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Civil Systems Engineering – Modeling Engineering Products

Individual Assignment I – Ontological Modeling

0. General

What is purpose?

This ontology is developed to summarize the conceptual design of this timber room module, which is part of the whole composition for a student housing project.

What is the scope?

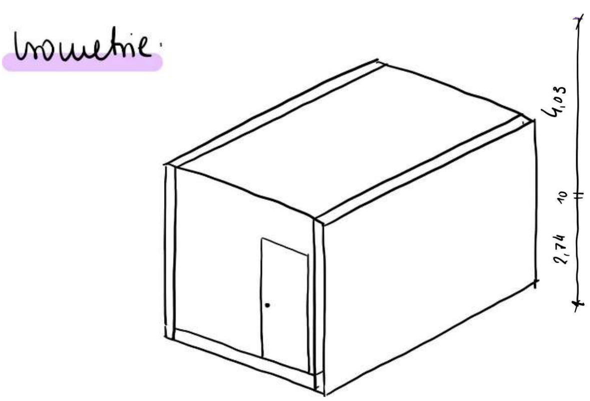
This ontology includes concepts such as physical components, their respective functions, their relation to each other and their possible materials.

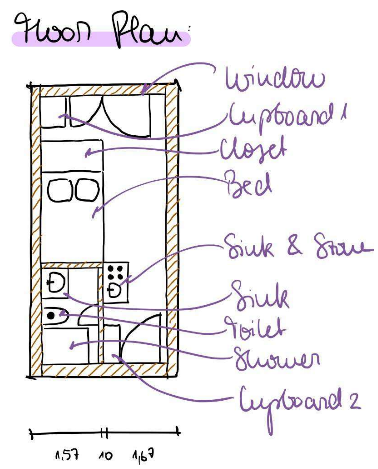
Who are the intended users?

The intended users are planners in early as well as later planning phases, looking for a summary about the function and logic behind the timber module and its elements.

What is the intended use?

As a guideline for planners to integrate these timber room modules into a bigger system that will function as a student housing.





1. Background Research

Civil Engineering System: timber room modules

Main components of system:[i]

- Construction 6 Sides:
  - 2 horizontal
    - Ceiling: CLT with layer of chippings and impact sound insulation
    - Floor: CLT with layer of natural rubber
  - 4 vertical
    - 2 long walls, 2 short walls: 12.5cm CLT, 10cm plasterboard and 5cm fire resistant mineral wool insulation
- Not constructive:

  - 1 short, 1 long wall CLT 10cm
- Wooden Windows, thee layered
- Door: wood
- Interior Installations:
  - Sink and stove
  - Shower
  - Sink and Toilet
  - 2 lamps (each room)
  - 1 heating underneath the window
- Interior mobiliary:
  - Bed
  - 1 closet
  - 2 cupboards
- Technical Equipment: Modules contain cables and pipes
- Connections: bolts from the sides

Main functions of system as a whole and interfaces:

Building Services:

The connection to larger networks such as electricity, heating and water are essential to comply with our standard of living. Also a source of light needs to be thought of, letting in natural light and an artificial light source for moments without natural light available.

The modules have heating, electricity and water that is connected with respective interfaces to a central system of the building that is connected to the local network.

Statically:

As part of a larger structure, the room modules play a relevant role in statically supporting the models above, as well as vertical forces due to snow and wind load.

The room modules must sustain a certain horizontal wind force as well, by itself as well as the composition of modules.

The modules, especially being cuboid need to be stiffened in themselves, to prevent torsion of the construct.

The static interfaces are carrying the modules above as well as the roof, as well as being stuck on the module below.

Building Physics:

Especially considering the high density of people living in one space, the sound insulation needs planned accordingly. Outside walls as well as the ceilings are all equipped with acoustic insulation materials.

Also thermal insulation is important, to keep the need for heating low in winters. At the same time a frequent airflow must be allowed to prevent mold and secure air quality.

Another hazard, especially with the amount of timber in the modules, to ensure fire safety and segregation of inflammable spaces.

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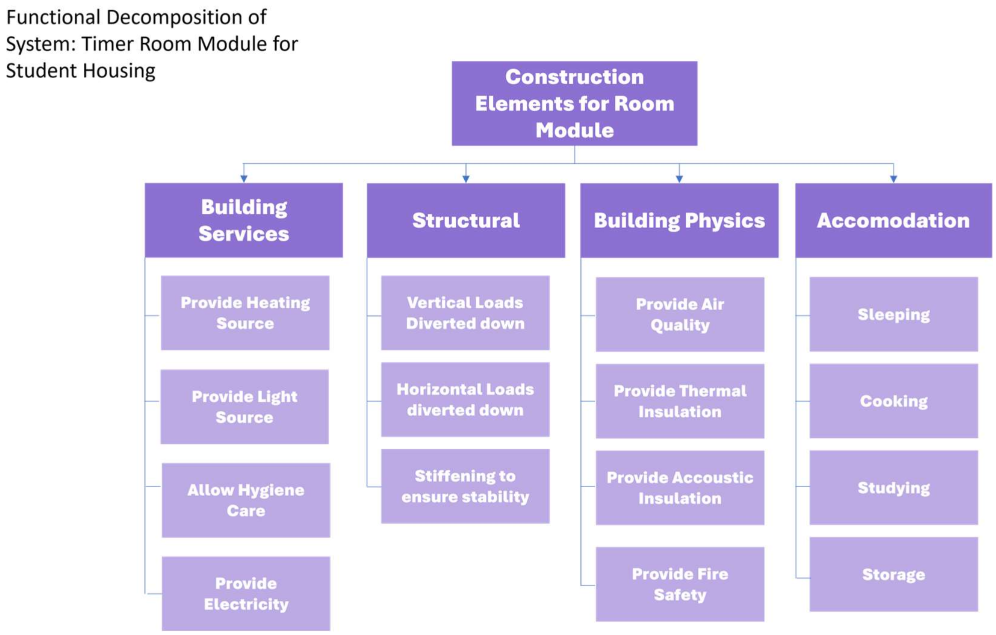
Accommodation:

As a student housing room, the module needs to accommodate a person for sleeping, basic cooking as well as studying. Also storage needs to be provided, as the student has no other place to put his belongings.

Decomposition (physical, functional, logical)

Four top level requirements are discovered for the timber room modules, each with different functions that make up the requirements for the functional decomposition.



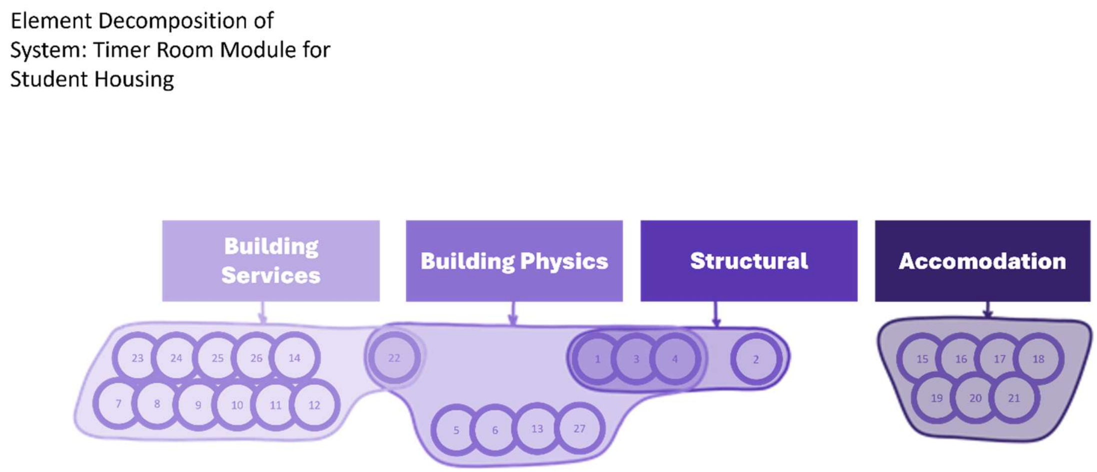
Every element has been listed, assigned an ID number, explained the function as well as sorted into the above declared functions and described its materials.

Nr.	Component	Function	Main Material
1	Ceiling	- Structural (Vertical Loads and Stiffening) - Building Physics (Thermal insulation, Acoustic Insulation and Fire Safety)	- CLT - Chippings - EPS Insulation
2	Floor	- Structural (Vertical Loads)	- CLT - Natural rubber
3	Long constructive wall installation	- Structural (Vertical Loads and Horizontal Loads) - Building Physics (Thermal insulation, Acoustic Insulation and Fire Safety)	- CLT - Plasterboard - Mineral Wool
4	Long constructive wall no installation	- Structural (Vertical Loads and Horizontal Loads)	- CLT - Plasterboard - Mineral Wool

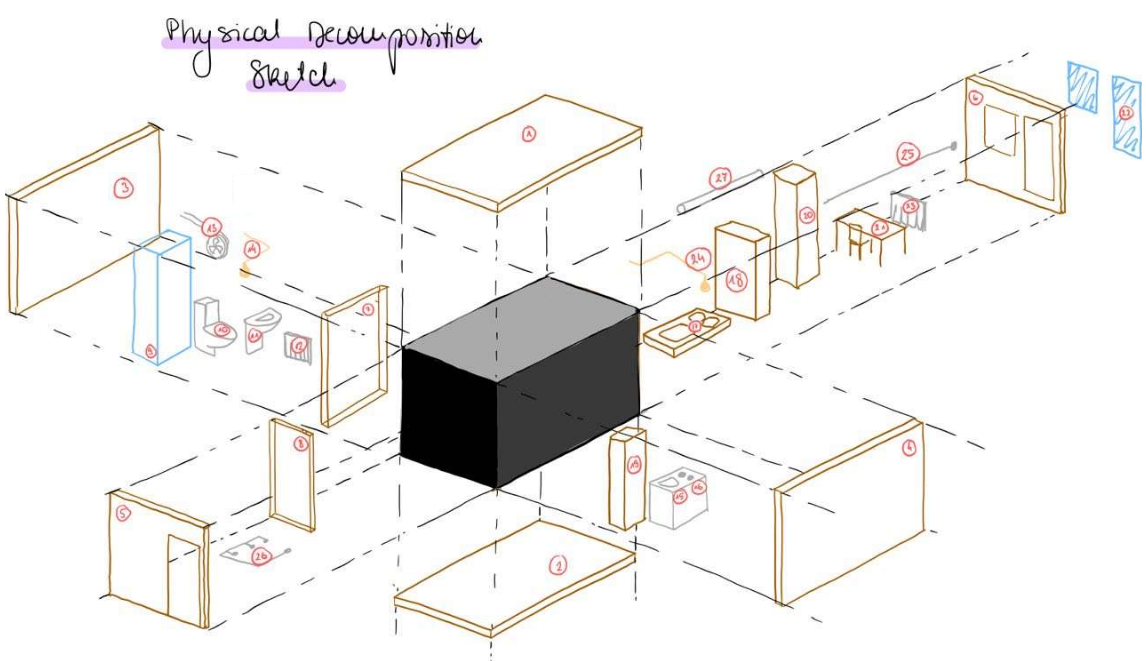
		- Building Physics (Thermal insulation, Acoustic Insulation and Fire Safety)	
5	Short constructive wall hallway	- Building Physics (Thermal insulation, Acoustic Insulation and Fire Safety)	- CLT - Plasterboard - Mineral Wool
6	Short constructive wall façade	- Building Physics (Thermal insulation, Acoustic Insulation and Fire Safety)	- CLT - Plasterboard - Mineral Wool
7	Non-constructive long wall	- Building Services (Hygiene)	- CLT
8	Non-constructive short wall	- Building Services (Hygiene)	- CLT
9	Shower	- Building Services (Hygiene)	- Glass - Steel
10	Toilet	- Building Services (Hygiene)	- Ceramic - Steel - Hard plastic
11	Sink Bathroom	- Building Services (Hygiene)	- Ceramic - Steel
12	Heating Bathroom	- Building Services (Heating Source)	- Iron
13	Air ventilation bathroom	- Building Physics (Air Quality)	- Aluminium
14	Ceiling Lamp Bathroom	- Building Services (Light Source)	- Glass - Copper
15	Sink Kitchen	- Accomodation (Cooking)	- Steel
16	Stove	- Accomodation (Cooking)	- Glass - Metal
17	Bed	- Accomodation (Sleeping)	- CLT - Foam
18	Closet	- Accomodation (Storage)	- CLT
19	Cupboard	- Accomodation (Storage)	- CLT
20	Shelf	- Accomodation (Storage)	- CLT
21	Desk	- Accomodation (Studying)	- CLT
22	Window	- Building Physics (Air Quality) - Building Services (Light Source)	- Timber - Glass
23	Heating Bedroom	- Building Services (Heating Source)	- Iron
24	Ceiling Lamp Bedroom	- Building Services (Light Source)	- Glass - Copper
25	Electricity cables	- Building Services (Electricity)	- Copper - Rubber
26	Plumbing	- Building Services (Hygiene)	- Hard plastic

27	Air duct	- Building Physics (Air Quality)	- Aluminium

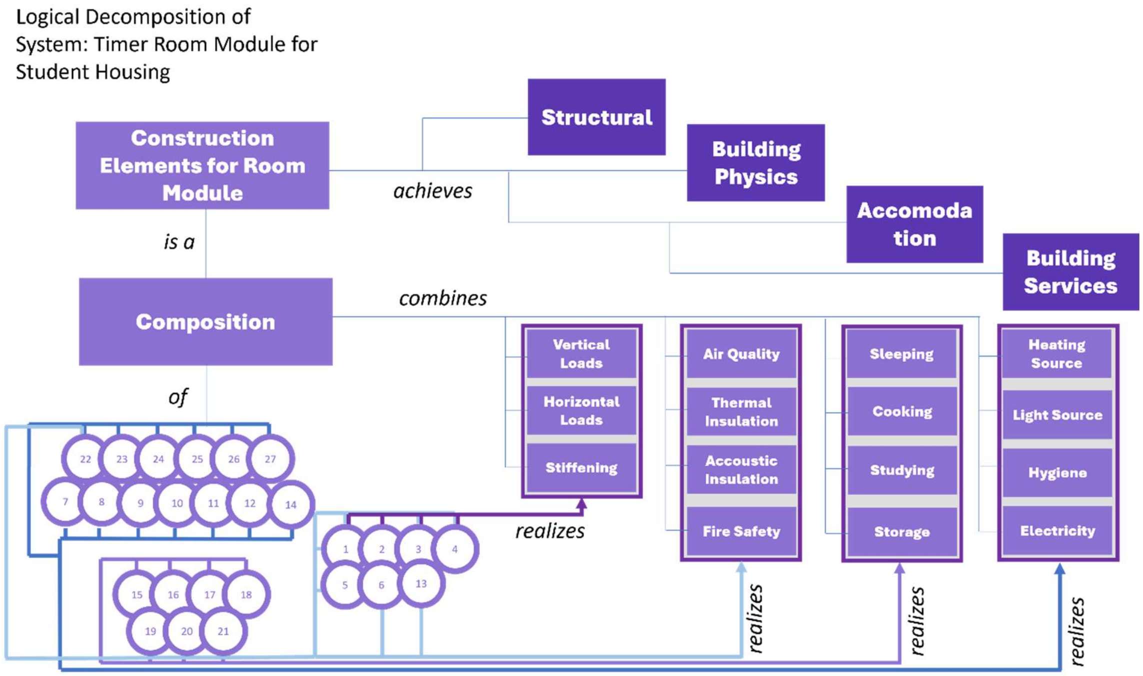
The elements are sorted into the four systems, some of which being part of two systems.



The physical decomposition has been done as an isometric explosion view, with each element numerated according to the table above.[ii]



The requirements of the system, as well as the elements in it and which functions they serve is summarized in the following logical decomposition.[iii]



2. Model System

Application in Onthological Model	Logical Axiom
Disjoint TimberRoomModule, TimberRoomModule, TimberRoomModuleMaterial, TimberRoomModuleUse	TimberRoomModule ⊓ TimberRoomModule ⊓ TimberRoomModuleMaterial ⊓ TimberRoomModuleUse ⊑ ⊥
Disjoint Materials	AluminumMaterial ⊓ CeramicMaterial ⊓ ChippingsMaterial ⊓ CopperMaterial ⊓ CrossLaminatedTimberMaterial ⊓ EPSInsulationMaterial ⊓ FoamMaterial ⊓ GlassMaterial ⊓ HardPlasticMatearial ⊓ IronMaterial ⊓ MineralWoolMaterial ⊓ NaturalRubberMaterial ⊓ RubberMaterial ⊓ SteelMaterial ⊑ ⊥
Disjoint Elements in AccomodationSystem	Bed ⊓ Closet ⊓ Cupboard ⊓ Desk ⊓ Shelf ⊓ SinkKitchen ⊓ Stove ⊑ AccomodationSystem
Disjoint Elements in BuildingPhysicsSystem	AirDuct ⊓ AirVentilationBathroom ⊓ Ceiling ⊓ LongConstructiveWallInstallation ⊓ LongConstructiveWallNoInstallation ⊓ ShortConstructiveWallFacade ⊓ ShortConstructiveWallHallway ⊓ Window ⊑ BuildingPhysicsSystem
Disjoint Elements in BuildingServicesSystem	CeilingLamp ⊓ CeilingLampBathroom ⊓ ElectricityCables ⊓ HeatingBathroom ⊓ HeatingBedroom ⊓

	Non-ConstructiveLongWall ⊓ Non-ConstructiveShortWall ⊓ Plumbing ⊓ Shower ⊓ SinkBathroom ⊓ Toilet ⊓ Window ⊑ BuildingServicesSystem
Disjoint Elements in StructuralSystem	Ceiling ⊓ Floor ⊓ LongConstructiveWallInstallation ⊓ LongConstructiveWallNoInstallation ⊑ Structural system
Disjoint TimberRoomModuleUses	AccousticInsulationUse ⊓ AirQualityUse ⊓ CookingUse ⊓ ElectricityUse ⊓ FireSafetyUse ⊓ HeatingUse ⊓ HygieneUse ⊓ LightUse ⊓ SleepingUse ⊓ StiffeningForStabilityUse ⊓ StorageUse ⊓ StudyingUse ⊓ ThermalInsulationUse ⊓ TransportHorizontalLoadsDownUse ⊓ TransportVerticalLoadsDownUse ⊑ ⊥
Elements with Two Functions	CeilingBuildingPhysics = CeilingStructuralSystem; LongConstructiveWallInstallationBuildingPhysics = LongConstructiveWallInstallationStructural System; LongConstructiveWallNoInstallationBuildingPhysics= LongConstructiveWallNoInstallationStructuralSystem; Window
Defining TimberRoomModuleUses	TimberRoomModuleUses ≡ {AirQualityUse} ⊓ {AccousticInsulationUse} ⊓ {CookingUse} ⊓ {ElectricityUse} ⊓ {FireSafetyUse} ⊓ {HeatingUse} ⊓ {HygieneUse} ⊓ {LightUse} ⊓ {SleepingUse} ⊓ {StiffeningForStabilityUse} ⊓ {StorageUse} ⊓ {StudyingUse} ⊓ {ThermalInsulationUse} ⊓ {TransportHorizontalLoadsDownUse} ⊓ {TransportVerticalLoadsDownUse}
Defining TimberRoomModuleMaterial	TimberRoomModuleMaterial ≡ {AluminumMaterial} ⊓ {CeramicMaterial} ⊓ {ChippingsMaterial} ⊓ {CopperMaterial} ⊓ {CrossLaminatedTimberMaterial} ⊓ {EPSInsulationMaterial} ⊓ {FoamMaterial} ⊓ {GlassMaterial} ⊓ {HardPlasticMaterial} ⊓ {IronMaterial} ⊓ {MineralWoolMaterial} ⊓ {NaturalRubberMaterial} ⊓ {RubberMaterial} ⊓ {SteelMaterial}
Defining TimberRoomModuleDomain	TimberRoomModuleDomain ≡ {AccomodationSystemBuildingPhysicsSystem} ⊓ {BuildingServicesSystem} ⊓ {StructuralSystem}

Defining AccomodationSystem	AccomodationSystem ≡ {Bed} ⊓ {Closet} ⊓ {Cupboard} ⊓ {Desk} ⊓ {Shelf} ⊓ {SinkKitchen} ⊓ {Stove}
Defining BuildingPhysicsSystem	BuildingPhysicsSystem ≡ {AirDuct} ⊓ {AirVentilationBathroom} ⊓ {Ceiling} ⊓ {LongConstructiveWallInstallation} ⊓ {LongConstructiveWallNoInstallation} ⊓ {ShortConstructiveWallFacade} ⊓ {ShortConstructiveWallHallway} ⊓ {Window}
Defining BuildingServicesSystem	BuildingServicesSystem ≡ {CeilingLamp} ⊓ {CeilingLampBathroom} ⊓ {ElectricityCables} ⊓ {HeatingBathroom} ⊓ {HeatingBedroom} ⊓ {Non-} ⊓ {ConstructiveLongWall} ⊓ {Non-ConstructiveShortWall} ⊓ {Plumbing} ⊓ {Shower} ⊓ {SinkBathroom} ⊓ {Toilet} ⊓ {Window}
Defining StructuralSystem	StructuralSystem ≡ {Ceiling} ⊓ {Floor} ⊓ {LongConstructiveWallInstallation} ⊓ {LongConstructiveWallNoInstallation}
Defining hasComponent	hasComponent ≡ {hasStructuralSystem} ⊓ {hasAccomodationSystem} ⊓ {hasBuildingServicesSystem} ⊓ {hasBuildinsPhysicsSystem}
Defining hasCeiling	hasCeiling ⊑ hasStructuralSystem
Defining isComponentOf	isComponentOf ≡ {isAccomodationSystemOf} ⊓ {isBuildingServicesSystemOf} ⊓ {isStructuralSystemOf} ⊓ {isBuildingPhysicsSystemOf}
Inverses	isComponentOf ≡ hasComponent- ; isAccomodationSystemOf ≡ hasAccomodationSystem- ; isBuildingServicesSystemOf ≡ hasBuildingServicesSystemOf- ; isStructuralSystemOf ≡ hasStructuralSystem- ; hasBuildingPhysicsSystem ≡ isBuildingPhysicsSystemOf- ; isUseOf ≡ hasUse- ; isMaterialOf ≡ hasMaterial-

How was the ontology developed[iv]:

First the domain and scope of the ontology was defined: we are only considering the timber room module, as part of the entire student housing complex.

The ontology will be used as a help for planners of a student housing complex, to detail the exact constellation of room modules to each other as well as how they are made up in themselves.

This ontology will answer questions concerning the number and types of elements in a module, what functions they serve as well as which material they contain.

The ontology will be used by planners of student housing projects who can give feedback to the producer of said student housing modules, so that they can update and maintain the ontology.

As the timber room modules are a rather new phenomenon, no matching ontologies were found to be reused.

After enumerating the important terms that were supposed to be entailed in the ontology, the classes and their hierarchy were developed.

For these classes, properties aka. Slots were written out as well as the hierarchy and relation of properties to each other.

We defined which cardinality, value type, as well as domain and range were figured out for the slots.

The last step was to create instances, examples of the classes and slots applied to an individual.

3. Examples for Ontology

Example 1: Adding living space to an existing student housing

Scenario: A student housing was created 25 years ago, since then a new university has opened in the area, increasing the need for affordable housing above the capacity of the existing student housing.

Use case: A team of engineers analyze the current building and compare it to the needs of the timber wood modules. What interfaces exist? Which need to be created? They can document their insights in a model of the project where all elements are given parameters on their functions, systems as well as materials and mass, as well as a phase parameter: are the elements "existing", "new", or "toBeTakeOut".

Example 2: Establishing the prefabrication production sequence

Scenario: A recently new producer of timber room modules wants to plan their production hall. For this a sequence of construction of the room modules needs to be established.

Use case: The producer refers to the ontology to gather insights on all the systems, which elements they are made up of and how they intwine. Based on this he knows which elements are based on others and such, a sequence develops.

Example 3: Deconstructing a multi-story student housing project

Scenario: A multi-story student housing project, using the timber room modules is no longer needed in a certain location. To minimize the environmental impact of the deconstruction process, the materials are supposed to be disassembled in an orderly manner.

Use case: A deconstruction engineer refers to the ontology to gather information on how the elements of the room module are connected and therefore with which method they can be disconnected and in which order.

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[i] Freve N. (2018) Deutsche BauZeitschrift: Studentenwohnheim Woodie, Hamburg (https://www.dbz.de/artikel/dbz_Studentenwohnheim_WOODIE_Hamburg-3172596.html)
[ii] Liu Z., Freeman W., Tenebaum J., Wu J. (2018) arXiv e-prints: Physical Primitive Decomposition. [online] https://ui.adsabs.harvard.edu/abs/2018arXiv180905070L/exportcitation [last called on 21.11.2023]
[iii] Dunbar, B. (26.07.2023) NASA: Logical Decomposition [online] https://www.nasa.gov/reference/4-3-logical-decomposition/ [last called on 21.11.2023]
[iv] Noy, N. F. & McGuinness, D. L. (2001), 'Ontology Development 101: A Guide to Creating Your First Ontology' .