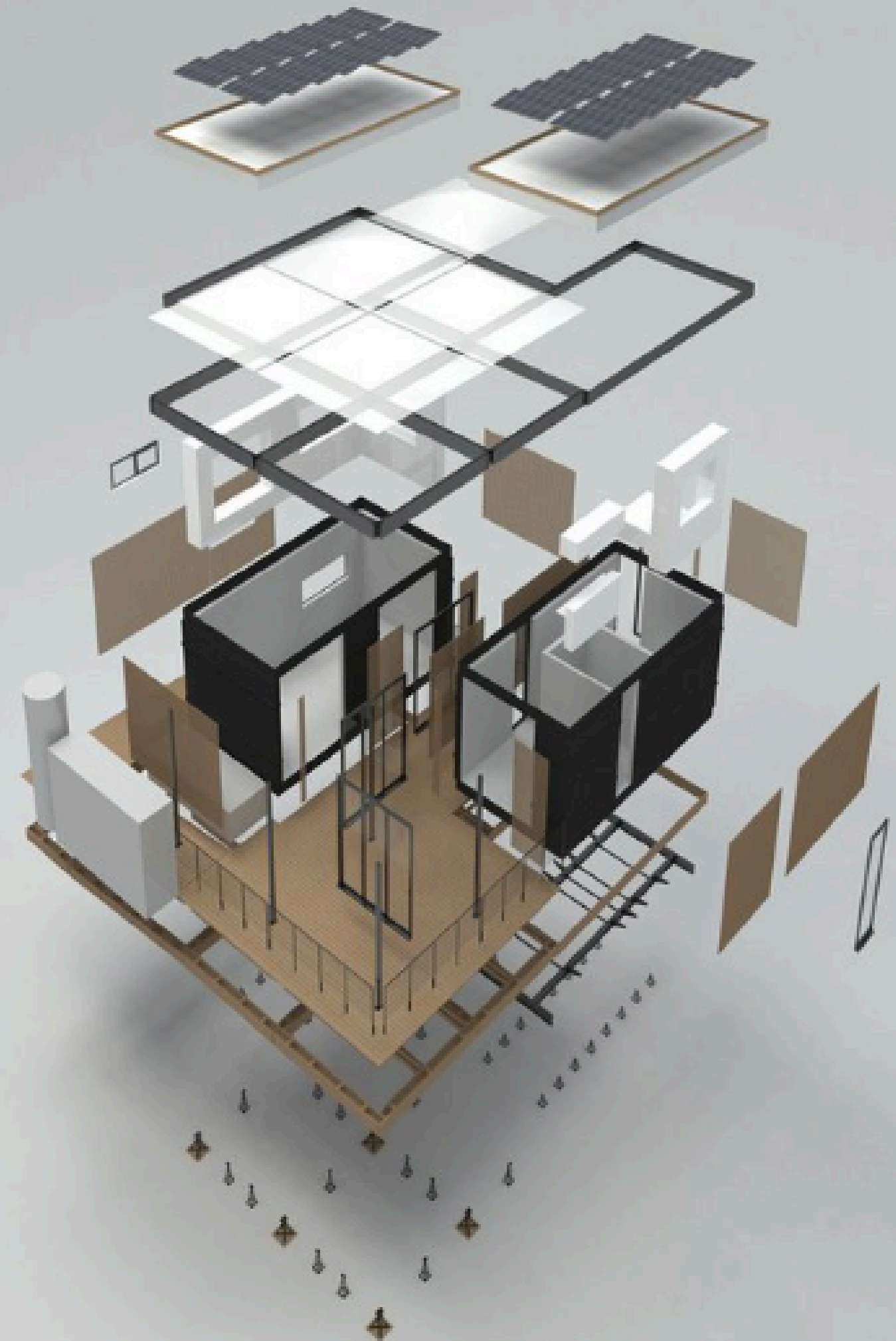# Proposal for the integration of a Building Materials part: (ISO 19152-7) within the Land Administration Domain Model

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Second supervisor: Wilko Quak

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1

Motivation

The construction sector significantly impacts the environment through high resource and energy consumption, and waste production.

Environmental Impact of the construction sector

- Responsible for 21% of global greenhouse gas emissions

- Accounts for 34% of global energy demand

- Contributes 37% of energy and process-related CO_2 emissions

Transitioning to a Circular Economy, as proposed by the European Union (EU) (McMillan, 2019), offers a solution to this problem.

To reuse materials their location, type and quantity must be registered

Source: https://www.unep.org/resources/report/global-status-report-buildings-and-construction
Source: https://www.bamb2020.eu/wp-content/uploads/2019/02/BAMB_MaterialsPassports_BestPractice.pdf
Source: McMillan, Sarah E (2019). "Closing the Loop": THE EUROPEAN UNION & THE CIRCULAR ECONOMY". In: Scitech Lawyer 15.4, pp. 4–8

Main Question

How can building materials registration be achieved based on (inter)national standards?

Sub-questions

1. What are the applications of the Building Material registration?

2. What criteria are necessary to obtain the Material Passport?

3. How can the registration and management of the Material Passport be standardised?

4. How can the Material Passport be created and evaluated?

Methodology

Step 1

Desk Research

Step 2

**Developing Harmonized Information Model**

Step 3

Evaluating the Model

MATERIALS PASSPORT

- **EU's Horizon 2020: Building as Material Banks (BAMB) project – aims to enable the shift to a circular building sector.**

- **Material Passports, Energy Passports, Reversible Building Design, Business Models, Policy and Standards**

Source: https://www.bamb2020.eu/wp-content/uploads/2019/02/BAMB_MaterialsPassports_BestPractice.pdf
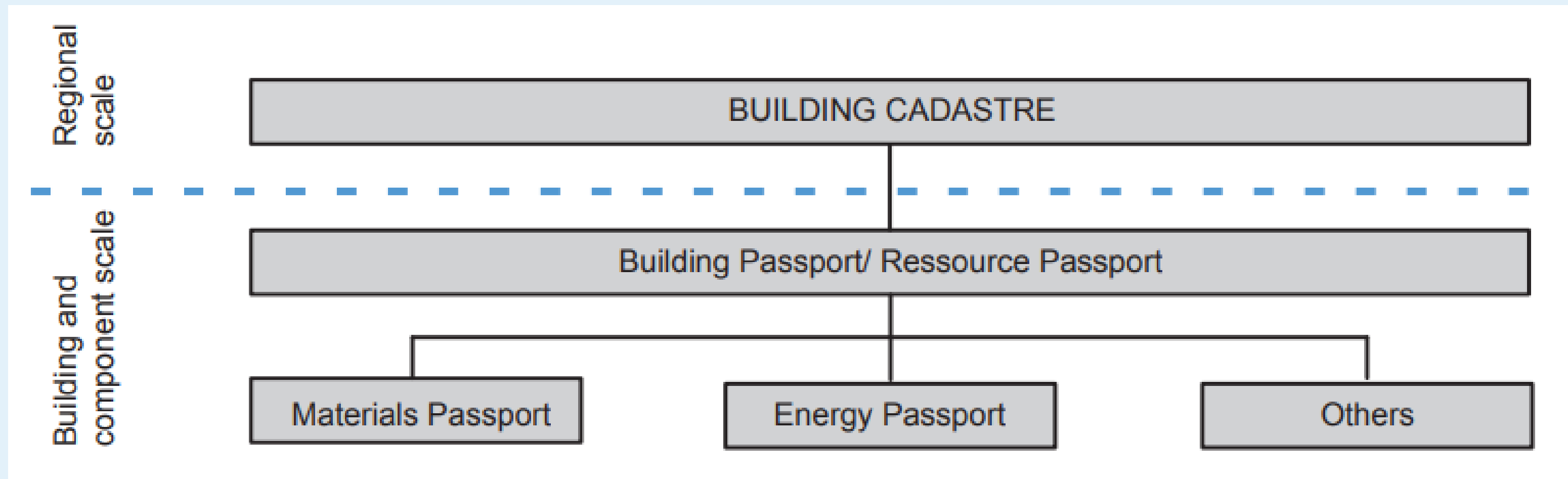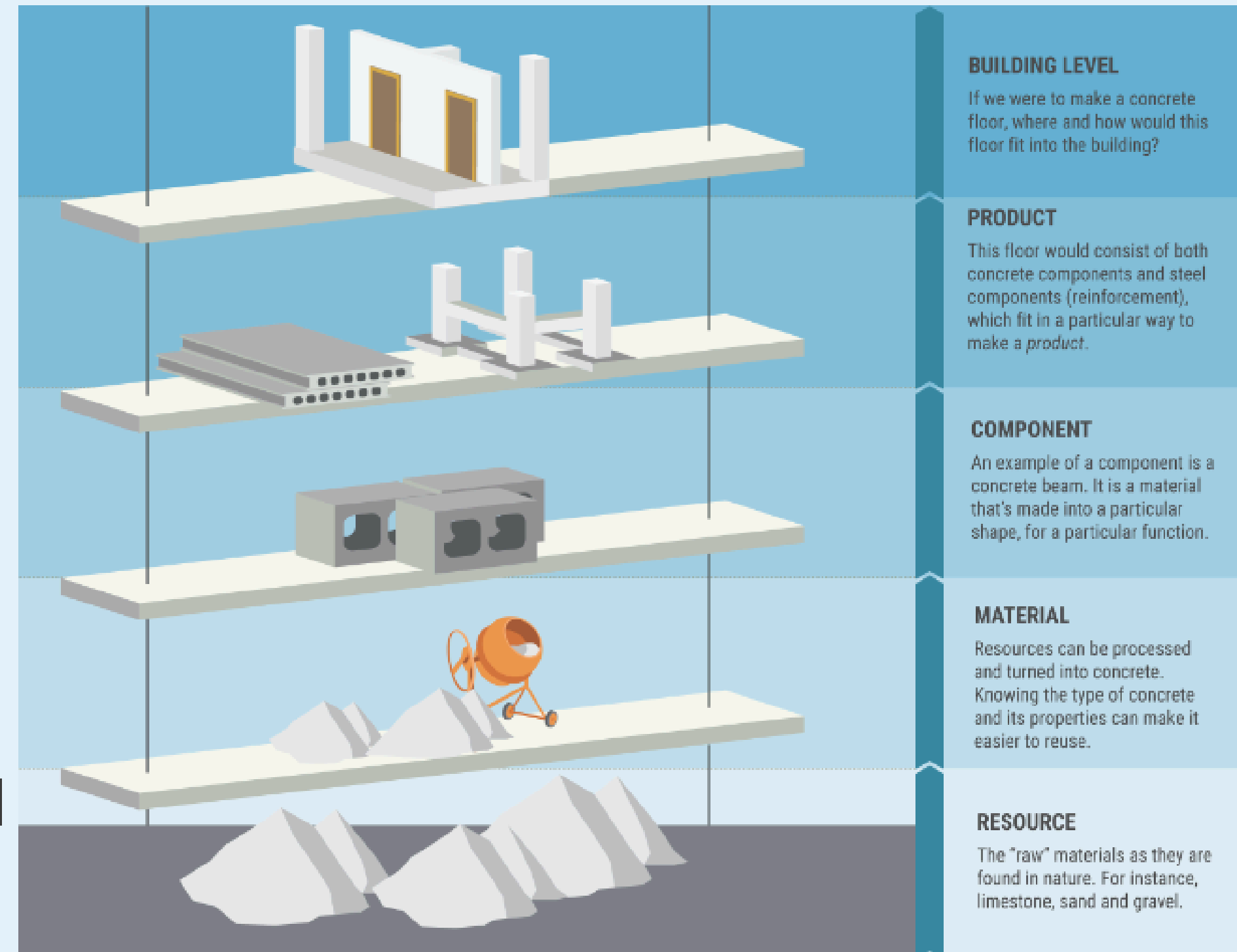
MATERIALS PASSPORT

The Material Passports (MP) is an electronic set of data, which evaluates the recycling potential and environmental impact of materials embedded in buildings.

- **Building materials registration supports circularity, environmental impact, valuation of the building, and safety and security.**
- **Data entered into a centralised database**
- **Customised reports tailored to diverse user needs**
- **Material passports comprise multiple hierarchical levels**

Currently, Material Passport – **no standardisation**

BUILDING LEVEL
If we were to make a concrete floor, where and how would this floor fit into the building?

PRODUCT
This floor would consist of both concrete components and steel components (reinforcement), which fit in a particular way to make a product.

COMPONENT
An example of a component is a concrete beam. It is a material that's made into a particular shape, for a particular function.

MATERIAL
Resources can be processed and turned into concrete. Knowing the type of concrete and its properties can make it easier to reuse.

RESOURCE
The "raw" materials as they are found in nature. For instance, limestone, sand and gravel.

MADASTER

- **Madaster is a platform with an online library of materials in the built environment, it links the material identity to the location and records this in a Materials Passport.**
- **Currently, Madaster operates in the Netherlands, Germany, Norway, Switzerland, Belgium and is expanding to more countries**
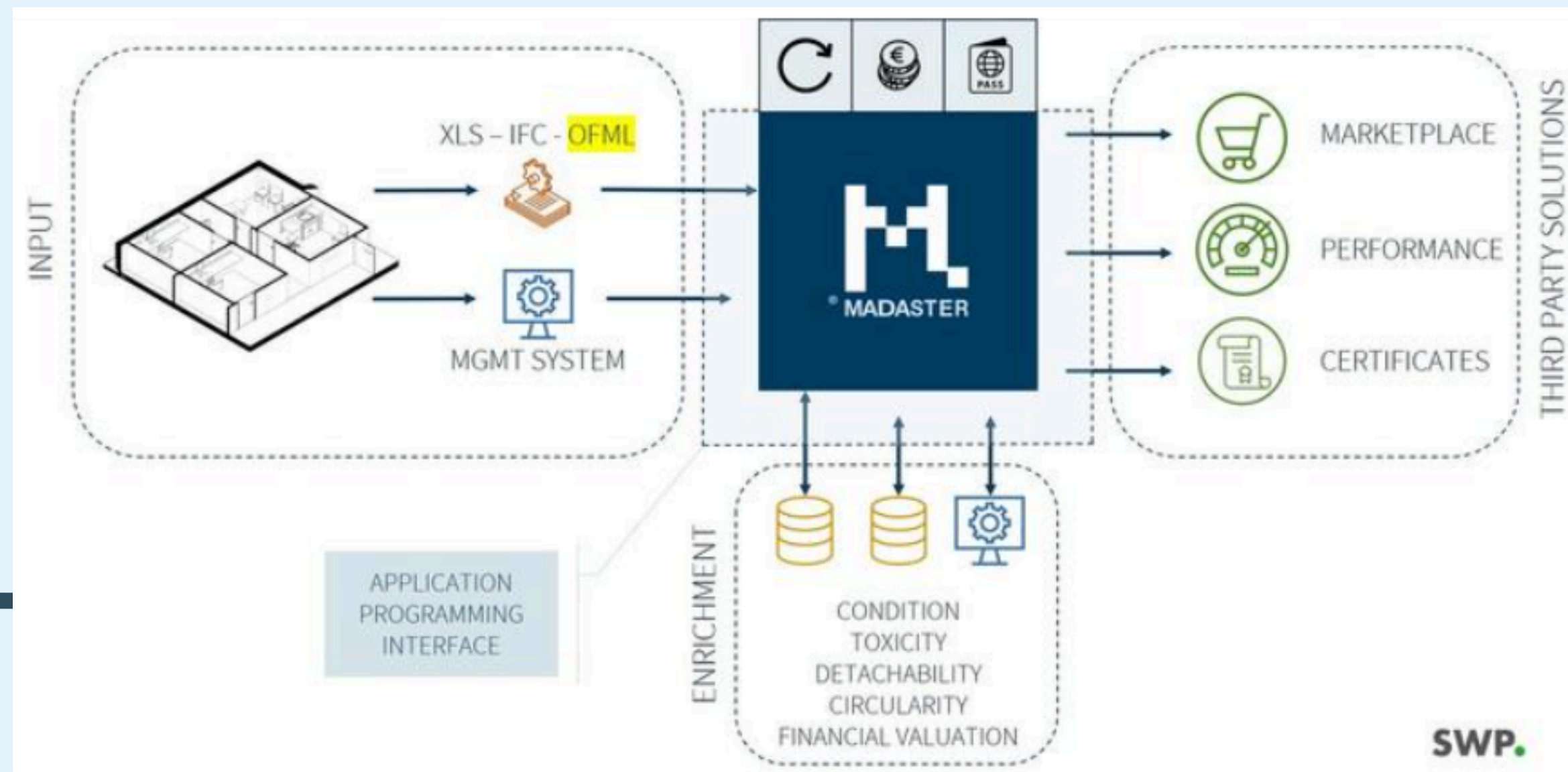
USE CASES

Use Case I- A building company is looking for 30K wooden panels of reasonable quality for a project in Delft. Before finalizing the purchase, a representative plans to conduct a visual quality inspection to ensure the panels meet their standards. The company specifically aims to source reused materials from an existing building that is about to be demolished, aligning with its commitment to circularity.

Additionally, the company prefers panels that come with certifications for sustainability and fire resistance though these are not mandatory.

USE CASE

30K wooden panels

reasonable quality

construction site in Delft

purchase

visual inspection

certifications

REQUIREMENTS

Use Case I

- 30K wooden panels
- reasonable quality
- purchase
- construction site in Delft
- visual inspection
- **certifications**

Material Info (type, quantity, quality)

Owner details

3D Location

Certificates

USE CASE

Use Case II- A building owner in Delft is constructing a new office complex and wants to register all materials used for future maintenance and for circularity aspects.

USE CASE

register all materials

building owner

in Delft

certifications

REQUIREMENTS

Use Case II

- **register all materials**
- **building owner**
- **in Delft**
- **certifications**

**Material Info (type, quantity, quality)**

Owner details

3D Location

Certificates

Why use LADM to building material registration ?

1. Ownership information from the land administration is needed for the registration of building materials

2. Restrictions, e.g. due to heritage or monument statis, is also required (both in Part 2)

3. The valuation is relevant (knowing the materials, better valuation can be done), LADM Part 4

4. LADM provides data on location and distance details

5. The systematic registration approach used in land administration are well-suited to the concept of a material passport

   - Registration of Building Material (Information gathering)

   - Information Provision of Building Material (search function)

6. Land Administration style legislation, governance, and organization would be suitable

Land Administration Domain Model (LADM)

LADM is a conceptual model designed to facilitate the standardisation of land administration.
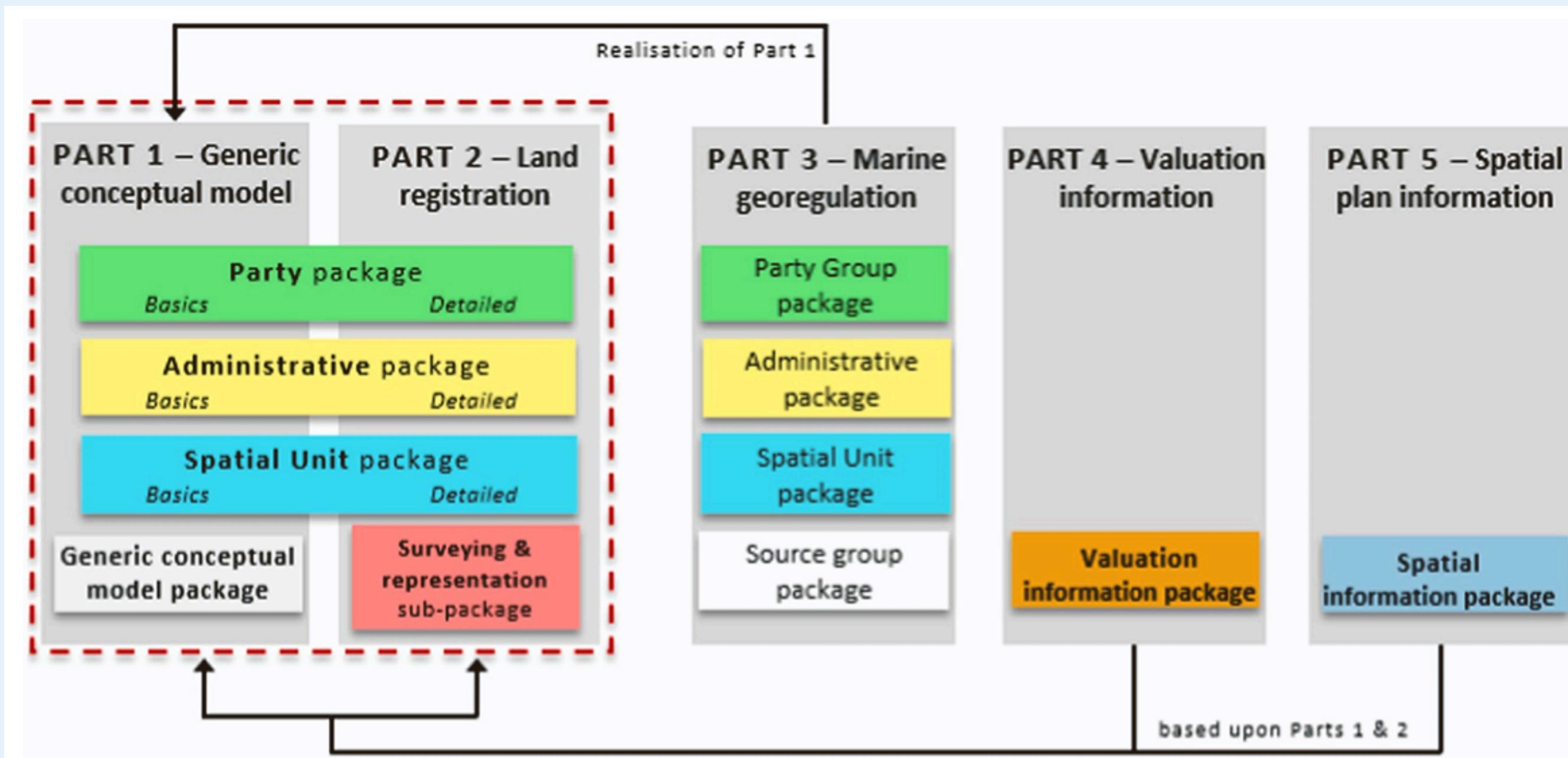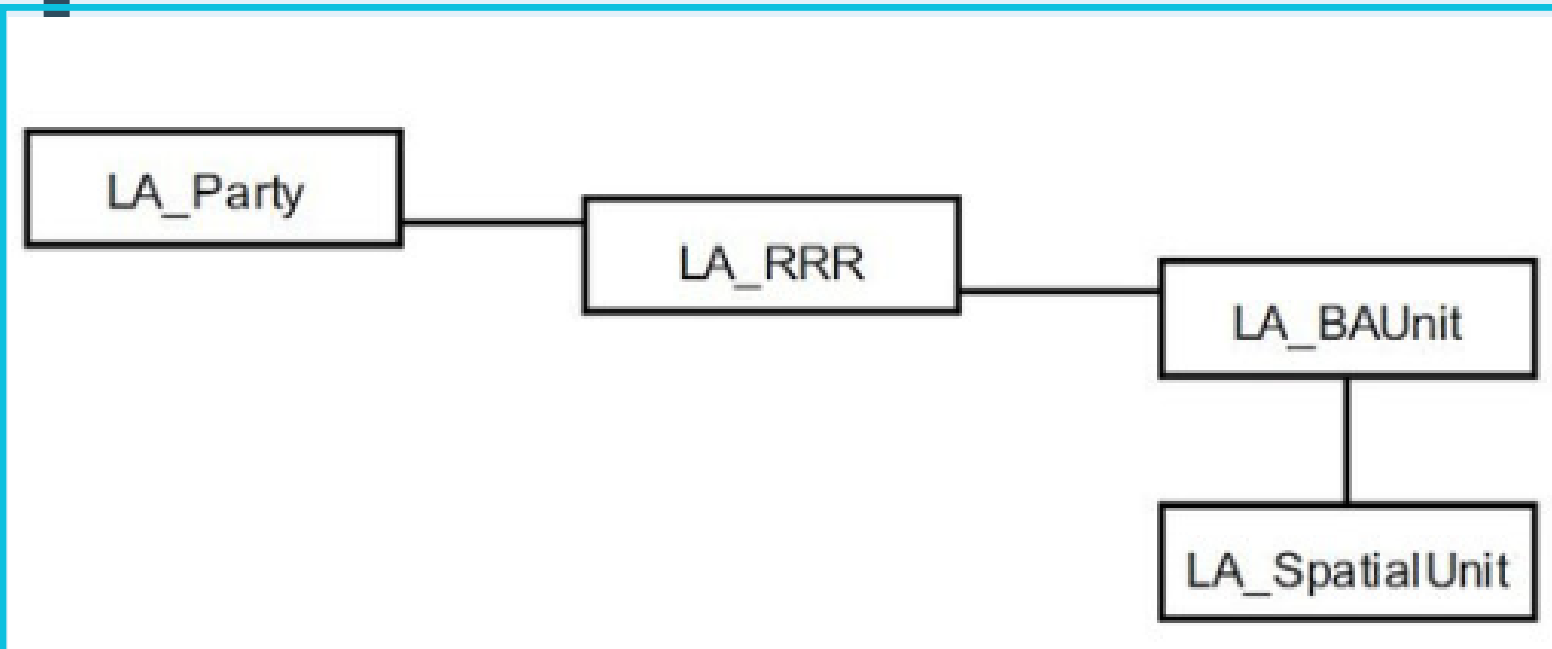

The LADM ISO19152 II contains 6 parts–

1. Conceptual Model
2. Land Registration
3. Marine Georegulation
4. Valuation Information
5. Spatial Plan Information
6. Implementation aspects
7. Building Materials?

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Land Administration Domain Model (LADM)

The four fundamental categories of the core Land Administration Domain Model (LADM)

**Basic classes of the LADM Valuation Information Package**
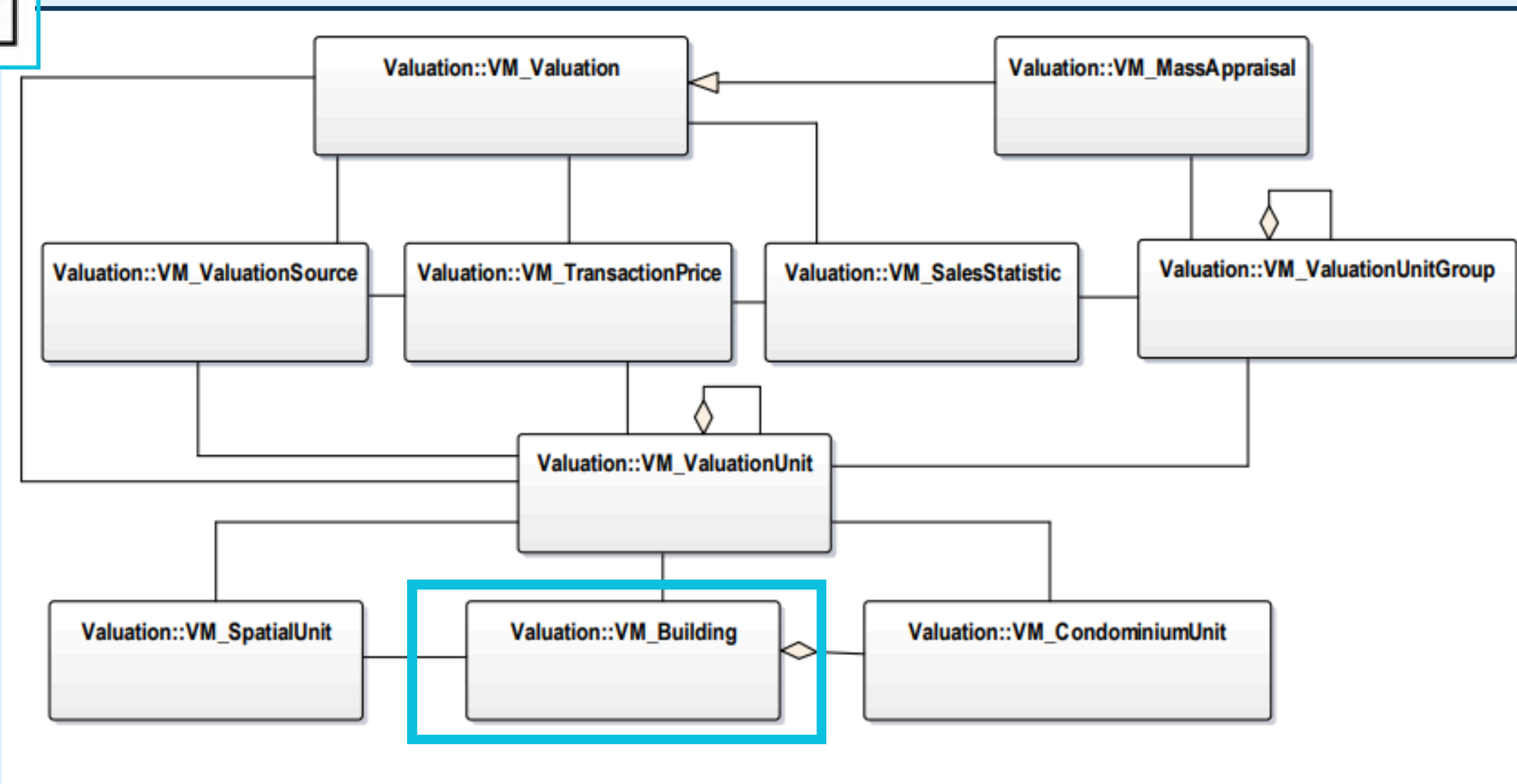
Land Administration Domain Model (LADM)

- **LA_Source class** – **supports different types of sources and represents events that trigger changes in the registration process.**
- **VersionedObject class** – **abstract class** – **management and maintenance of historical data**

Source:ISO 19152-1:2024Geographic information — Land Administration Domain Model (LADM)Part 1: Generic conceptual model
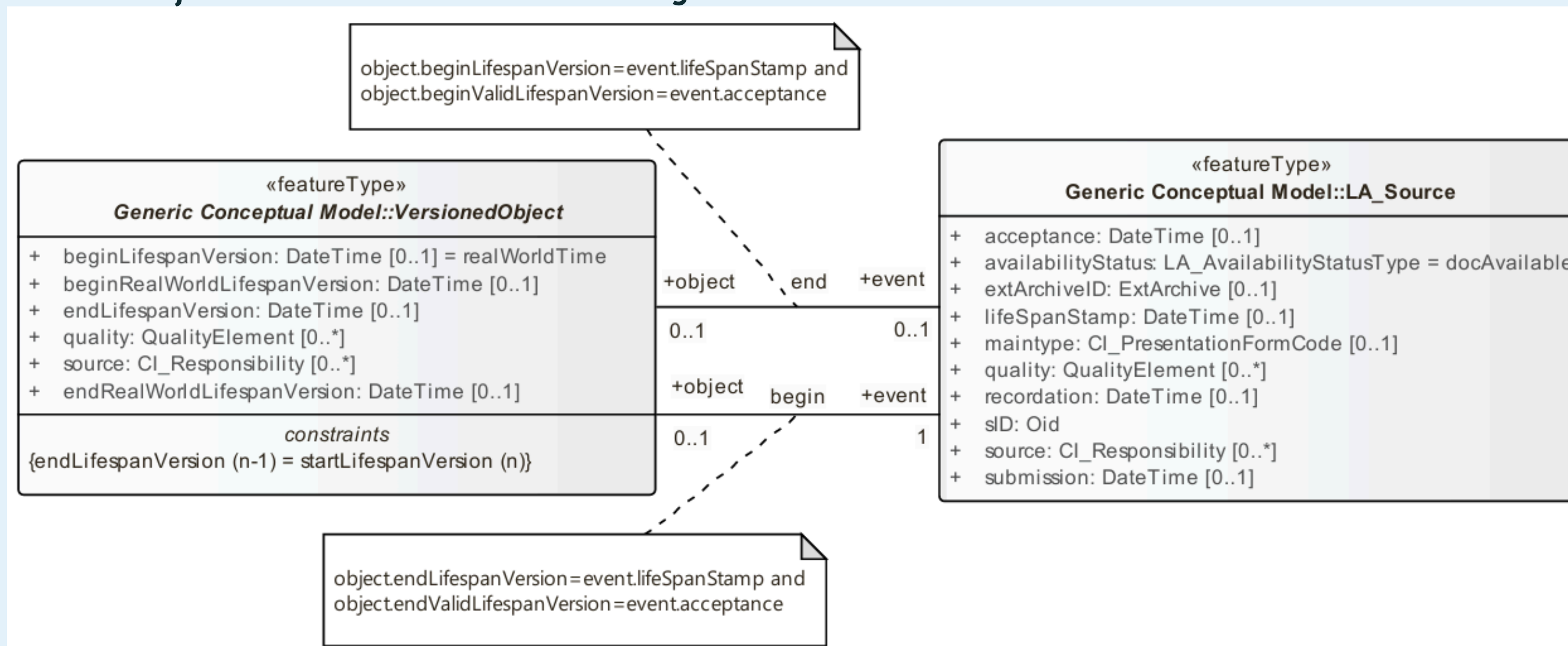
INITIAL DEVELOPED MODEL A
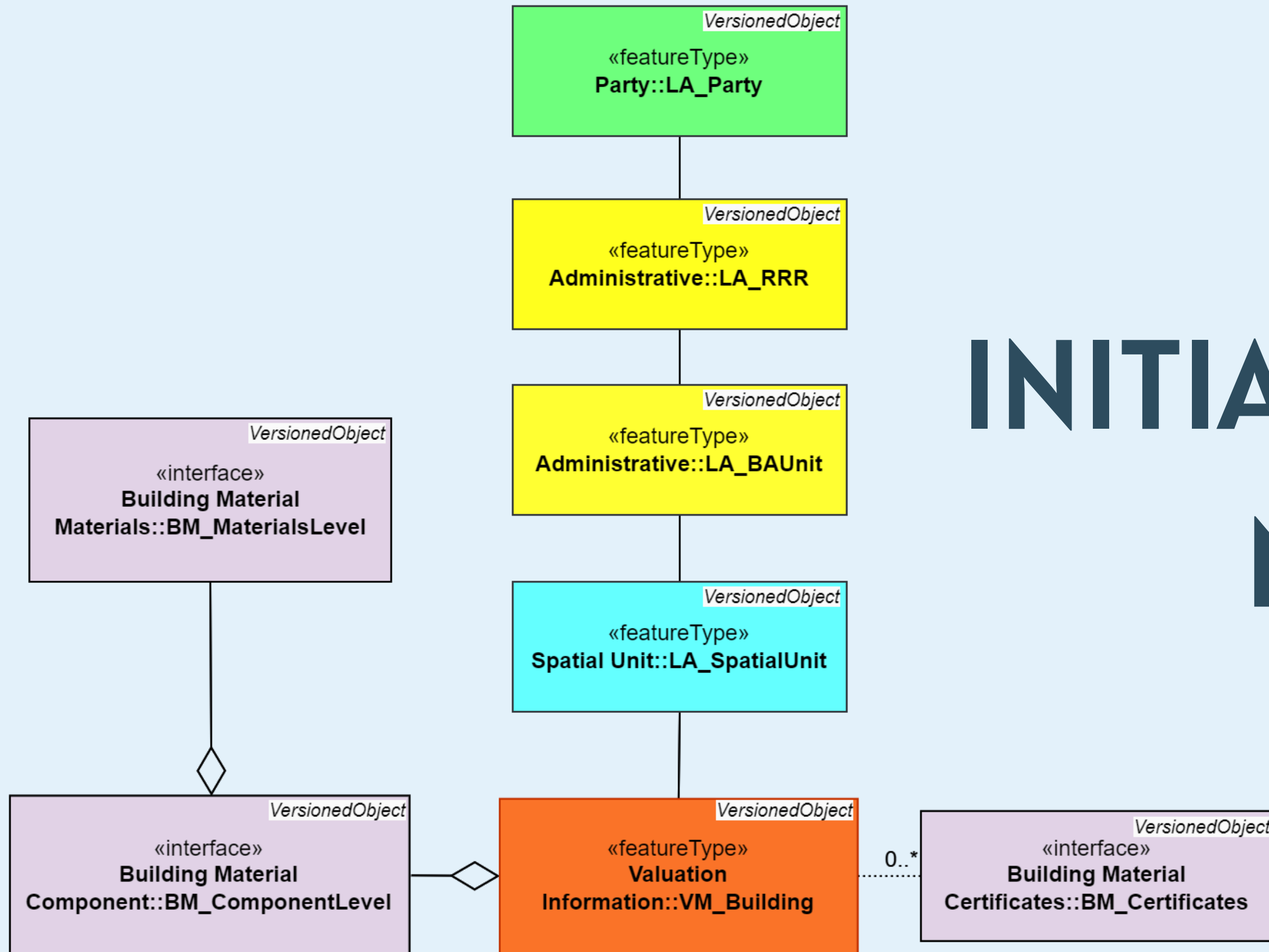
UML diagram showing the classes of Building materials part and its relation to the existing LADM classes

INITIAL MODEL A

- All the classes inherits properties of Versioned Object class
- For Building materials – 2 classes were developed
    BM_ComponentLevel & BM_MaterialsLevel
- VM_Building class will aggregate instances of the BM_ComponentLevel class, BM_ComponentLevel will aggregate instances of the BM_MaterialLevel class.
- BM_Certificates class – optional – multiplicity is 0..*

INITIAL MODEL A– DRAWBACKS

- Building materials more complex – needs more hierarchies– Building, System, Product, Component, Materials
- Redundancy – All the levels are interrelated and follow similar properties.
- how to add the renovations at system level like ,Fire alarm system,CCTV,Burglary alarm system
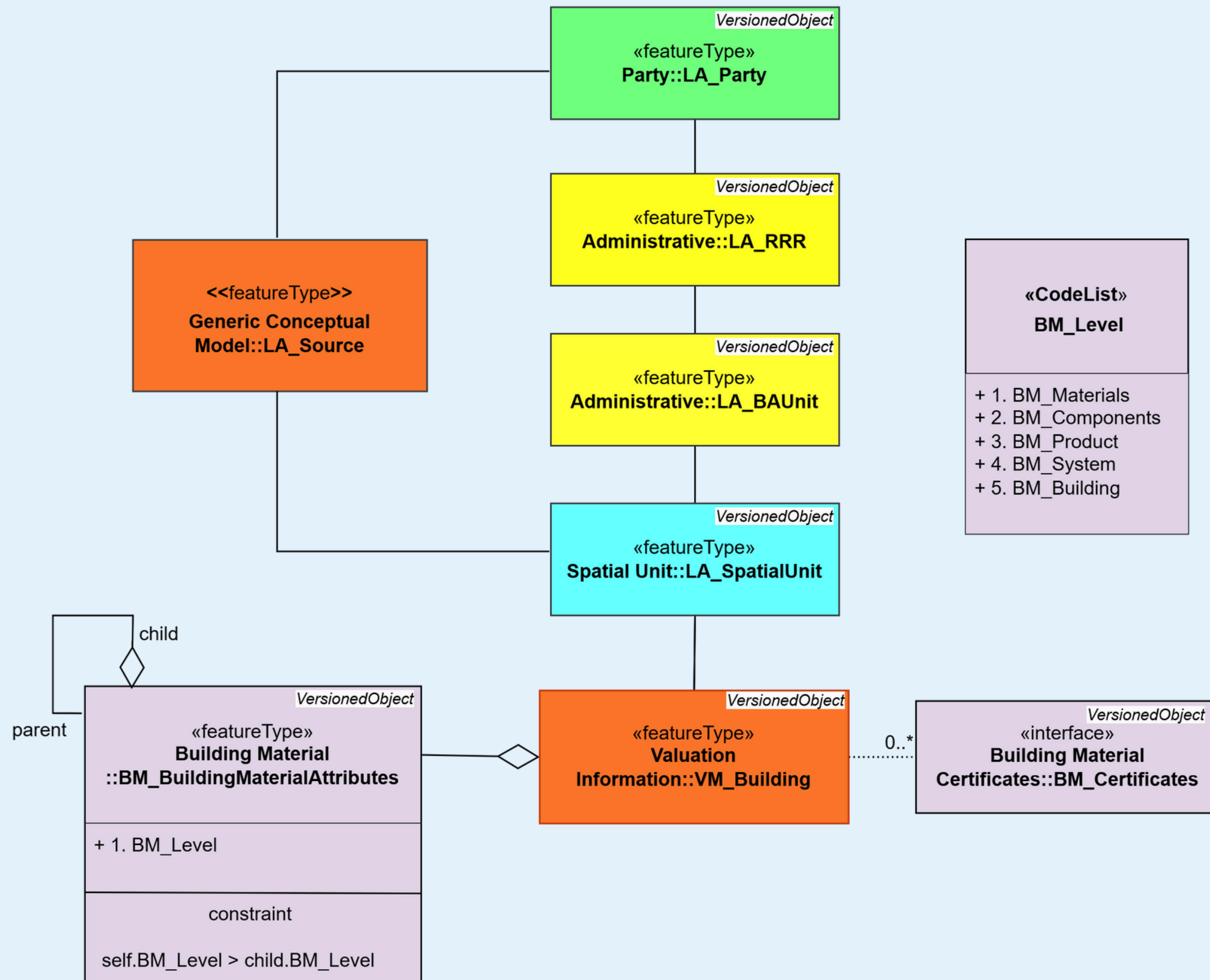
REVISED MODEL

- **New class BM_BuildingMaterialAttributes was developed for attributes to eliminate data redundancy to model a generic building materials hierarchy**
- **BM_Level codelist - reflects- hierarchy of building materials**
- **BM_Attributes self aggregates with the constraint - parent.BM_Level > child.BM_Level**

REVISED MODEL- DRAWBACKS

- **Hierarchy is abstract and needs to check the constraint to verify the order could be tricky**
- **parent-child structure maintains a flow that each level naturally builds upon the previous one. Model prevents skipping intermediate levels**
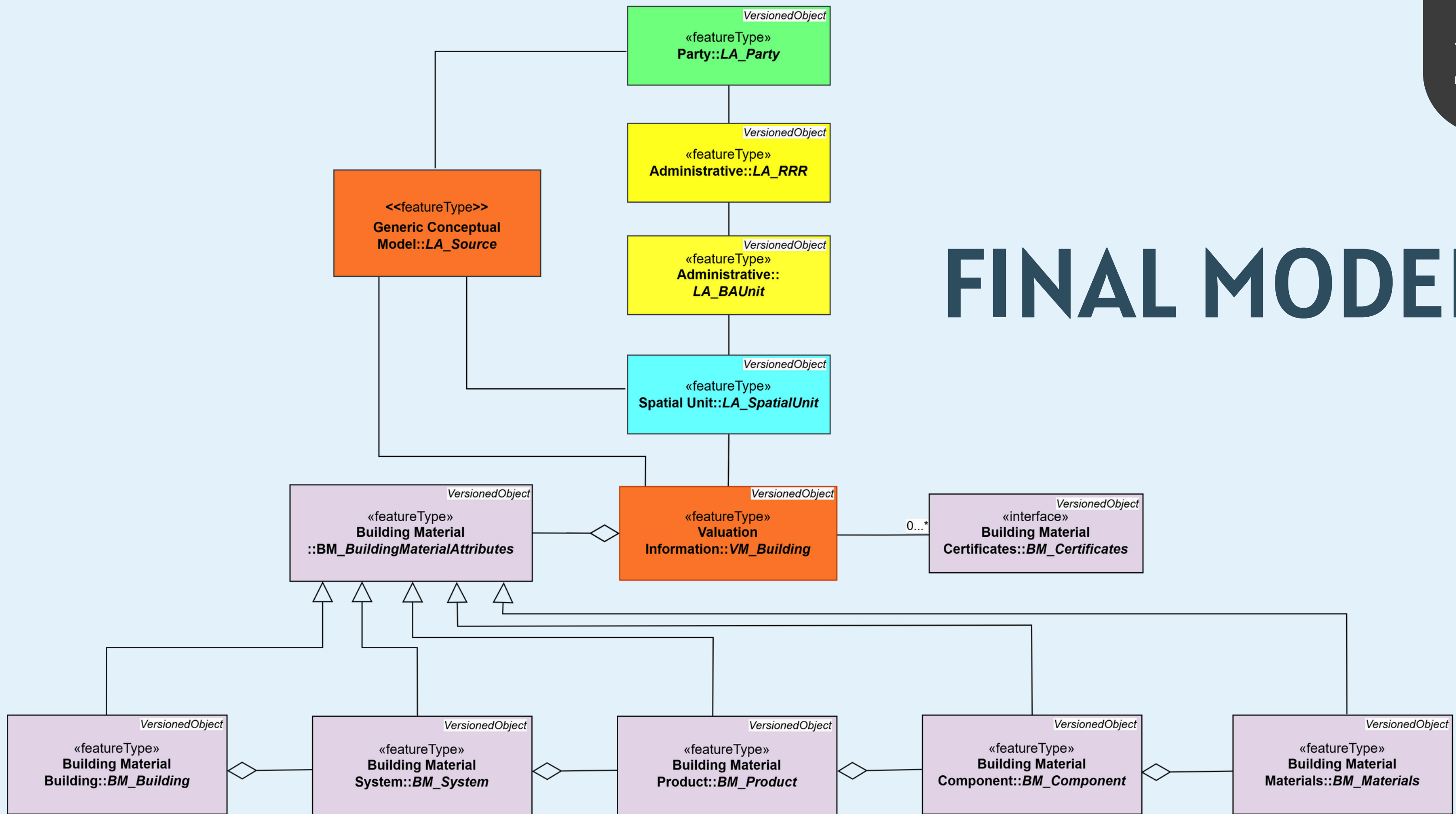
FINAL MODEL – REFLECTION

- Classes was developed based on the hierarchy levels of the Material Passport
- Higher-level classes is the aggregates of lower-level classes.
- System level have an additional attribute BM_ConstructionMethods represents the structural or functional systems of the building. Hence, all the attributes are the same for all levels, except for the system level.
- New super class was created BM_BuildingMaterialAttributes for the attributes

VersionedObject

«featureType»
Building Material ::BM_*BuildingMaterialAttributes*

+ name: CharacterString [0..1]
+ bmID: Oid
+ classificationCode: CharacterString [0..1]
+ floor: Integer [0..1]
+ area: Integer
+ volume: Integer
+ length: Integer
+ weight: Integer
+ description: CharacterString [0..1]
+ GTIN: CharacterString [0..1]
+ articleNumber: CharacterString [0..1]
+ thickness: Integer [0..1]
+ height: Integer [0..1]
+ width: Integer [0..1]
+ diameter: Integer [0..1]
+ detachability: CharacterString [0..1]
+ materialStatus: BM_MaterialStatus
+ natureOfWaste: BM_NatureOfWaste
+ buildingType: BM_BuildingType
+ shearingLayer: BM_ShearingLayer
+ endOfLifeScenario: BM_EndOfLifeScenarion
+ wasteCodes: BM_WasteCodes

SUPER CLASS
BM_BuildingMaterialAttributes

All the other classes of the building material part **inherit** these attributes except the BM_Certificates class.

RELATION

- **Inheritance** – a class inherits properties from a parent class

    Ex: BM Materials, BM_Components, BM_Product, BM_System and BM_building classes inherits the attributes from BM_BuildingMaterialAttributes

- **Aggregation** – higher class is the aggregation of the lower class

    Ex: BM_Product aggregates BM_Componentand BM_Materials which can also exist independently of the BM_Product

- **Association** – the relationship between two or more classes

    Ex: BM_Certificates associates with a multiplicity of 0..* VM_Building

CODELIST

Codelist was developed based on Madaster Excel file

- ≪CodeList≫ Building Material Status::BM_MaterialStatus
- ≪CodeList≫ Shearing Layer:: BM_ShearingLayer
- ≪CodeList≫ Nature of Waste:: BM_NatureOfWaste
- ≪CodeList≫ End of life scenario::BM_EndOfLifeScenarion
- ≪CodeList≫ End of life scenario::BM EndOfLifeScenarionType
- ≪CodeList≫ Waste codes::BM Waste codes
- ≪CodeList≫ Waste codes::BM WasteCodesType
- ≪CodeList≫ ConstructionMethods:: BM ConstructionMethods
- ≪CodeList≫ Construction Methods Type::BM ConstructionMethodsType

EVALUATION OF THE MODEL

i) Prototype

Developing the Database
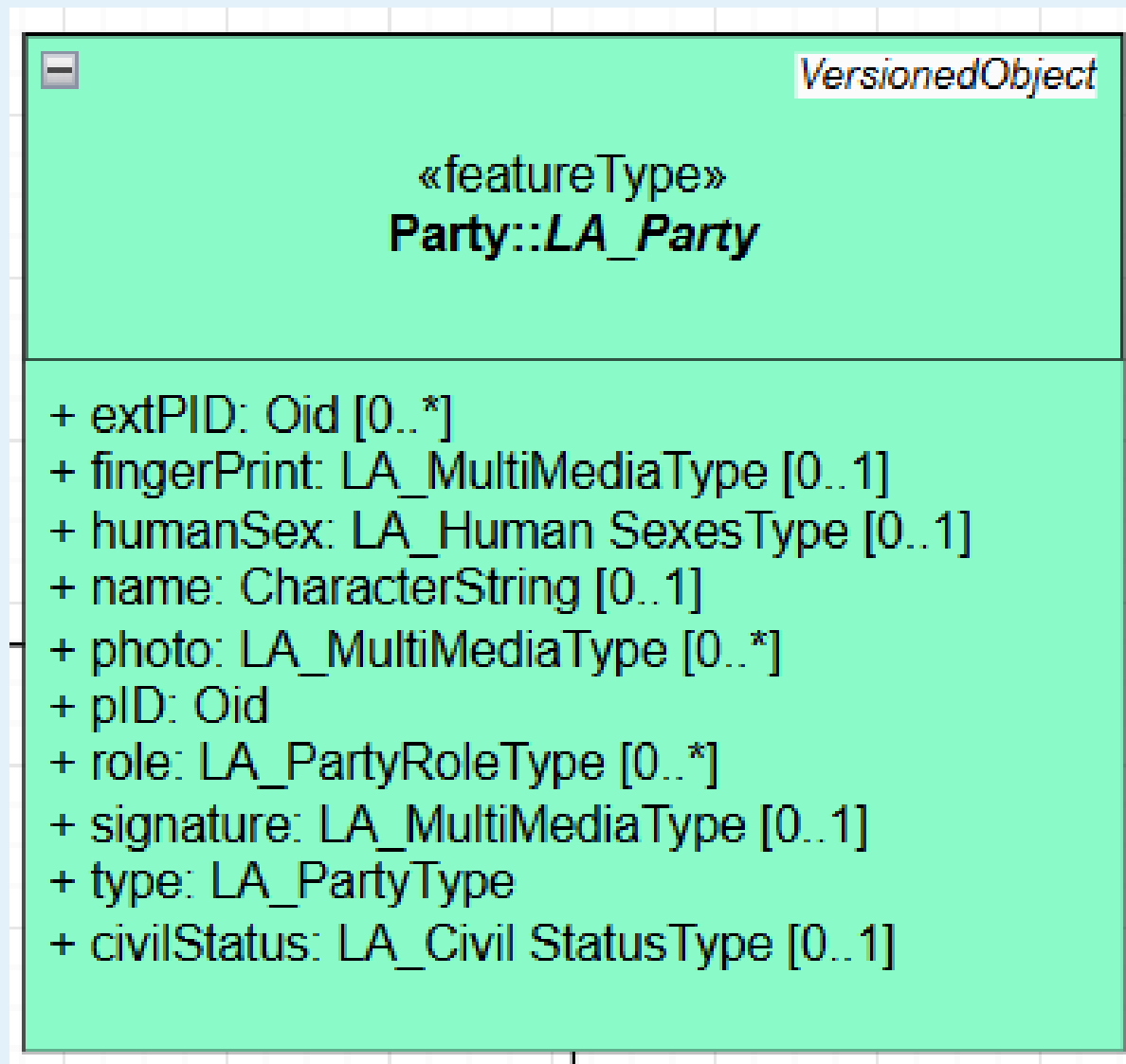
Importing the data to database

Testing the data

ii) Workshop

DEVELOPING THE DATABASE

- **PostgreSQL and PostGIS tools were used.**

CLASS/CODELIST TO TABLE

«featureType»
Party::*LA_Party*

VersionedObject

+ extPID: Oid [0..*]
+ fingerPrint: LA_MultiMediaType [0..1]
+ humanSex: LA_Human SexesType [0..1]
+ name: CharacterString [0..1]
+ photo: LA_MultiMediaType [0..*]
+ pID: Oid
+ role: LA_PartyRoleType [0..*]
+ signature: LA_MultiMediaType [0..1]
+ type: LA_PartyType
+ civilStatus: LA_Civil StatusType [0..1]

- **class name– table name**
- **attribute type– data type**
- **attribute name– column name**

- public
- la_party
- la_party_id character varying(255)
- fingerprint text
- humansex text
- name text
- photo text
- role text
- signature text
- type text
- civilstatus text
- beginlifespanversion timestamp with time zone
- endlifespanversion timestamp with time zone
- beginrealworldlifespanversion timestamp with time zone
- endrealworldlifespanversion timestamp with time zone

CONSTRAINTS

- **Primary Key**
- **Foreign Key**
- **Not NULL**
- **Unique**

```sql
 7
 8 ⌄  CREATE TABLE public.BM_Materialstatus (
 9       BM_Materialstatus_ID integer NOT NULL DEFAULT nextval('public.BM_Materialstatus_ID_seq')
10       type text,
11       PRIMARY KEY (BM_Materialstatus_ID)
12  );
13
14 ⌄  INSERT INTO public.BM_Materialstatus (type)
15  VALUES
16    ('Demolition'),
17    ('Preserved'),
18    ('Construction Waste'),
19    ('New Materials'),
20    ('Others');
```

TEST DATA

- **Data from Campus Real Estate & Facility Management (CREFM) of TU Delft**
- **Two test data**
  - **Building 45– Old Building**
  - **Building 25– The Green Village**

BUILDING 45

- constructed in 1952
- no 3D spatial data
- Data available –
   i) Kadastral number
   ii) Original architectural drawings
   iii) Excel file cataloging all renovated and replaced materials

- Excel file follows the NL/SfB Dutch classification system

Vrije Code	NL/SfB:	Conditi	Naam	Tag	NL/SfB	Elemen	Capacitei	Soort	Locatie	QR-code
1040	31		45 Low Speed Wind Laboratory / VSSD / Inholland		31.20	Waterslagen		Waterslag beton	G45 - BD0 - Zuid	
1021	31		45 Low Speed Wind Laboratory / VSSD / Inholland		31.20	Blankglas		Doorzichtig gevelglas	G45 - BD0 - Noord	
1022	31		45 Low Speed Wind Laboratory / VSSD / Inholland		31.20	Blankglas		Doorzichtig gevelglas	G45 - BD0 - Oost	
1023	31		45 Low Speed Wind Laboratory / VSSD / Inholland		31.20	Blankglas		Doorzichtig gevelglas	G45 - BD0 - Zuid	
1024	31		45 Low Speed Wind Laboratory / VSSD / Inholland		31.20	Blankglas		Doorzichtig gevelglas	G45 - BD0 - West	
1041	31		45 Low Speed Wind Laboratory / VSSD / Inholland		31.21	Kozijnen			G45 - BD0 - Noord	45.31.KOZIJ NEN
1042	31		45 Low Speed Wind Laboratory / VSSD / Inholland		31.21	Kozijnen			G45 - BD0 - Oost	45.31.KOZIJ NEN
1043	31		45 Low Speed Wind Laboratory / VSSD / Inholland		31.21	Kozijnen			G45 - BD0 - Zuid	45.31.KOZIJ NEN

The excel file was cleaned by python and uploaded to the database
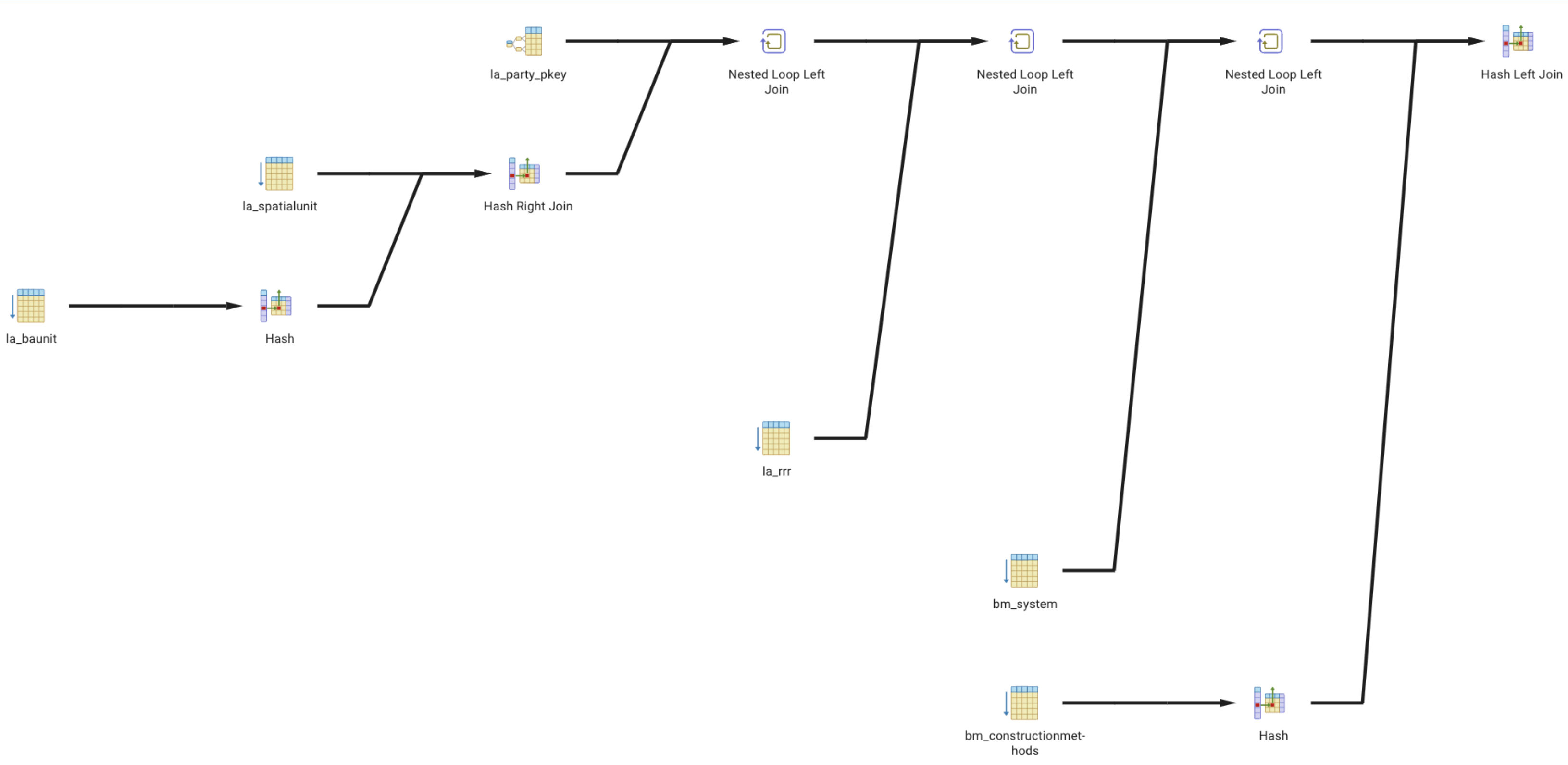
Function pathway of generating Material Passport

Material Passport for Building 45

Data Output	Explain ✕	Messages	Notifications					

	name text 🔒	description text 🔒	beginlifespanversion timestamp with time zone 🔒	beginrealworldlifespanversion timestamp with time zone 🔒	nameofthebuilding text 🔒	area numeric	code integer 🔒	quantity numeric 🔒	unit character varying (
1	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	0	1.00	pst
2	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	0	1.00	pst
3	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	21	81.95	m2
4	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	21	531.94	m2
5	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	24	1.00	st
6	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	27	1.00	st
7	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	27	13.55	m2
8	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	28	1.31	m2
9	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	31	372.35	m2
10	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	31	1.00	st
11	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	31	5.00	st
12	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	31	3.00	st
13	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	31	4.00	st
14	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	31	793.41	m2
15	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	31	17.42	m2
16	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	31	9.40	m1
17	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	32	1.00	st
18	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	32	1.00	pst
19	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	32	1.00	st
20	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	37	4.00	st
21	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	41	91.52	m1
22	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	41	659.77	m1
23	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	41	932.47	m2
24	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	42	850.00	st
25	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	43	336.00	m2
26	TU Delft	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	43	1278.00	m2

Total rows: 96 of 96   Query complete 00:00:00.097   Ln 12, Col 44

```
1 ∨ SELECT
2       la_party.name,
3       la_rrr.description,
4       la_rrr.beginlifespanversion,
5       la_rrr.beginrealworldlifespanversion,
6       la_baunit.name AS "nameofthebuilding",
7       la_spatialunit.area,
8       la_spatialunit.geometry,
9       --la_spatialunit.referecepoint,
10
11      bm_constructionmethods.code,
12      ROUND (bm_constructionmethods.quantity, 2) AS quantity,
13      bm_constructionmethods.unit,
14      bm_constructionmethods.bm_constructionmethods_id AS "constructionmethod_id"
15 FROM
16      la_party
17 LEFT JOIN
18      la_rrr ON la_party.la_party_id = la_rrr.la_party_id AND la_party.la_party_id = '1'
19 LEFT JOIN
20      la_baunit ON la_party.la_party_id = la_baunit.la_party_id AND la_party.la_party_id = '1'
21 LEFT JOIN
22      la_spatialunit ON la_baunit.la_baunit_id = la_spatialunit.la_baunit_id AND la_baunit.la_baunit_id = '1'
23 LEFT JOIN
24      bm_system ON bm_system.vm_building_id = '1'
25 LEFT JOIN
26      bm_constructionmethods ON bm_constructionmethods.bm_constructionmethods_id = bm_system.bm_constructionmethods_id
27 WHERE
28      la_party.la_party_id = '1'
29      AND bm_constructionmethods.code = 21;
```

37

BUILDING 45

Querying the database based on bm _construction methods code '21' - facade construction

Data Output   Messages   Notifications

	description text	beginlifespanversion timestamp with time zone	beginrealworldlifespanversion timestamp with time zone	nameofthebuilding text	area numeric	geometry geometry	code integer	quantity numeric	unit character va
1	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	[null]	21	81.95	m2
2	Owner	2022-12-05 00:00:00+01	1952-06-01 00:00:00+01	45 Low Speed Wind Laboratory / VSSD / Inholland	3156.3	[null]	21	531.94	m2

Madaster platform created for the Building 45

- **Madaster platform for cross-verification to generate Material Passport.**
- **the address and cadastral information were manually added into the platform**
- **Madaster Excel template operates at the materials and products level rather than the system level, the platform was unable to generate a material passport.**

BUILDING 25

- **constructed in 2015**
- **Revit data**
- **Data available –**
    - **I) Kadastral number**
    - **ii) Original architectural drawings**
    - **iii) 3D spatial data in Revit format**

- **Revit file was converted to IFC**

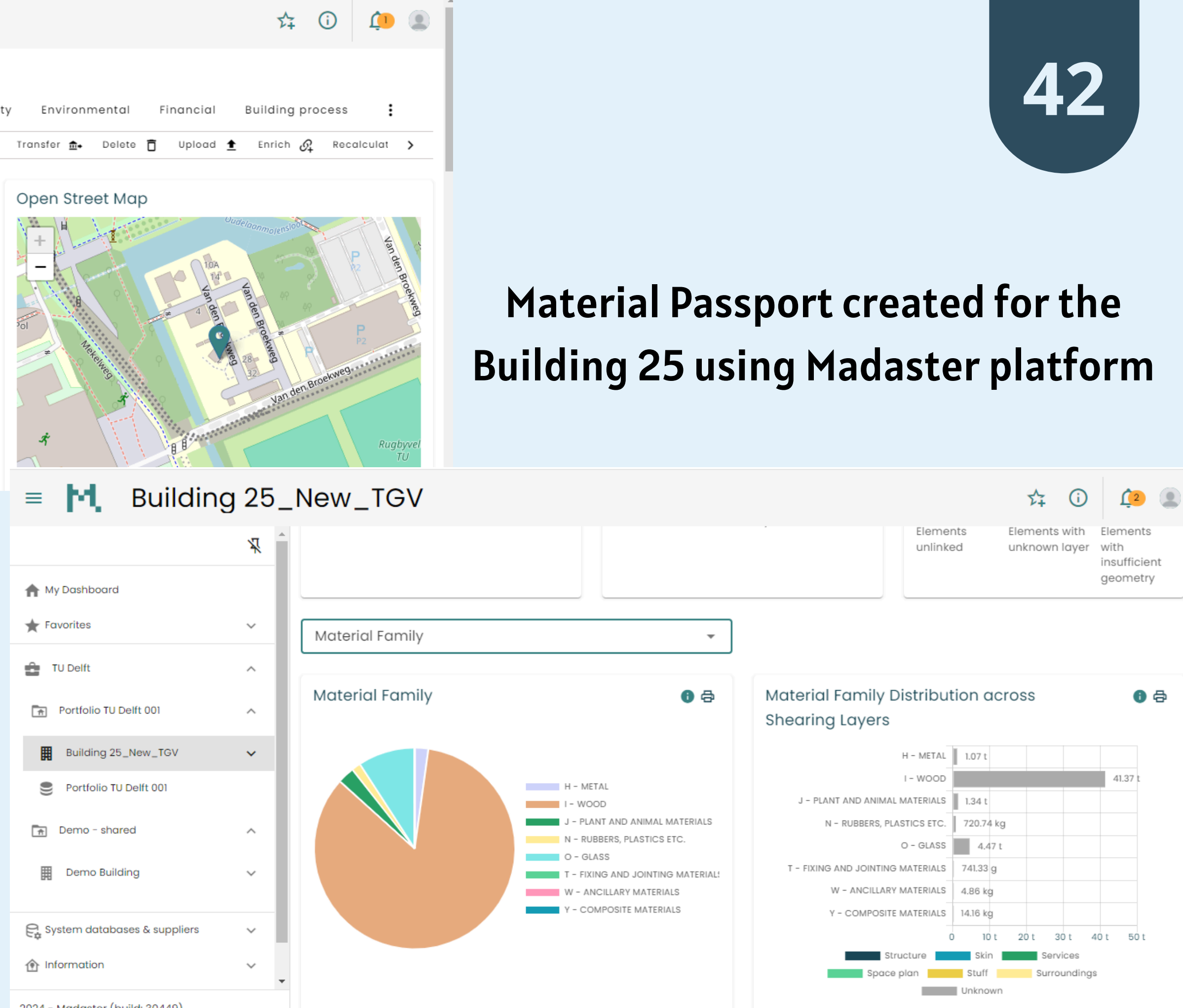- **Revit file was visualised in Revit software**
- **data missing**

- **Revit file was converted into a IFC in the Revit software**
- **data are wrongly assigned – wooden staircase was given as a name, not as the attribute of the elements**
- **IFC is uploaded to FME and was unable to load on DBMS due to misaligned data**

Material Passport created for the Building 25 using Madaster platform

- **Missing data – due to missing material definition and the wrong IFC export setting configuration**
- **It affected the quality and reliability of the generated Material Passport.**

Building 25_New_TGV

Home / TU Delft / Portfolio TU Delft 001 / Building 25_New_TGV

General   Performance   3D   Dossier   Mass   Circularity   Environmental   Financial   Building process

Edit building   Move   Archive the building   Design   Transfer   Delete   Upload   Enrich   Recalculat

Address
Van Den Broekweg 2 25
2628CR Delft
Netherlands
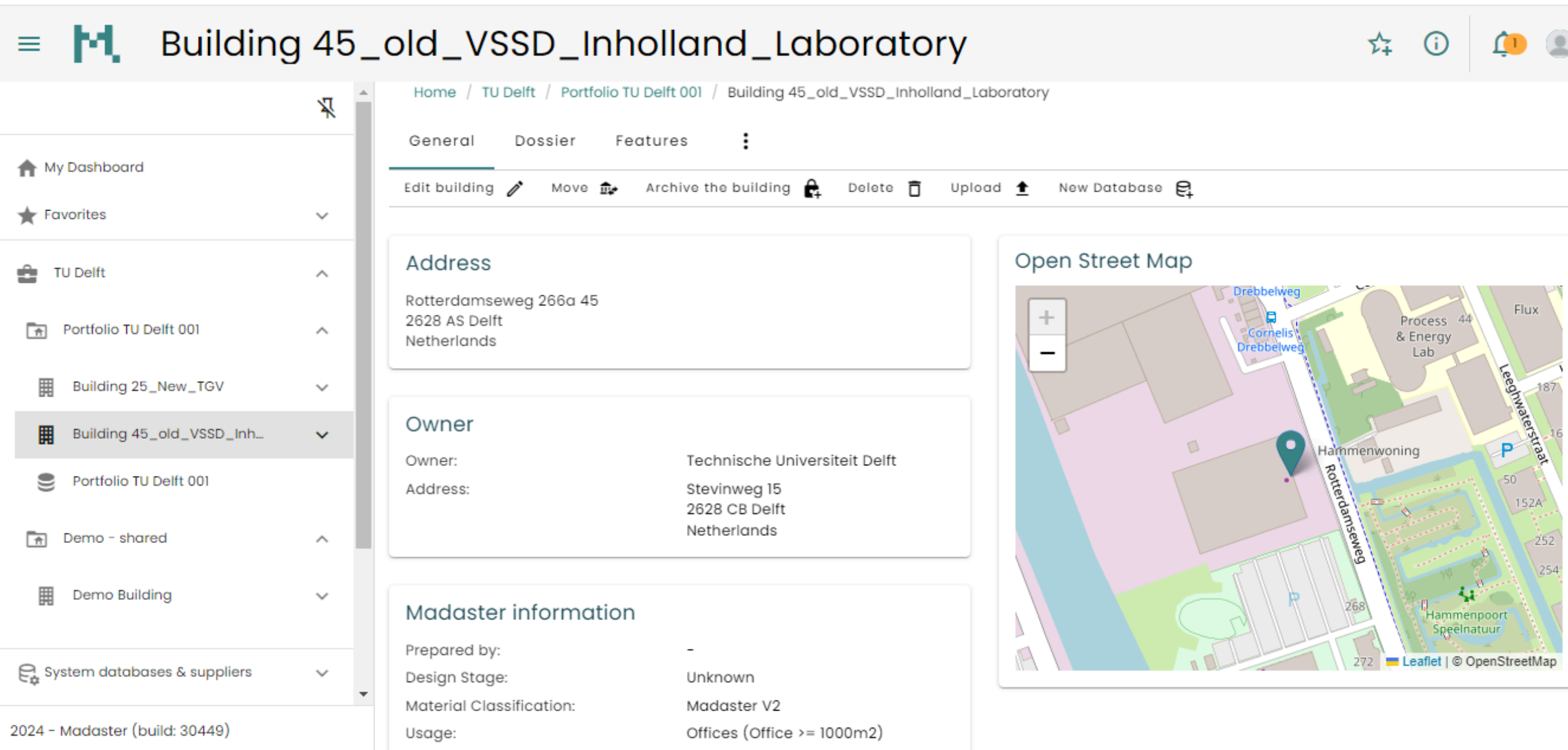
Owner
Owner: Technische Universiteit Delft
Address: Stevinweg 15
2628 CB Delft
Netherlands

Madaster information
Prepared by: -

Open Street Map

Building 25_New_TGV

My Dashboard
Favorites
TU Delft
Portfolio TU Delft 001
Building 25_New_TGV
Portfolio TU Delft 001
Demo - shared
Demo Building
System databases & suppliers
Information

2024 - Madaster (build: 30449)

Elements unlinked   Elements with unknown layer   Elements with insufficient geometry

Material Family

Material Family
- H – METAL
- I – WOOD
- J – PLANT AND ANIMAL MATERIALS
- N – RUBBERS, PLASTICS ETC.
- O – GLASS
- T – FIXING AND JOINTING MATERIAL
- W – ANCILLARY MATERIALS
- Y – COMPOSITE MATERIALS

Material Family Distribution across Shearing Layers

Material	Amount
H – METAL	1.07 t
I – WOOD	41.37 t
J – PLANT AND ANIMAL MATERIALS	1.34 t
N – RUBBERS, PLASTICS ETC.	720.74 kg
O – GLASS	4.47 t
T – FIXING AND JOINTING MATERIALS	741.33 g
W – ANCILLARY MATERIALS	4.86 kg
Y – COMPOSITE MATERIALS	14.16 kg

Structure   Skin   Services   Space plan   Stuff   Surroundings   Unknown

REFLECTION

- Model shows adaptable as it was able to generate material passport with limited data.
- Despite the limitations, model was able to perform database queries
- Data conversion issues- source files conversion leads to data loss during conversion due to incorrectly assigned or not transferred attributes
- Incorrect data assignment, which was the primary obstacle preventing the import of the data into the database

- **Stakeholders – Madaster and the Circular Built Environment Hub at TU Delft to gather feedbacks on the model**
- **fixed complex hierarchy- in real life, not all the info about the levels availabale. To ensure no data is overlooked, all levels are represented in model**
- **simplify the model – concentrate on specific aspects instead of trying to accommodate every detail. However, as an initial draft model serves as a foundational standard for building materials registration, with scalability and long-term applicability in mind**
- **Privacy and access control**
- **Owner Incentives- What benefits would encourage owners to adopt this system**
- **Integration of Customer Relationship Management (CRM)**

What are the applications of the Building Material registration?

1. Supports Circularity

2. Valuation of Building
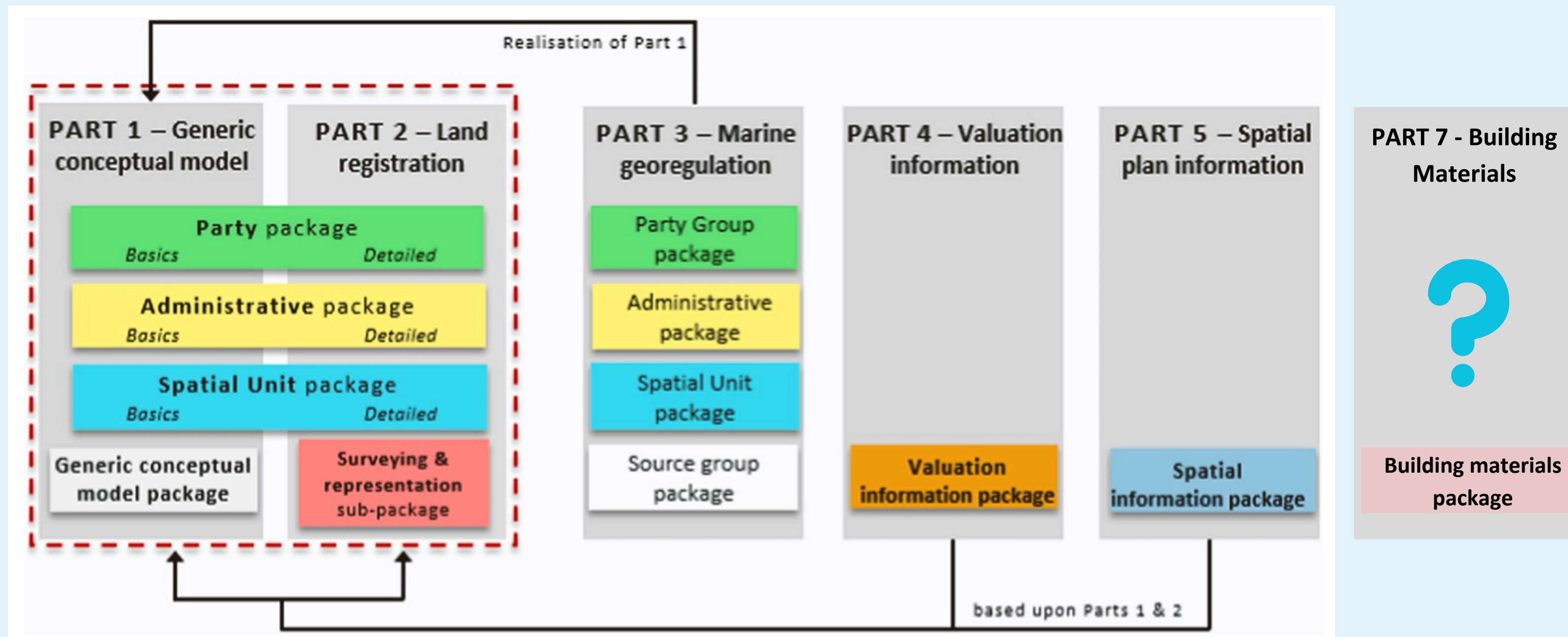
3. Environmental Impact

4. Safety and Security

MATERIALS PASSPORT
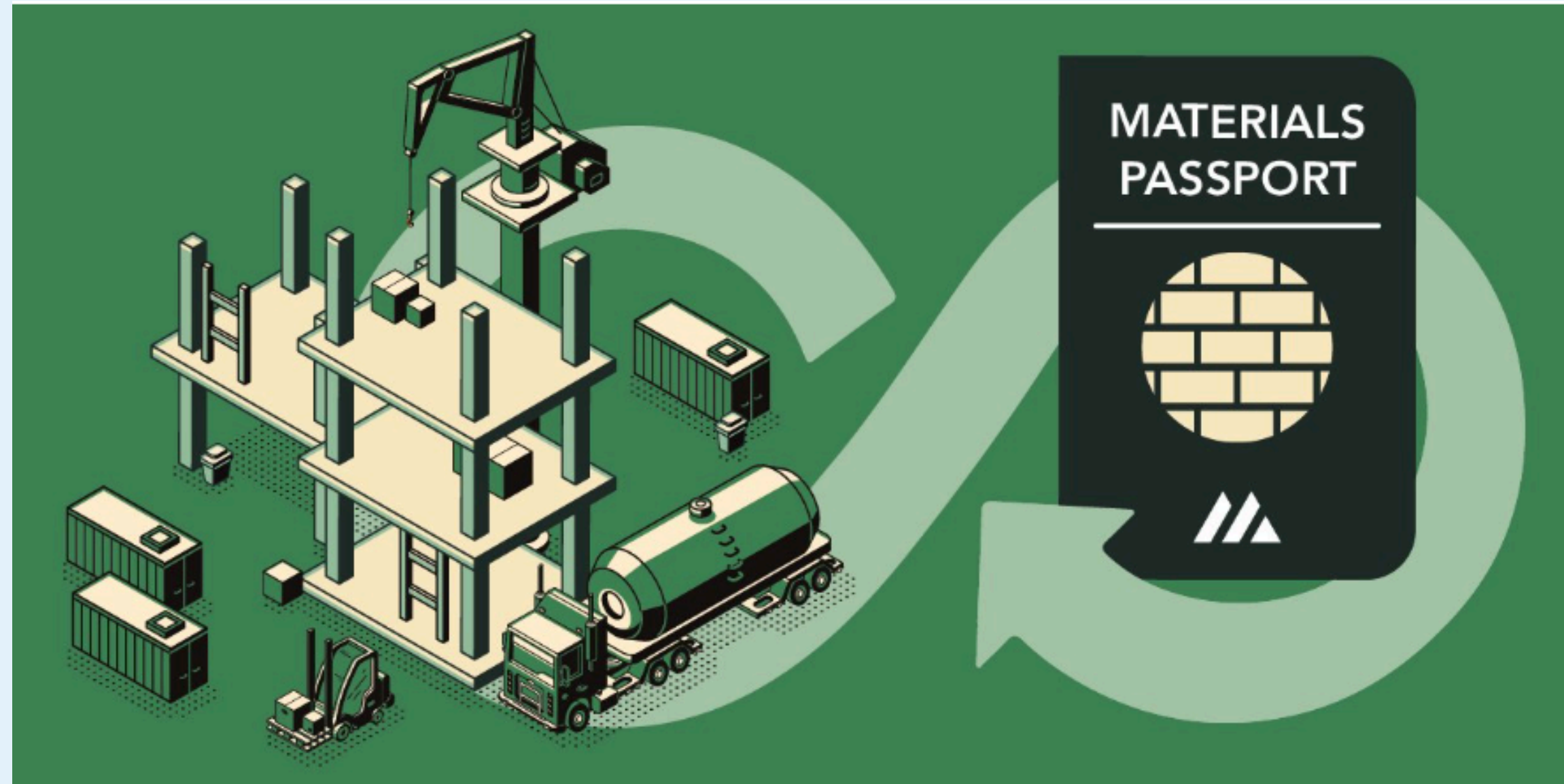
What criteria are necessary to obtain the Material Passport?
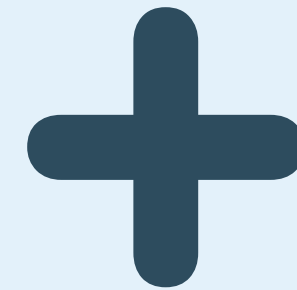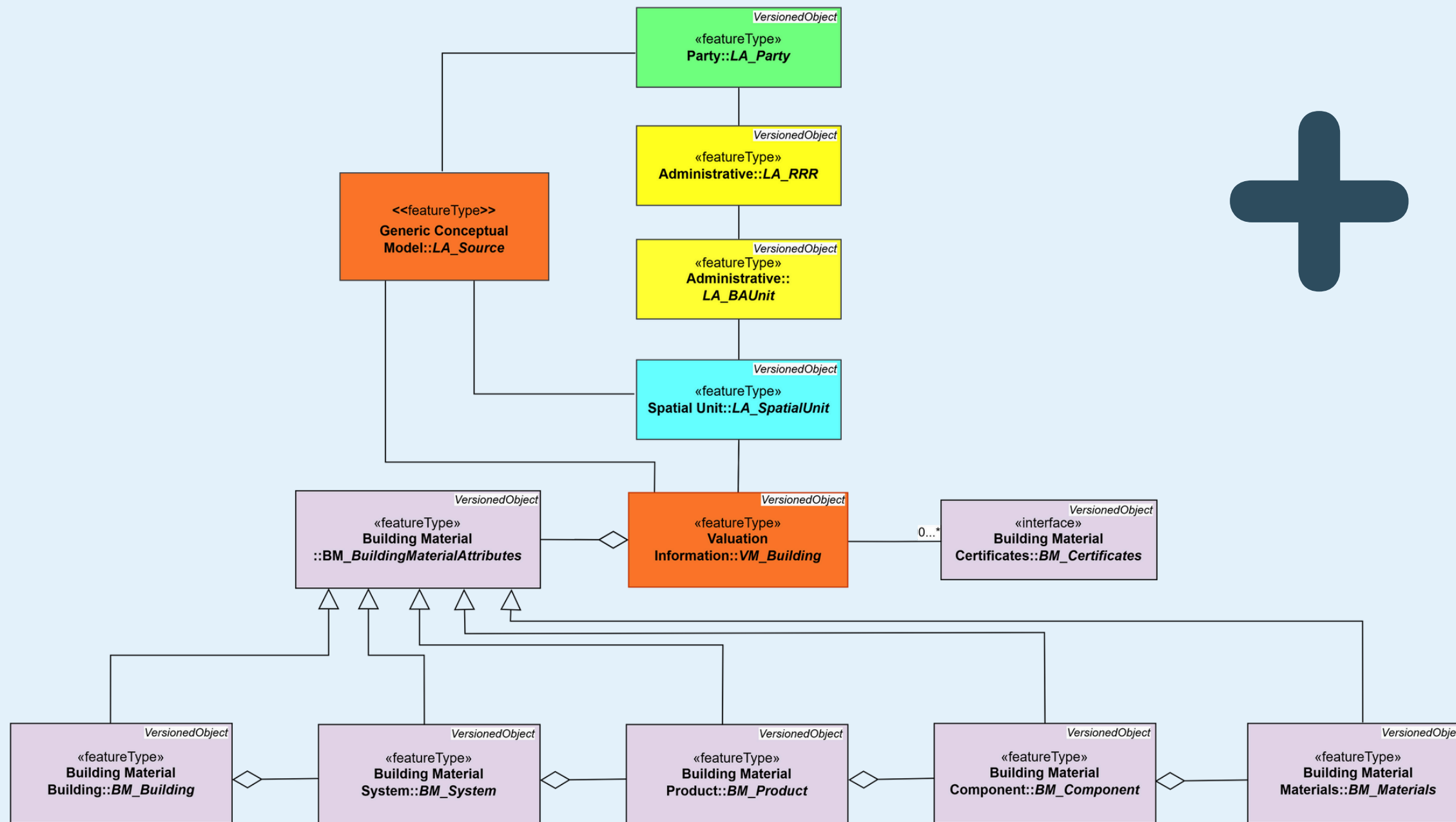
Derived from the use cases

1. Material Info (type, quantity, quality)

2. Owner/Seller details

3. 3D Location

4. Certificates

How can the registration and management of the Material Passport be standardised?

How can the Material Passport be created and evaluated?

+ Workshop

CONCLUSION

- Selecting the classification for the building materials.
- Development of codelist
- Lack of international standard
- Lack of availability of complete and accurate data for existing building - Building 45 and 25
- Lack of georeference in real-world models.
- Geometric invalidities and overlaps.

FUTURE WORK

- Propose guidelines- Georeferencing, Geometric and Topological Validity
- Refine the attributes and codelist
- Refine the model if necessary
- Explore the legal and organizational aspects of building material registration
- Establishing a standardized data format for material passport
- Extend the system to support the selling of the materials present and address the privacy concerns
- Develop the examining of cross-border regulations and certification of material passport

QUESTIONS ?