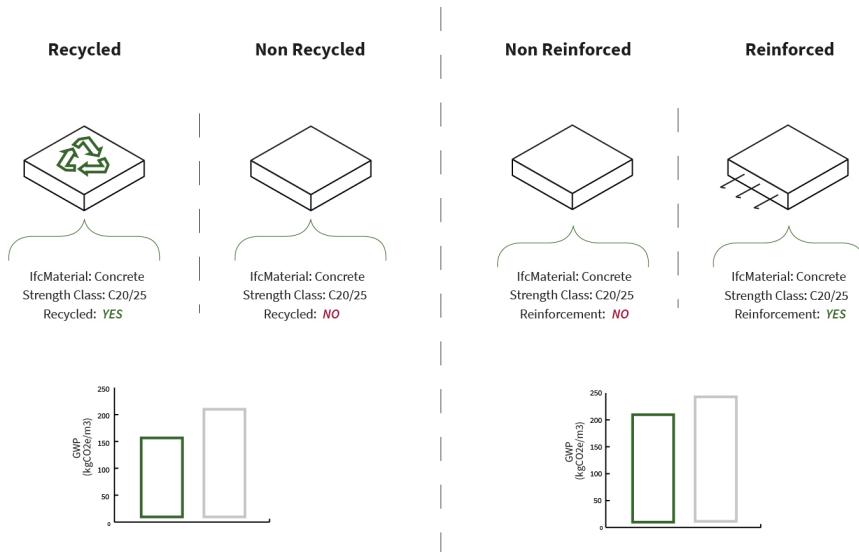


Figure 25: Material comparison based on properties

Below are the respective SparQL Queries:

```

1   SELECT ?instance ?gwpTotal
2   WHERE {
3       {
4           ?instance
5               bsdd:uri/Al-Qazzaz/Circularity/0.0.1/prop/Recycled
6                   yes ;
7               bsdd:uri/buildingsmart/ifc/4.3/class/
8                   Pset_ConcreteElementGeneral/prop/
9                   Pset_ConcreteElementGeneral/StrengthClass C20
10                  /25 ;
11                  bsdd:uri/LCA/LCA/3.0/prop/GWP_total ?gwpTotal .
12
13   UNION
14   {
15       ?instance
16           bsdd:uri/buildingsmart/ifc/4.3/class/
17               Pset_ConcreteElementGeneral/prop/
18               Pset_ConcreteElementGeneral/StrengthClass C20
19               /25 .
20
21       OPTIONAL {
22           ?instance bsdd:uri/Al-Qazzaz/Circularity/0.0.1/prop/
23               Recycled ?recycled .
24
25       }
26       FILTER (!bound(?recycled))
27       OPTIONAL {
28           ?instance bsdd:uri/LCA/LCA/3.0/prop/GWP_total ?
29               gwpTotal .
30
31       }
32   }
33
34   SELECT ?finalGWP ?gwpTotal WHERE {
35       BIND(2400 * 0.025 AS ?densityWithReinforcement)
36       BIND(?densityWithReinforcement * 0.763693331 AS ?
37           intermediateResult)
38
39       <https://www.oekobaudat.de/OEKOBAU.DAT/resource/processes/6739667
40           a-49d1-4a9c-a4b2-eb542167710c?version=20.23.050>
41           <https://identifier.buildingsmart.org/uri/LCA/LCA/3.0/
42               prop/GWP_total> ?gwpTotal .
43
44       BIND(?intermediateResult + ?gwpTotal AS ?finalGWP)
45   }

```

6 Future Work

6.1 Automation instead of Manual Data Input

Since most of this work has been done manually, the automation of translating databases into RDF Triples has significant potential to be further investigated. Analysing a classification structure and identifying all important data-points is a very time-consuming process, which is why the focus in this thesis has only been on one material (concrete). To allow automatic RDF creation, the semantic web created in this thesis can be used as a template. For an efficient automation, the use of a Large Language Model like Llama3 could be considered.

6.2 Expansion of the Semantic Web

A big advantage of this semantic web approach is that the semantic structure can be expanded infinitely as the construction industry keeps evolving. By simply adding more databases using RDF, the web can be extended, and a construction project can be evaluated more holistically including all data added.

6.3 Connecting LCA Databases and Tools to bSDD

To enrich the semantic web with currently existing LCA information it would be very valuable to connect the present LCA tools and databases to the web. Dervishaj and Gudmundsson suggested to enrich the LCA tools with bSDD definitions and taxonomies to make a linkage and common naming scheme possible. In their study conducted none of the tools investigated were enriched with bSDD Definitions (Dervishaj & Gudmundsson, 2024). A common naming scheme is crucial for fast knowledge distribution and an effective way of comparing environmental data.

7 Summary

This thesis is to serve as a template of how databases can be connected to an IFC model using the bSDD. The chosen semantic web approach effectively creates mappings between data points, allowing for efficient retrieval of information based on metadata. This methodology has strong potential to enhance the efficiency, reliability, and streamlining of LCA in the AEC industry. Future work should focus on automating the expansion of the semantic web and delving deeper into the mapping process. Overall, the semantic web offers significant opportunities for multidisciplinary collaboration in the construction sector.

The following QR code can be scanned to access the GitHub repository, where all Python scripts have been uploaded (see fig.26).

<https://github.com/IsaSei/Semantic-Web-linking-Databases-to-IFC-Data>



Figure 26: QR Code to GitHub Repository

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Acronyms

AEC Architecture, Engineering and Construction. 3

BIM Building Information Modelling. 4

bSDD buildingSMART Data Dictionary. 3

GHG Greenhouse Gas Emissions. 3

GWP Global Warming Potential. 12

IFC Industry Foundation Classes. 9

LCA Life Cycle Assessment. 4

OWL Web Ontology Language. 10

RDF Resource Description Framework. 3

RDFS RDF Schema. 10

SKOS Simple Knowledge Organization System. 11

SparQL SPARQL Protocol and RDF Query Language. 8

URI Universal Resource Identifier. 7

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Appendices

A Appendix Section

Also available on GitHub:

<https://github.com/IsaSei/Semantic-Web-linking-Databases-to-IFC-Data>

```

1 @base <http://example.org/ .
2 @prefix bSDD: <https://identifier.buildingsmart.org/ .
3 @prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns# .
4 @prefix rdfs: <http://www.w3.org/2000/01/rdf-schema# .
5 @prefix skos: <http://www.w3.org/2004/02/skos/core# .
6 @prefix owl: <http://www.w3.org/2002/07/owl# .
7 @prefix xsd: <http://www.w3.org/2001/XMLSchema# .
8 @prefix dbp: <https://dbpedia.org/page/ .
9 @prefix dbpp: <https://dbpedia.org/property/ .
10 @prefix fcl: <https://www.freeclass.de/ .
11 @prefix obd: <https://www.oekobaudat.de/OEKBAU.DAT/resource/
    processes/ .

12 # Dbpedia Material Definition
13
14
15 dbp:Material a owl:Class .
16 dbp:Concrete a owl:Class ;
17     rdfs:subClassOf dbp:Material .
18
19 # Define IFC structure
20
21 bSDD:uri/buildingsmart/ifc a owl:Class ;
22     rdfs:label "IFC"^^xsd:string .
23
24 bSDD:uri/buildingsmart/ifc/4.3 a owl:Class ;
25     rdfs:subClassOf bSDD:uri/buildingsmart/ifc ;
26     rdfs:label "IFC_4.3"^^xsd:string .
27
28 bSDD:uri/buildingsmart/ifc/4.3/class/IfcBuiltElement a owl:Class ;
29     rdfs:subClassOf bSDD:uri/buildingsmart/ifc/4.3 ;
30     rdfs:label "IfcBuiltElement"^^xsd:string .
31
32 # IfcMaterial as a class
33 bSDD:uri/buildingsmart/ifc/4.3/class/IfcMaterial a owl:Class ;
34     rdfs:label "IFC_Material"^^xsd:string ;
35     rdfs:subClassOf bSDD:uri/buildingsmart/ifc/4.3 ;
36     skos:sameAs dbp:Material .
37
38 # Pset_MaterialConcrete as an individual of IfcMaterial
39 bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral a
    bSDD:uri/buildingsmart/ifc/4.3/class/IfcMaterial ;
40     rdfs:label "Pset_MaterialConcrete"^^xsd:string ;
41     skos:sameAs dbp:Concrete ;
42     skos:sameAs fcl:eurobau_artikelstamm/120#trv .
43
44 #Strengthclass as Property of Pset_MaterialConcrete
45 bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/prop
    /Pset_ConcreteElementGeneral/StrengthClass a owl:Property ;
46     rdfs:domain bSDD:uri/buildingsmart/ifc/4.3/class/
        Pset_ConcreteElementGeneral ;
47     rdfs:range xsd:string ;
48     rdfs:label "Strength_Class"^^xsd:string ;
49     skos:sameAs dbp:Compressive_strength .
50
51 #GWP as Property of Pset_MaterialConcrete
52 bSDD:uri/LCA/LCA/3.0/prop/GWP_total a owl:Property ;
53     rdfs:domain bSDD:uri/buildingsmart/ifc/4.3/class/
        Pset_ConcreteElementGeneral ;
54     rdfs:range xsd:double ;
55     rdfs:label "GWP_total" .

56
57 #Recycled as Property of Pset_MaterialConcrete

```

```

58 bSDD:uri/Al-Qazzaz/Circularity/0.0.1/prop/Recycled a owl:Property ;
59   rdfs:domain bSDD:uri/buildingsmart/ifc/4.3/class/
60     Pset_ConcreteElementGeneral ;
61   rdfs:range xsd:boolean ;
62   rdfs:label "Recycled" ;
63   skos:sameAs dbp:Recycling .

64 #Concrete Reinforcement Area Ratio as Property of
65   Pset_MaterialConcrete - typically 2.5% avr
66 bSDD:uri/buildingsmart/ifc/4.3/prop/ReinforcementAreaRatio a owl:
67   Property ;
68   rdfs:domain bSDD:uri/buildingsmart/ifc/4.3/class/
69     Pset_ConcreteElementGeneral ;
70   rdfs:range xsd:double ;
71   rdfs:label "Reinforcement_Area_Ratio" .

72 #Density Concrete avr. 2400 kg/m3
73 bSDD:uri/buildingsmart/ifc/4.3/prop/MassDensity a owl:Property ;
74   rdfs:PropertyOf bSDD:uri/buildingsmart/ifc ;
75   rdfs:range xsd:double ;
76   rdfs:label "Concrete_Density" .

77 # LCA Properties
78 # Define Units for GWP
79 dbpp:unit a owl:Property ;
80   rdfs:domain bSDD:uri/LCA/LCA/3.0/prop/GWP_total .

81 dbp:kg_CO2_m2 a dbpp:unit ;
82   rdfs:label "kg_CO2/m2" .

83 dbp:kg_CO2_kg a dbpp:unit ;
84   rdfs:label "kg_CO2/kg" .

85 dbp:kg_CO2_pcs a dbpp:unit ;
86   rdfs:label "kg_CO2/pcs" .

87 dbp:kg_CO2_m3 a dbpp:unit ;
88   rdfs:label "kg_CO2/m3" .

89 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties a owl:Property ;
90   rdfs:label "Life-cycle_assessment_properties" ;
91   rdfs:subPropertyOf bSDD:uri/buildingsmart/ifc/4.3/class/
92     Pset_MaterialConcrete ;
93   skos:sameAs dbp:Life-cycle_assessment .

94 # GWP range is datatype xsd:integer and ddbpuain is IfcMaterial as
95   Class
96 bSDD:uri/LCA/LCA/3.0/prop/GWP_total a owl:DatatypeProperty ;
97   rdfs:label "global_warming_potential_-total"^^xsd:string ;
98   rdfs:subPropertyOf bSDD:uri/LCA/LCA_properties/0.1/class/
99     LCA_properties ;
100  rdfs:range xsd:double .

101 #A1-A3
102 bSDD:cPset_EnvironmentalImpactValues_A1_A3 a owl:DatatypeProperty ;
103   rdfs:label "cPset_EnvironmentalImpactValues_A1-A3"^^xsd:string ;
104   rdfs:subPropertyOf bSDD:uri/LCA/LCA_properties/0.1/class/
105     LCA_properties ;
106   rdfs:range xsd:double .

107 #A4
108 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
109   cPset_EnvironmentalImpactValues_A4 a owl:DatatypeProperty ;
110   rdfs:label "cPset_EnvironmentalImpactValues_A4"^^xsd:string ;
111   rdfs:subPropertyOf bSDD:cPset_EnvironmentalImpactValues_A1_A3 ;
112   rdfs:range xsd:double .

113 #C1
114 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/

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119 cPset_EnvironmentalImpactValues_C1 a owl:DatatypeProperty ;
120 rdfs:label "cPset_EnvironmentalImpactValues_C1"^^xsd:string ;
121 rdfs:subPropertyOf bSDD:uri/LCA/LCA_properties/0.1/class/
    LCA_properties ;
122 rdfs:range xsd:double .
123
124 #C2
125 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
    cPset_EnvironmentalImpactValues_C2 a owl:DatatypeProperty ;
126 rdfs:label "cPset_EnvironmentalImpactValues_C2"^^xsd:string ;
127 rdfs:subPropertyOf bSDD:uri/LCA/LCA_properties/0.1/class/
    LCA_properties ;
128 rdfs:range xsd:double .
129
130 #C3
131 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
    cPset_EnvironmentalImpactValues_C3 a owl:DatatypeProperty ;
132 rdfs:label "cPset_EnvironmentalImpactValues_C3"^^xsd:string ;
133 rdfs:subPropertyOf bSDD:uri/LCA/LCA_properties/0.1/class/
    LCA_properties ;
134 rdfs:range xsd:double .
135
136 #D
137 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
    cPset_EnvironmentalImpactValues_D a owl:DatatypeProperty ;
138 rdfs:label "cPset_EnvironmentalImpactValues_D"^^xsd:string ;
139 rdfs:subPropertyOf bSDD:uri/LCA/LCA_properties/0.1/class/
    LCA_properties ;
140 rdfs:range xsd:double .
141
142 # oekobaudat Structure
143
144 # Mineralische_Baustoffe + connection to DBpedia Material + bSDD
    IfcMaterial
145 obd:Mineralische_Baustoffe a owl:Class ;
146 rdfs:label "Mineralische_Baustoffe"^^xsd:string ;
147 rdfs:subClassOf dbp:Material ;
148 rdfs:subClassOf bSDD:IfcMaterial .
149
150 # Moertel_und_Beton
151 obd:Moertel_und_Beton a owl:Class ;
152 rdfs:label "Moertel_und_Beton"^^xsd:string ;
153 rdfs:subClassOf obd:Mineralische_Baustoffe .
154
155 # Steine_und_Elemente
156 obd:Steine_und_Elemente a owl:Class ;
157 rdfs:label "Steine_und_Elemente"^^xsd:string ;
158 rdfs:subClassOf obd:Mineralische_Baustoffe .
159
160 # Beton
161 obd:Beton a owl:Class ;
162 rdfs:label "Beton"^^xsd:string ;
163 rdfs:subClassOf obd:Moertel_und_Beton ;
164 skos:sameAs bSDD:Beton ;
165 skos:sameAs fcl:eurobau_artikelstamm/120#trv.
166
167 # Betonfertigteile_und_Betonwaren
168 obd:Betonfertigteile_und_Betonwaren a owl:Class ;
169 rdfs:label "Betonfertigteile_und_Betonwaren"^^xsd:string ;
170 rdfs:subClassOf obd:Steine_und_Elemente .
171
172 # Leichtbeton
173 obd:Leichtbeton a owl:Class ;
174 rdfs:label "Leichtbeton"^^xsd:string ;
175 rdfs:subClassOf obd:Steine_und_Elemente ;
176 skos:closeMatch dbp:Foam_Concrete .
177
178 # Porenbeton
179 obd:Porenbeton a owl:Class ;
180 rdfs:label "Porenbeton"^^xsd:string ;

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180 skos:narrowMatch obd:Leichtbeton ;
181 rdfs:subClassOf obd:Steine_und_Elemente .
182
183 # Transportbeton
184 obd:Transportbeton a owl:Class ;
185 rdfs:label "Transportbeton"^^xsd:string ;
186 rdfs:subClassOf obd:Beton .
187
188 # Bl hton LB
189 obd:Bl hton_LB a owl:Class ;
190 rdfs:label "Bl hton_LB"^^xsd:string ;
191 rdfs:subClassOf obd:Leichtbeton .
192
193 # Metalle
194 obd:Metalle a owl:Class ;
195 rdfs:label "Metalle"^^xsd:string ;
196 rdfs:subClassOf dbp:Material ;
197 rdfs:subClassOf bSDD:IfcMaterial .
198
199 # Stahl und Eisen
200 obd:Stahl_und_Eisen a owl:Class ;
201 rdfs:label "Stahl_und_Eisen"^^xsd:string ;
202 rdfs:subClassOf obd:Metalle .
203
204 #Betonstahlmatten
205 obd:8565038f-5c21-48d7-94cb-958498ba9dd3?version=20.23.050 a owl:
206 Class ;
207 rdfs:label "Betonstahlmatten"^^xsd:string ;
208 rdfs:subClassOf obd:Stahl_und_Eisen ;
209 bSDD:uri/LCA/LCA/3.0/prop/GWP_total 0.763693331 ;
210 dbp:unit dbp:kg_CO2_kg ;
211 bSDD:cPset_EnvironmentalImpactValues_A1_A3 0.615355365 ;
212 dbp:unit dbp:kg_CO2_kg ;
213 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
214 cPset_EnvironmentalImpactValues_C1 0.000319976 ;
215 dbp:unit dbp:kg_CO2_kg ;
216 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
217 cPset_EnvironmentalImpactValues_C2 0.003551029 ;
218 dbp:unit dbp:kg_CO2_kg ;
219 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
220 cPset_EnvironmentalImpactValues_D 0.144466961 ;
221 dbp:unit dbp:kg_CO2_kg .

222 # Beton-Mauersteine
223 obd:bdda4364-451f-4df2-a68b-5912469ee4c9?version=20.19.120 a owl:
224 Class ;
225 rdfs:label "Beton-Mauersteine"^^xsd:string ;
226 rdfs:subClassOf obd:Betonfertigteile_und_Betonwaren ;
227 bSDD:uri/LCA/LCA/3.0/prop/GWP_total 258.1184091 ;
228 dbp:unit dbp:kg_CO2_m3 ;
229 bSDD:cPset_EnvironmentalImpactValues_A1_A3 242.3509272 ;
230 dbp:unit dbp:kg_CO2_m3 ;
231 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
232 cPset_EnvironmentalImpactValues_C1 1.317929344 ;
233 dbp:unit dbp:kg_CO2_m3 ;
234 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
235 cPset_EnvironmentalImpactValues_C2 5.105946955 ;
236 dbp:unit dbp:kg_CO2_m3 ;
237 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
238 cPset_EnvironmentalImpactValues_C3 13.45156788 ;
239 dbp:unit dbp:kg_CO2_m3 ;
240 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
241 cPset_EnvironmentalImpactValues_D -4.107962265 ;
242 dbp:unit dbp:kg_CO2_m3 .

243 # Betonfertigteil_Decke_20cm
244 obd:9357b7fc-cf0a-45fc-8299-e794e3889a40?version=20.19.120 a owl:
245 Class ;
246 rdfs:label "Betonfertigteil_Decke_20cm"^^xsd:string ;

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240 rdfs:subClassOf obd:Betonfertigteile_und_Betonwaren ;
241   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 88.78006398;
242     dbp:unit dbp:kg_CO2_m2 ;
243   bSDD:cPset_EnvironmentalImpactValues_A1_A3 84.47914226 ;
244     dbp:unit dbp:kg_CO2_m2 ;
245   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
246     cPset_EnvironmentalImpactValues_C1 0.362310758 ;
247     dbp:unit dbp:kg_CO2_m2 ;
248   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
249     cPset_EnvironmentalImpactValues_C2 1.403671236 ;
250     dbp:unit dbp:kg_CO2_m2 ;
251   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
252     cPset_EnvironmentalImpactValues_C3 3.5204563 ;
253     dbp:unit dbp:kg_CO2_m2 ;
254   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
255     cPset_EnvironmentalImpactValues_D -0.985516579 ;
256     dbp:unit dbp:kg_CO2_m2 .
257
258 # Betonfertigteil_Wand_12cm
259 obd:b342696e-2ebb-4fe1-a71d-f3520db0cee9?version=20.19.120 a owl:
260   Class ;
261   rdfs:label "Betonfertigteil_Wand_12cm"^^xsd:string ;
262   rdfs:subClassOf obd:Betonfertigteile_und_Betonwaren ;
263   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 41.50863986 ;
264     dbp:unit dbp:kg_CO2_m2 ;
265   bSDD:cPset_EnvironmentalImpactValues_A1_A3 38.97678704 ;
266     dbp:unit dbp:kg_CO2_m2 ;
267   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
268     cPset_EnvironmentalImpactValues_C1 0.20919133 ;
269     dbp:unit dbp:kg_CO2_m2 ;
270   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
271     cPset_EnvironmentalImpactValues_C2 0.810453035 ;
272     dbp:unit dbp:kg_CO2_m2 ;
273   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
274     cPset_EnvironmentalImpactValues_C3 2.100114541 ;
275     dbp:unit dbp:kg_CO2_m2 ;
276   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
277     cPset_EnvironmentalImpactValues_D -0.58790609 ;
278     dbp:unit dbp:kg_CO2_m2 .
279
280 # Leichtbetonstein_aus_100_Prozent_Naturbims
281 obd:63ddb7e1-4e0b-43cb-8a8d-82c5c137a2a2?version=20.20.020 a owl:
282   Class ;
283   rdfs:label "Leichtbetonstein_aus_100_Prozent_Naturbims"^^xsd:
284     string ;
285   rdfs:subClassOf obd:Leichtbeton ;
286   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 47.36261087 ;
287     dbp:unit dbp:kg_CO2_m3 ;
288   bSDD:cPset_EnvironmentalImpactValues_A1_A3 42.96902575 ;
289     dbp:unit dbp:kg_CO2_m3 ;
290   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
291     cPset_EnvironmentalImpactValues_C1 0.359435276 ;
292     dbp:unit dbp:kg_CO2_m3 ;
293   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
294     cPset_EnvironmentalImpactValues_C2 1.392530988 ;
295     dbp:unit dbp:kg_CO2_m3 ;
296   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
297     cPset_EnvironmentalImpactValues_C3 3.668609423 ;
298     dbp:unit dbp:kg_CO2_m3 ;
299   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
300     cPset_EnvironmentalImpactValues_D -1.026990566 ;
301     dbp:unit dbp:kg_CO2_m3 .
302
303 # Bims-Planstein (SFK-4)
304 obd:8f44840b-28ae-418b-bf12-fcac5b7c68b3?version=20.20.020 a owl:
305   Class ;
306   rdfs:label "Bims-Planstein_(SFK-4)"^^xsd:string ;
307   rdfs:subClassOf obd:Leichtbeton ;
308   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 85.9531013 ;

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294     dbp:unit dbp:kg_CO2_m3 ;
295     bSDD:cPset_EnvironmentalImpactValues_A1_A3 78.04464808 ;
296     dbp:unit dbp:kg_CO2_m3 ;
297     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
298         cPset_EnvironmentalImpactValues_C1 0.646983496 ;
299         dbp:unit dbp:kg_CO2_m3 ;
300         bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
301             cPset_EnvironmentalImpactValues_C2 2.506555778 ;
302             dbp:unit dbp:kg_CO2_m3 ;
303             bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
304                 cPset_EnvironmentalImpactValues_C3 6.603496961 ;
305                 dbp:unit dbp:kg_CO2_m3 ;
306                 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
307                     cPset_EnvironmentalImpactValues_D -1.848583019 ;
308                     dbp:unit dbp:kg_CO2_m3 .
309
310 # Bl hton LB Hohlbllockstein Trennwand
311 obd:c7e171fb-d5eb-4867-9fb2-961dec81d6aa?version=20.20.020 a owl:
312     Class ;
313     rdfs:label "Bl hton_LB_Hohlblblockstein_Trennwand"^^xsd:string ;
314     rdfs:subClassOf obd:Bl hton_LB ;
315     bSDD:uri/LCA/LCA/3.0/prop/GWP_total 398.4009055 ;
316     dbp:unit dbp:kg_CO2_m3 ;
317     bSDD:cPset_EnvironmentalImpactValues_A1_A3 385.78692 ;
318     dbp:unit dbp:kg_CO2_m3 ;
319     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
320         cPset_EnvironmentalImpactValues_C1 1.054343475 ;
321         dbp:unit dbp:kg_CO2_m3 ;
322         bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
323             cPset_EnvironmentalImpactValues_C2 4.084757564 ;
324             dbp:unit dbp:kg_CO2_m3 ;
325             bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
326                 cPset_EnvironmentalImpactValues_C3 10.76125431 ;
327                 dbp:unit dbp:kg_CO2_m3 ;
328                 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
329                     cPset_EnvironmentalImpactValues_D -3.286369812 ;
330                     dbp:unit dbp:kg_CO2_m3 .
331
332 # Bl hton LB Planstein Innenwand
333 obd:1b978129-dd5e-45ea-9c82-1c3510e9c965?version=20.20.020 a owl:
334     Class ;
335     rdfs:label "Bl hton_LB_Planstein_Innenwand"^^xsd:string ;
336     rdfs:subClassOf obd:Bl hton_LB ;
337     bSDD:uri/LCA/LCA/3.0/prop/GWP_total 218.1619195 ;
338     dbp:unit dbp:kg_CO2_m3 ;
339     bSDD:cPset_EnvironmentalImpactValues_A1_A3 212.6433008 ;
340     dbp:unit dbp:kg_CO2_m3 ;
341     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
342         cPset_EnvironmentalImpactValues_C1 0.46127527 ;
343         dbp:unit dbp:kg_CO2_m3 ;
344         bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
345             cPset_EnvironmentalImpactValues_C2 1.787081434 ;
346             dbp:unit dbp:kg_CO2_m3 ;
347             bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
348                 cPset_EnvironmentalImpactValues_D -1.437786793 ;
349                 dbp:unit dbp:kg_CO2_m3 .
350
351 # Bl hton LB Planstein Au enwand
352 obd:21a40e8f-3897-4465-975b-81b6370936fb?version=20.20.020 a owl:
353     Class ;
354     rdfs:label "Bl hton_LB_Planstein_Au_enwand"^^xsd:string ;
355     rdfs:subClassOf obd:Bl hton_LB ;
356     bSDD:uri/LCA/LCA/3.0/prop/GWP_total 175.9923338 ;
357     dbp:unit dbp:kg_CO2_m3 ;
358     bSDD:cPset_EnvironmentalImpactValues_A1_A3 172.0504633 ;
359     dbp:unit dbp:kg_CO2_m3 ;
360     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/

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349   cPset_EnvironmentalImpactValues_C1 0.329482336 ;
350   dbp:unit dbp:kg_CO2_m3 ;
351   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
352     cPset_EnvironmentalImpactValues_C2 1.276486739 ;
353     dbp:unit dbp:kg_CO2_m3 ;
354   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
355     cPset_EnvironmentalImpactValues_C3 3.362891971 ;
356     dbp:unit dbp:kg_CO2_m3 ;
357   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
358     cPset_EnvironmentalImpactValues_D -1.026990566 ;
359     dbp:unit dbp:kg_CO2_m3 .
360
361 # Htensteine
362 obd:a4fceab4-71a2-46c9-ac9a-19a964d48ce5?version=20.19.120 a owl:
363   Class ;
364   rdfs:label "Htensteine"^^xsd:string ;
365   rdfs:subClassOf obd:Leichtbeton ;
366   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 365.1396426 ;
367     dbp:unit dbp:kg_CO2_m3 ;
368   bSDD:cPset_EnvironmentalImpactValues_A1_A3 352.8376043 ;
369     dbp:unit dbp:kg_CO2_m3 ;
370   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
371     cPset_EnvironmentalImpactValues_C1 1.006418771 ;
372     dbp:unit dbp:kg_CO2_m3 ;
373   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
374     cPset_EnvironmentalImpactValues_C2 3.899086766 ;
375     dbp:unit dbp:kg_CO2_m3 ;
376   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
377     cPset_EnvironmentalImpactValues_C3 10.27210638 ;
378     dbp:unit dbp:kg_CO2_m3 ;
379   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
380     cPset_EnvironmentalImpactValues_D -2.875573586 ;
381     dbp:unit dbp:kg_CO2_m3 .
382
383 # Porenbeton_Granulat
384 obd:57a87943-dbdd-4221-bbd2-481b8fcfd1d2b?version=20.19.120 a owl:
385   Class ;
386   rdfs:label "Porenbeton_Granulat"^^xsd:string ;
387   rdfs:subClassOf obd:Porenbeton ;
388   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 8.438178486 ;
389     dbp:unit dbp:kg_CO2_m3 ;
390   bSDD:cPset_EnvironmentalImpactValues_A1_A3 5.284682102 ;
391     dbp:unit dbp:kg_CO2_m3 ;
392   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
393     cPset_EnvironmentalImpactValues_C1 0.263585869 ;
394     dbp:unit dbp:kg_CO2_m3 ;
395   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
396     cPset_EnvironmentalImpactValues_C2 1.021189391 ;
397     dbp:unit dbp:kg_CO2_m3 ;
398   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
399     cPset_EnvironmentalImpactValues_C3 2.690313577 ;
400     dbp:unit dbp:kg_CO2_m3 ;
401   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
402     cPset_EnvironmentalImpactValues_D -0.821592453 ;
403     dbp:unit dbp:kg_CO2_m3 .
404
405 # Porenbeton_P2_04_unbewehrt
406 obd:906b4864-0511-480f-a8bc-7b8302efbf0b?version=20.19.120 a owl:
407   Class ;
408   rdfs:label "Porenbeton_P2_04_unbewehrt"^^xsd:string ;
409   rdfs:subClassOf obd:Porenbeton ;
410   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 185.3873766 ;
411     dbp:unit dbp:kg_CO2_m3 ;
412   bSDD:cPset_EnvironmentalImpactValues_A1_A3 182.391555 ;
413     dbp:unit dbp:kg_CO2_m3 ;
414   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
415     cPset_EnvironmentalImpactValues_C1 0.250406575 ;
416     dbp:unit dbp:kg_CO2_m3 ;
417   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
418     cPset_EnvironmentalImpactValues_C2 0.970129921 ;

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402     dbp:unit dbp:kg_CO2_m3 ;
403     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
404         cPset_EnvironmentalImpactValues_C3 2.555797898 ;
405     dbp:unit dbp:kg_CO2_m3 ;
406     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
407         cPset_EnvironmentalImpactValues_D -0.78051283 ;
408     dbp:unit dbp:kg_CO2_m3 .
409
410 # Porenbeton_P4_05_bewehrt
411 obd:d3b59cac-3b4e-4d18-8c3a-780b553c9591?version=20.19.120 a owl:
412     Class ;
413     rdfs:label "Porenbeton_P4_05_bewehrt"^^xsd:string ;
414     rdfs:subClassOf obd:Porenbeton ;
415     bSDD:uri/LCA/LCA/3.0/prop/GWP_total 267.1326394 ;
416     dbp:unit dbp:kg_CO2_m3 ;
417     bSDD:cPset_EnvironmentalImpactValues_A1_A3 263.192077 ;
418     dbp:unit dbp:kg_CO2_m3 ;
419     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
420         cPset_EnvironmentalImpactValues_C1 0.329482336 ;
421     dbp:unit dbp:kg_CO2_m3 ;
422     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
423         cPset_EnvironmentalImpactValues_C2 1.276486739 ;
424     dbp:unit dbp:kg_CO2_m3 ;
425     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
426         cPset_EnvironmentalImpactValues_C3 3.361008751 ;
427     dbp:unit dbp:kg_CO2_m3 ;
428     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
429         cPset_EnvironmentalImpactValues_D -1.026415452 ;
430     dbp:unit dbp:kg_CO2_m3 .
431
432 # Porenbeton_P4_05_unbewehrt
433 obd:1a43ae76-2dc9-4a3a-9926-47e7137e773d?version=20.19.120 a owl:
434     Class ;
435     rdfs:label "Porenbeton_P4_05_unbewehrt"^^xsd:string ;
436     rdfs:subClassOf obd:Porenbeton ;
437     bSDD:uri/LCA/LCA/3.0/prop/GWP_total 226.3260792 ;
438     dbp:unit dbp:kg_CO2_m3 ;
439     bSDD:cPset_EnvironmentalImpactValues_A1_A3 222.6049535 ;
440     dbp:unit dbp:kg_CO2_m3 ;
441     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
442         cPset_EnvironmentalImpactValues_C1 0.311031325 ;
443     dbp:unit dbp:kg_CO2_m3 ;
444     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
445         cPset_EnvironmentalImpactValues_C2 1.205003481 ;
446     dbp:unit dbp:kg_CO2_m3 ;
447     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
448         cPset_EnvironmentalImpactValues_C3 3.17457002 ;
449     dbp:unit dbp:kg_CO2_m3 ;
450     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
451         cPset_EnvironmentalImpactValues_D -0.969479095 ;
452     dbp:unit dbp:kg_CO2_m3 .
453
454 # Recycling_Transportbeton_C20/25
455 obd:6739667a-49d1-4a9c-a4b2-eb542167710c?version=20.23.050 a owl:
456     Class ;
457     rdfs:label "Recycling_Transportbeton_C20/25"^^xsd:string ;
458     rdfs:subClassOf obd:Transportbeton ;
459     bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
460         prop/Pset_ConcreteElementGeneral/StrengthClass "C20/25" ;
461     bSDD:uri/Al-Qazzaz/Circularity/0.0.1/prop/Recycled "yes" ;
462     bSDD:uri/LCA/LCA/3.0/prop/GWP_total 239.3317391 ;
463     dbp:unit dbp:kg_CO2_m3 ;
464     bSDD:cPset_EnvironmentalImpactValues_A1_A3 217.0292701 ;
465     dbp:unit dbp:kg_CO2_m3 ;
466     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
467         cPset_EnvironmentalImpactValues_A4 2.230283908 ;
468     dbp:unit dbp:kg_CO2_m3 ;
469     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
470         cPset_EnvironmentalImpactValues_C1 0.67356176 ;
471     dbp:unit dbp:kg_CO2_m3 ;

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456 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
457   cPset_EnvironmentalImpactValues_C2 7.474639473 ;
458   dbp:unit dbp:kg_CO2_m3 ;
459 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
460   cPset_EnvironmentalImpactValues_C3 15.54075056 ;
461   dbp:unit dbp:kg_CO2_m3 ;
462 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
463   cPset_EnvironmentalImpactValues_D -3.616766705 ;
464   dbp:unit dbp:kg_CO2_m3 .

465 # Recycling_Transportbeton_C25/30
466 obd:899ad6d2-c598-4831-bc0a-8638aa034a69?version=20.23.050 a owl:
467   Class ;
468   rdfs:label "Recycling_Transportbeton_C25/30"^^xsd:string ;
469   rdfs:subClassOf obd:Transportbeton ;
470   bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
471     prop/Pset_ConcreteElementGeneral/StrengthClass "C25/30" ;
472   bSDD:uri/Al-Qazzaz/Circularity/0.0.1/prop/Recycled "yes" ;
473   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 238.8663118 ;
474   dbp:unit dbp:kg_CO2_m3 ;
475   bSDD:cPset_EnvironmentalImpactValues_A1_A3 219.2800857 ;
476   dbp:unit dbp:kg_CO2_m3 ;
477   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
478     cPset_EnvironmentalImpactValues_A4 2.03122474 ;
479   dbp:unit dbp:kg_CO2_m3 ;
480   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
481     cPset_EnvironmentalImpactValues_C1 0.613077197 ;
482   dbp:unit dbp:kg_CO2_m3 ;
483   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
484     cPset_EnvironmentalImpactValues_C2 6.802978586 ;
485   dbp:unit dbp:kg_CO2_m3 ;
486   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
487     cPset_EnvironmentalImpactValues_C3 14.12378105 ;
488   dbp:unit dbp:kg_CO2_m3 ;
489   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
490     cPset_EnvironmentalImpactValues_D -3.984835459 ;
491   dbp:unit dbp:kg_CO2_m3 .

492 # Recycling_Transportbeton_C30/37
493 obd:b38f2dac-fa08-4a9c-ae8d-017f6e2f169f?version=20.23.050 a owl:
494   Class ;
495   rdfs:label "Recycling_Transportbeton_C30/37"^^xsd:string ;
496   rdfs:subClassOf obd:Transportbeton ;
497   bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
498     prop/Pset_ConcreteElementGeneral/StrengthClass "C30/37" ;
499   bSDD:uri/Al-Qazzaz/Circularity/0.0.1/prop/Recycled "yes" ;
500   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 303.4689735 ;
501   dbp:unit dbp:kg_CO2_m3 ;
502   bSDD:cPset_EnvironmentalImpactValues_A1_A3 281.0739412 ;
503   dbp:unit dbp:kg_CO2_m3 ;
504   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
505     cPset_EnvironmentalImpactValues_A4 2.244422486 ;
506   dbp:unit dbp:kg_CO2_m3 ;
507   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
508     cPset_EnvironmentalImpactValues_C1 0.676193458 ;
509   dbp:unit dbp:kg_CO2_m3 ;
510   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
511     cPset_EnvironmentalImpactValues_C2 7.503843911 ;
512   dbp:unit dbp:kg_CO2_m3 ;
513   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
514     cPset_EnvironmentalImpactValues_C3 15.6014704 ;
515   dbp:unit dbp:kg_CO2_m3 ;
516   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
517     cPset_EnvironmentalImpactValues_D -3.630897907 ;
518   dbp:unit dbp:kg_CO2_m3 .

519 # Recycling_Transportbeton_C50/60
520 obd:5c89cce2-688c-4fed-aa02-eda80ffba5f7?version=20.23.050 a owl:
521   Class ;
522   rdfs:label "Recycling_Transportbeton_C50/60"^^xsd:string ;

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508 rdfs:subClassOf obd:Transportbeton ;
509 bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
   prop/Pset_ConcreteElementGeneral/StrengthClass "C50/60" ;
510 bSDD:uri/Al-Qazzaz/Circularity/0.0.1/prop/Recycled "yes" ;
511 bSDD:uri/LCA/LCA/3.0/prop/GWP_total 343.7623072 ;
512 dbp:unit dbp:kg_CO2_m3 ;
513 bSDD:cPset_EnvironmentalImpactValues_A1_A3 324.0369363 ;
514 dbp:unit dbp:kg_CO2_m3 ;
515 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
   cPset_EnvironmentalImpactValues_A4 2.045883972 ;
516 dbp:unit dbp:kg_CO2_m3 ;
517 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
   cPset_EnvironmentalImpactValues_C1 0.617424632 ;
518 dbp:unit dbp:kg_CO2_m3 ;
519 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
   cPset_EnvironmentalImpactValues_C2 6.851219671 ;
520 dbp:unit dbp:kg_CO2_m3 ;
521 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
   cPset_EnvironmentalImpactValues_C3 14.2239352 ;
522 dbp:unit dbp:kg_CO2_m3 ;
523 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
   cPset_EnvironmentalImpactValues_D -4.013092608 ;
524 dbp:unit dbp:kg_CO2_m3 .

525 # Transportbeton_C20/25
526 obd:9702d9ab-2af2-4fdc-9d99-225583a9ffb7?version=20.20.020 a owl:
527   Class ;
528   rdfs:label "Transportbeton_C20/25"^^xsd:string ;
529   rdfs:subClassOf obd:Transportbeton ;
530   bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
      prop/Pset_ConcreteElementGeneral/StrengthClass "C20/25" ;
531   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 248.9199851 ;
532   dbp:unit dbp:kg_CO2_m3 ;
533   bSDD:cPset_EnvironmentalImpactValues_A1_A3 228.6183481 ;
534   dbp:unit dbp:kg_CO2_m3 ;
535   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
      cPset_EnvironmentalImpactValues_C1 1.696008299 ;
536   dbp:unit dbp:kg_CO2_m3 ;
537   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
      cPset_EnvironmentalImpactValues_C2 1.555156625 ;
538   dbp:unit dbp:kg_CO2_m3 ;
539   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
      cPset_EnvironmentalImpactValues_C3 15.8728501 ;
540   dbp:unit dbp:kg_CO2_m3 ;
541   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
      cPset_EnvironmentalImpactValues_D -4.847395473 ;
542   dbp:unit dbp:kg_CO2_m3 .

543 # Transportbeton_C25/30
544 obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version=20.23.050 a owl:
545   Class ;
546   rdfs:label "Transportbeton_C25/30"^^xsd:string ;
547   rdfs:subClassOf obd:Transportbeton ;
548   bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
      prop/Pset_ConcreteElementGeneral/StrengthClass "C25/30" ;
549   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 242.5490161 ;
550   dbp:unit dbp:kg_CO2_m3 ;
551   bSDD:cPset_EnvironmentalImpactValues_A1_A3 222.9636637 ;
552   dbp:unit dbp:kg_CO2_m3 ;
553   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
      cPset_EnvironmentalImpactValues_A4 2.030350996 ;
554   dbp:unit dbp:kg_CO2_m3 ;
555   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
      cPset_EnvironmentalImpactValues_C1 0.613077197 ;
556   dbp:unit dbp:kg_CO2_m3 ;
557   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
      cPset_EnvironmentalImpactValues_C2 6.802978586 ;
558   dbp:unit dbp:kg_CO2_m3 ;
559   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
      cPset_EnvironmentalImpactValues_C3 14.12378105 ;

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560      dbp:unit dbp:kg_CO2_m3 ;
561      bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
562          cPset_EnvironmentalImpactValues_D -3.984835459 ;
563          dbp:unit dbp:kg_CO2_m3 .
564
565 # Transportbeton_C30/37
566 obd:a758fb6a-7fb1-4cdc-b652-c42cf2f7632c?version=20.20.020 a owl:
567     Class ;
568     rdfs:label "Transportbeton_C30/37"^^xsd:string ;
569     rdfs:subClassOf obd:Transportbeton ;
570     bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
571         prop/Pset_ConcreteElementGeneral/StrengthClass "C30/37" ;
572         bSDD:uri/LCA/LCA/3.0/prop/GWP_total 303.3659512 ;
573         dbp:unit dbp:kg_CO2_m3 ;
574         bSDD:cPset_EnvironmentalImpactValues_A1_A3 283.0643142 ;
575         dbp:unit dbp:kg_CO2_m3 ;
576         bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
577             cPset_EnvironmentalImpactValues_A4 1.696008299 ;
578             dbp:unit dbp:kg_CO2_m3 ;
579             bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
580                 cPset_EnvironmentalImpactValues_C1 1.555156625 ;
581                 dbp:unit dbp:kg_CO2_m3 ;
582                 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
583                     cPset_EnvironmentalImpactValues_C2 6.025017407 ;
584                     dbp:unit dbp:kg_CO2_m3 ;
585                     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
586                         cPset_EnvironmentalImpactValues_C3 15.8728501 ;
587                         dbp:unit dbp:kg_CO2_m3 ;
588                         bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
589                             cPset_EnvironmentalImpactValues_D -4.847395473 ;
590                             dbp:unit dbp:kg_CO2_m3 .
591
592 # Transportbeton_C50/60
593 obd:079ed601-8b92-49cd-9c09-ab8e067366cf?version=20.23.050 a owl:
594     Class ;
595     rdfs:label "Transportbeton_C50/60"^^xsd:string ;
596     rdfs:subClassOf obd:Transportbeton ;
597     bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
598         prop/Pset_ConcreteElementGeneral/StrengthClass "C50/60" ;
599         bSDD:uri/LCA/LCA/3.0/prop/GWP_total 347.2850623 ;
600         dbp:unit dbp:kg_CO2_m3 ;
601         bSDD:cPset_EnvironmentalImpactValues_A1_A3 327.5596914 ;
602         dbp:unit dbp:kg_CO2_m3 ;
603         bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
604             cPset_EnvironmentalImpactValues_A4 2.045883972 ;
605             dbp:unit dbp:kg_CO2_m3 ;
606             bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
607                 cPset_EnvironmentalImpactValues_C1 0.617424632 ;
608                 dbp:unit dbp:kg_CO2_m3 ;
609                 bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
610                     cPset_EnvironmentalImpactValues_C2 6.851219671 ;
611                     dbp:unit dbp:kg_CO2_m3 ;
612                     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
613                         cPset_EnvironmentalImpactValues_C3 14.2239352 ;
614                         dbp:unit dbp:kg_CO2_m3 ;
615                         bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
616                             cPset_EnvironmentalImpactValues_D -4.013092608 ;
617                             dbp:unit dbp:kg_CO2_m3 .
618
619 # Betonfertigteil_Treppe_(1.1_m_Breite._9_Stufen_a_16_cm)
620 obd:ab0a0f3c-41f6-4b0a-a12c-f8bd0c8a4a23?version=20.19.120 a owl:
621     Class ;
622     rdfs:label "Betonfertigteil_Treppe_(1.1_m_Breite.
623         _9_Stufen_a_16_cm)"^^xsd:string ;
624     rdfs:subClassOf obd:Betonfertigteile_und_Betonwaren ;
625     bSDD:uri/LCA/LCA/3.0/prop/GWP_total 329.7597014 ;
626         dbp:unit dbp:kg_CO2_pcs ;
627         bSDD:cPset_EnvironmentalImpactValues_A1_A3 312.8355034 ;
628         dbp:unit dbp:kg_CO2_pcs ;
629         bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/

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613   cPset_EnvironmentalImpactValues_C1 1.412580633 ;
614   dbp:unit dbp:kg_CO2_pcs ;
615   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
616     cPset_EnvironmentalImpactValues_C2 5.472646782 ;
617     dbp:unit dbp:kg_CO2_pcs ;
618   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
619     cPset_EnvironmentalImpactValues_C3 13.94185307 ;
620     dbp:unit dbp:kg_CO2_pcs ;
621   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
622     cPset_EnvironmentalImpactValues_D -3.902882519 ;
623     dbp:unit dbp:kg_CO2_pcs .
624
625 #Betonrohr_bewehrt
626 obd:16e0f5b5-8090-4466-b303-7b8ae71110d8?version=20.23.050 a owl:
627   Class ;
628   rdfs:label "Betonrohr_bewehrt"^^xsd:string ;
629   rdfs:subClassOf obd:Betonfertigteile_und_Betonwaren ;
630   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 0.150445554 ;
631   dbp:unit dbp:kg_CO2_kg ;
632   bSDD:cPset_EnvironmentalImpactValues_A1_A3 0.141743443 ;
633   dbp:unit dbp:kg_CO2_kg ;
634   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
635     cPset_EnvironmentalImpactValues_C1 0.000718871 ;
636     dbp:unit dbp:kg_CO2_kg ;
637   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
638     cPset_EnvironmentalImpactValues_C2 0.002785062 ;
639     dbp:unit dbp:kg_CO2_kg ;
640     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
641       cPset_EnvironmentalImpactValues_C3 0.00721909 ;
642     dbp:unit dbp:kg_CO2_kg ;
643     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
644       cPset_EnvironmentalImpactValues_D -0.002020912 ;
645     dbp:unit dbp:kg_CO2_kg .
646
647 #Betonrohr_unbewehrt
648 obd:0ead4728-b626-4f79-ba67-020635b4e67f?version=20.19.120 a owl:
649   Class ;
650   rdfs:label "Betonrohr_unbewehrt"^^xsd:string ;
651   rdfs:subClassOf obd:Betonfertigteile_und_Betonwaren ;
652   bSDD:uri/LCA/LCA/3.0/prop/GWP_total 0.140978586 ;
653   dbp:unit dbp:kg_CO2_kg ;
654   bSDD:cPset_EnvironmentalImpactValues_A1_A3 0.132191415 ;
655   dbp:unit dbp:kg_CO2_kg ;
656   bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
657     cPset_EnvironmentalImpactValues_C1 0.000718871 ;
658     dbp:unit dbp:kg_CO2_kg ;
659     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
660       cPset_EnvironmentalImpactValues_C2 0.002785062 ;
661     dbp:unit dbp:kg_CO2_kg ;
662     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
663       cPset_EnvironmentalImpactValues_C3 0.007337219 ;
664     dbp:unit dbp:kg_CO2_kg ;
665     bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
666       cPset_EnvironmentalImpactValues_D -0.002053981 ;
667     dbp:unit dbp:kg_CO2_kg .
668
669
670
671 # FreeClass Class Structure
672
673 fcl:eurobau_artikelstamm/12#trv a owl:Class ;
674   rdfs:label "12_Rohbau_Konstruktion"^^xsd:string .
675
676 fcl:eurobau_artikelstamm/120#trv a owl:Class ;
677   rdfs:label "120_Beton"^^xsd:string ;
678   rdfs:subClassOf fcl:eurobau_artikelstamm/12#trv .
679
680 fcl:eurobau_artikelstamm/1200#trv a owl:Class ;
681   rdfs:label "1200_Transportbeton"^^xsd:string ;
682   rdfs:subClassOf fcl:eurobau_artikelstamm/120#trv .

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669
670 #Transportbeton C25/30 B1 + Manufacturers (as instances)
671 fcl:europbau_artikelstamm/12002501#trv a owl:Class ;
672   rdfs:label "Transportbeton_C25/30_B1"^^xsd:string ;
673   rdfs:subClassOf fcl:europbau_artikelstamm/1200#trv ;
674   skos:narrowMatch obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version
       =20.23.050 .
675
676 fcl:produkt_info/529/AT0052 a fcl:europbau_artikelstamm/12002501#trv ;
677   rdfs:label "LANG_Ing._Hans"^^xsd:string .
678
679 #Transportbeton C25/30 B3 + Manufacturers (as instances)
680 fcl:europbau_artikelstamm/12002503#trv a owl:Class ;
681   rdfs:label "Transportbeton_C25/30_B3"^^xsd:string ;
682   rdfs:subClassOf fcl:europbau_artikelstamm/1200#trv ;
683   skos:narrowMatch obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version
       =20.23.050 .
684
685 fcl:produkt_info/529/AT0052 a fcl:europbau_artikelstamm/12002503#trv ;
686   rdfs:label "LANG_Ing._Hans"^^xsd:string .
687
688 #Transportbeton C25/30 B4 + Manufacturers (as instances)
689 fcl:europbau_artikelstamm/12002504#trv a owl:Class ;
690   rdfs:label "Transportbeton_C25/30_B4"^^xsd:string ;
691   rdfs:subClassOf fcl:europbau_artikelstamm/1200#trv ;
692   skos:narrowMatch obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version
       =20.23.050 .
693
694 fcl:produkt_info/529/AT0052 a fcl:europbau_artikelstamm/12002504#trv ;
695   rdfs:label "LANG_Ing._Hans"^^xsd:string .
696
697 #Transportbeton C20/25 B7 GK 32 mm + Manufacturers (as instances)
698 fcl:europbau_artikelstamm/12002732#trv a owl:Class ;
699   rdfs:label "Transportbeton_C20/25_B7_GK_32_mm"^^xsd:string ;
700   rdfs:subClassOf fcl:europbau_artikelstamm/1200#trv ;
701   skos:narrowMatch obd:6739667a-49d1-4a9c-a4b2-eb542167710c?version
       =20.23.050 .
702
703 fcl:produkt_info/529/AT0052 a fcl:europbau_artikelstamm/12002732#trv ;
704   rdfs:label "LANG_Ing._Hans"^^xsd:string .
705
706 #Pumpbeton C25/30 GK 4 mm + Manufacturers (as instances)
707 fcl:europbau_artikelstamm/12005004#trv a owl:Class ;
708   rdfs:label "Pumpbeton_C25/30_GK_4_mm"^^xsd:string ;
709   rdfs:subClassOf fcl:europbau_artikelstamm/1200#trv ;
710   skos:narrowMatch obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version
       =20.23.050 .
711
712 fcl:produkt_info/558/AT0076 a fcl:europbau_artikelstamm/12005004#trv ;
713   rdfs:label "Baumit_PumpBeton"^^xsd:string .
714
715 #Trockenbeton C16/20 + Manufacturers (as instances)
716 fcl:europbau_artikelstamm/12005516#trv a owl:Class ;
717   rdfs:label "Trockenbeton_C16/20"^^xsd:string ;
718   rdfs:subClassOf fcl:europbau_artikelstamm/1200#trv .
719
720 fcl:produkt_info/556/AT0076 a fcl:europbau_artikelstamm/12005516#trv ;
721   rdfs:label "Baumit_ALL_IN_TrockenBeton_20"^^xsd:string .
722
723 fcl:produkt_info/561/AT0076 a fcl:europbau_artikelstamm/12005516#trv ;
724   rdfs:label "Baumit_GO2morrow_Recycling_Beton_B20"^^xsd:string .
725
726 fcl:produkt_info/553/AT0076 a fcl:europbau_artikelstamm/12005516#trv ;
727   rdfs:label "Baumit_NixMix_Beton"^^xsd:string .
728
729 fcl:produkt_info/555/AT0076 a fcl:europbau_artikelstamm/12005516#trv ;
730   rdfs:label "Baumit_TrockenBeton_20"^^xsd:string .
731
732 fcl:produkt_info/629/AT0986 a fcl:europbau_artikelstamm/12005516#trv ;
733   rdfs:label "PROFI_Trockenbeton_DC16/20"^^xsd:string .

```

```

734
735 fcl:produkt_info/580/AT1490 a fcl:eurobau_artikelstamm/12005516#trv ;
736   rdfs:label "Faser-Trockenbeton_B225F"^^xsd:string .
737
738 fcl:produkt_info/579/AT1490 a fcl:eurobau_artikelstamm/12005516#trv ;
739   rdfs:label "Trockenbeton_B225"^^xsd:string .
740
741 # Trockenbeton C25/30 + Manufacturers (as instances)
742 fcl:eurobau_artikelstamm/12005525#trv a owl:Class ;
743   rdfs:label "Trockenbeton_C25/30"^^xsd:string ;
744   rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv ;
745   skos:narrowMatch obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version
746   =20.23.050 .
747
748 fcl:produkt_info/559/AT0076 a fcl:eurobau_artikelstamm/12005525#trv ;
749   rdfs:label "Baumit_Dicht_und_SichtBeton"^^xsd:string .
750
751 fcl:produkt_info/560/AT0076 a fcl:eurobau_artikelstamm/12005525#trv ;
752   rdfs:label "Baumit_HobbyBeton"^^xsd:string .
753
754 fcl:produkt_info/554/AT0076 a fcl:eurobau_artikelstamm/12005525#trv ;
755   rdfs:label "Baumit_TrockenBeton_30"^^xsd:string .
756
757 fcl:produkt_info/517/AT0522 a fcl:eurobau_artikelstamm/12005525#trv ;
758   rdfs:label "Trockenbeton_C_25/30_-_Trockenestrich_C_30-F5"^^xsd:
759   string .
760
761 fcl:produkt_info/627/AT0986 a fcl:eurobau_artikelstamm/12005525#trv ;
762   rdfs:label "PROFI_Beton_4_mm"^^xsd:string .
763
764 fcl:produkt_info/628/AT0986 a fcl:eurobau_artikelstamm/12005525#trv ;
765   rdfs:label "PROFI_Einfach_Schnell_Beton"^^xsd:string .
766
767 fcl:produkt_info/632/AT0986 a fcl:eurobau_artikelstamm/12005525#trv ;
768   rdfs:label "PROFI_Fliessbeton_DC25/30"^^xsd:string .
769
770 fcl:produkt_info/633/AT0986 a fcl:eurobau_artikelstamm/12005525#trv ;
771   rdfs:label "PROFI_Fliessbeton_DC25/30_WU"^^xsd:string .
772
773 fcl:produkt_info/630/AT0986 a fcl:eurobau_artikelstamm/12005525#trv ;
774   rdfs:label "PROFI_Trockenbeton_DC25/30"^^xsd:string .
775
776 fcl:produkt_info/581/AT1490 a fcl:eurobau_artikelstamm/12005525#trv ;
777   rdfs:label "Trockenbeton_B300"^^xsd:string .
778
779 # Trockenbeton C30/37 + Manufacturers (as instances)
780 fcl:eurobau_artikelstamm/12005530#trv a owl:Class ;
781   rdfs:label "Trockenbeton_C30/37"^^xsd:string ;
782   rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv ;
783   skos:narrowMatch obd:a758fb6a-7fb1-4cdc-b652-c42cf2f7632c?version
784   =20.20.020 .
785
786 fcl:produkt_info/634/AT0986 a fcl:eurobau_artikelstamm/12005530#trv ;
787   rdfs:label "PROFI_Fliessbeton_C30/37"^^xsd:string .
788
789 # Drainage Beton Groe tkorn 4 mm + Manufacturers (as instances)
790 fcl:eurobau_artikelstamm/12006004#trv a owl:Class ;
791   rdfs:label "Drainage_Beton_Groe tkorn_4_mm"^^xsd:string ;
792   rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv .
793
794 fcl:produkt_info/739/AT0076/22596 a fcl:eurobau_artikelstamm/12006004
795   #trv ;
796   rdfs:label "Baumit_PflasterDrainmoertel_GK_4_plus"^^xsd:string .
797
798 fcl:produkt_info/645/AT0986 a fcl:eurobau_artikelstamm/12006004#trv ;
799   rdfs:label "PROFI_Drainbeton"^^xsd:string .

```

```

800 # Drainage Beton Groe tkorn 8 mm + Manufacturers (as instances)
801 fcl:eurobau_artikelstamm/12006008#trv a owl:Class ;
802     rdfs:label "Drainage_Beton_Groe tkorn_8_mm"^^xsd:string ;
803     rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv .
804
805 fcl:produkt_info/557/AT0076/22457 a fcl:eurobau_artikelstamm/12006008
806     #trv ;
807     rdfs:label "Baumit_DrainBeton"^^xsd:string .
808
809 fcl:produkt_info/506/AT0031 a fcl:eurobau_artikelstamm/12006008#trv ;
810     rdfs:label "Creteo Gala_CC_633"^^xsd:string .
811
812 # Bl htonbeton
813 fcl:eurobau_artikelstamm/1201#trv a owl:Class ;
814     rdfs:label "1201_Bl htonbeton"^^xsd:string ;
815     rdfs:subClassOf fcl:eurobau_artikelstamm/120#trv .
816
817 #Spritzbeton Beton-Groe tkorn 4 mm + Manufacturers (as instances)
818 fcl:eurobau_artikelstamm/12010504#trv a owl:Class ;
819     rdfs:label "Spritzbeton_Beton-Groe tkorn_4_mm"^^xsd:string ;
820     rdfs:subClassOf fcl:eurobau_artikelstamm/1201#trv .
821
822 fcl:produkt_info/636/AT0986 a fcl:eurobau_artikelstamm/12010504#trv ;
823     rdfs:label "PROFI_Trockenspritzbeton_SP_GK4"^^xsd:string .
824
825 fcl:produkt_info/758/AT0031 a fcl:eurobau_artikelstamm/12010504#trv ;
826     rdfs:label "PCreteo Repair_CC_194_M"^^xsd:string .
827
828 fcl:produkt_info/733/AT0031 a fcl:eurobau_artikelstamm/12010504#trv ;
829     rdfs:label "Creteo Shot_CC_575"^^xsd:string .
830
831 #Spritzbeton Beton-Groe tkorn 8 mm + Manufacturers (as instances)
832 fcl:eurobau_artikelstamm/12010508#trv a owl:Class ;
833     rdfs:label "Spritzbeton_Beton-Groe tkorn_8_mm"^^xsd:string ;
834     rdfs:subClassOf fcl:eurobau_artikelstamm/1201#trv .
835
836 fcl:produkt_info/635/AT0986 a fcl:eurobau_artikelstamm/12010508#trv ;
837     rdfs:label "PROFI_Trockenspritzbeton_SP_GK8"^^xsd:string .
838
839 fcl:produkt_info/582/AT1490 a fcl:eurobau_artikelstamm/12010508#trv ;
840     rdfs:label "Spritzbeton_B350"^^xsd:string .
841
842 fcl:produkt_info/736/AT0031 a fcl:eurobau_artikelstamm/12010508#trv ;
843     rdfs:label "Creteo Shot_CC_555_J2"^^xsd:string .
844
845 fcl:1202#trv/eurobau_artikelstamm a fcl:eurobau_artikelstamm/120#trv
846     ;
847     rdfs:label "1202_Zusatzmittel._Haftbr cken_f._Beton-_und_Moertel"
848     "^^xsd:string .

```

B Appendix Section

```

1 graph = rdflib.Graph()
2 graph.parse (r"RDF.ttl") #insert path to RDF
3 print(f"Graph_has_{len(graph)}_statements.")
4 graph
5 for s,p,o in graph:
6     print(s, p, o)
7 import rdflib
8 import networkx as nx
9 import ipycytoscape
10
11 # Namespaces
12 SKOS = rdflib.Namespace("http://www.w3.org/2004/02/skos/core#")
13 RDFS = rdflib.namespace.RDFS

```

```

14 XSD = rdflib.namespace.XSD
15 OWL = rdflib.namespace.OWL
16 DBP = rdflib.Namespace("https://dbpedia.org/page/")
17 DBPP = rdflib.Namespace("https://dbpedia.org/property/")
18 BSDD = rdflib.Namespace("https://identifier.buildingsmart.org/")
19 FCL = rdflib.Namespace("https://www.freeclass.de/")
20
21 # Create a new RDFLib graph and parse the Turtle file
22 g = rdflib.Graph()
23 g.bind("skos", SKOS)
24 g.bind("rdfs", RDFS)
25 g.bind("xsd", XSD)
26 g.bind("owl", OWL)
27 g.bind("dbp", DBP)
28 g.bind("dbpp", DBPP)
29 g.bind("bsdd", BSDD)
30 g.bind("fcl", FCL)
31 g.parse(r"C:\AA_UNI_SS24\BA_DC\KOL_2\RDF_Concrete_KOL2_Aktuell.ttl")
    # Update with your file path
32
33 # Function to get label
34 def get_label(node):
35     label = g.value(node, RDFS.label)
36     return str(label) if label else str(node)
37
38 # Function to get label with prefix
39 def get_label_with_prefix(node):
40     for prefix, uri in g.namespaces():
41         if str(node).startswith(uri):
42             return f"{prefix}:{node.split(uri)[-1]}"
43     return str(node) # Return full URI if no namespace match
44
45 # Print node labels with prefixes
46 for subj, _, _ in g:
47     print(get_label_with_prefix(subj))
48
49 # Convert RDFLib graph to a NetworkX graph
50 nx_graph = nx.DiGraph()
51
52 # Function to get edge label with prefix
53 def get_edge_label(pred):
54     for prefix, uri in g.namespaces():
55         if str(pred).startswith(uri):
56             return f"{prefix}:{pred.split(uri)[-1]}"
57     return str(pred) # Return full URI if no namespace match
58
59 for subj, pred, obj in g:
60     subj_label = get_label(subj)
61     obj_label = get_label(obj)
62
63     if not nx_graph.has_node(subj):
64         nx_graph.add_node(subj, label=get_label_with_prefix(subj))
65     if not nx_graph.has_node(obj):
66         nx_graph.add_node(obj, label=get_label_with_prefix(obj))
67
68     edge_label = get_edge_label(pred)
69     nx_graph.add_edge(subj, obj, label=edge_label)
70
71 # Define layout options for concentric layout
72 layout_options = {
73     'name': 'concentric', # Change layout to concentric
74     'animate': True,
75     'spacingFactor': 5, # Adjust spacing between rings of nodes
76 }
77
78 # Convert NetworkX graph to Cytoscape JSON format
79 cyto_graph = ipycytoscape.CytoscapeWidget(layout=layout_options)
80 cyto_graph.graph.add_graph_from_networkx(nx_graph, directed=True)
81
82 # Define style for the nodes and edges

```

```
83 cyto_graph.set_style([
84     {
85         'selector': 'node',
86         'style': {
87             'label': 'data(label)',
88             'color': '#000000',
89             'text-valign': 'center',
90             'text-halign': 'right',
91             'background-color': '#11479e'
92         }
93     },
94     {
95         'selector': 'edge',
96         'style': {
97             'label': 'data(label)',
98             'curve-style': 'bezier',
99             'target-arrow-shape': 'triangle',
100            'color': '#9dbaea',
101            'line-color': '#9dbaea',
102            'target-arrow-color': '#9dbaea'
103        }
104    }
105 ])
106
107 cyto_graph
108 # Export the graph structure to GraphML
109 nx.write_graphml(nx_graph, "RDF.graphml")
```