Formalizing land indicators for SDGs: Implementation and evaluation using international standards

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content

Introduction

Understanding the SDGs in the Context of Land Administration

- **The United Nations' Sustainable Development Goals (SDGs)**
- **a set of 17 global objectives**
- **aimed at promoting social, economic, and environmental well-being by 2030.**

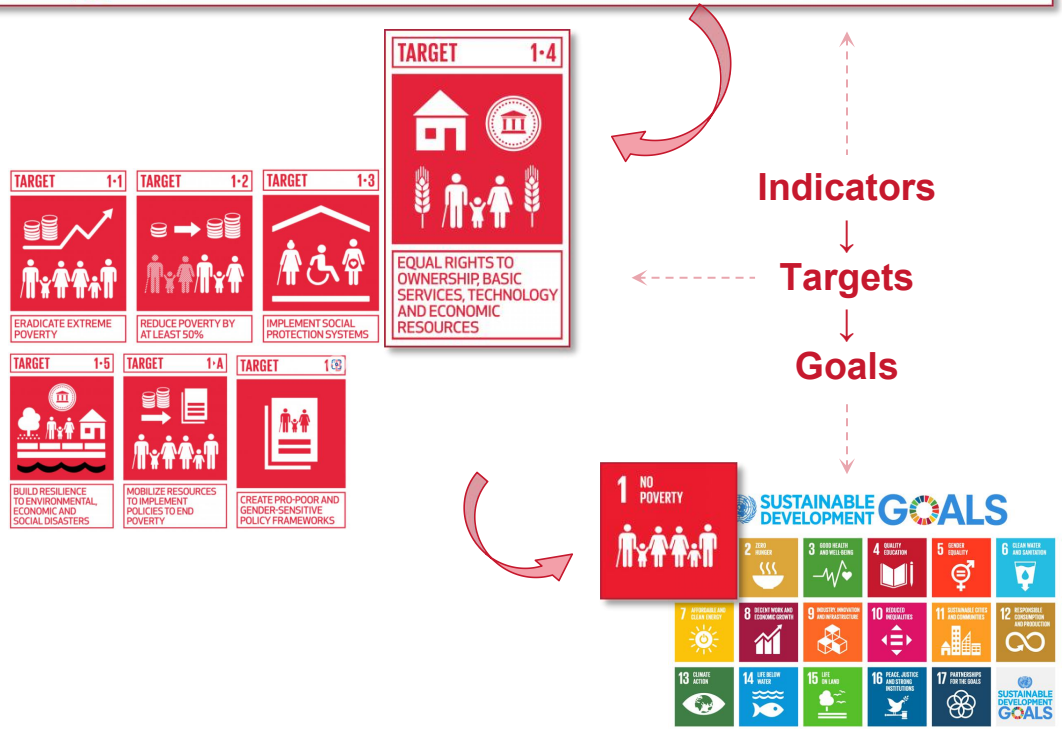
Why Land Administration Matters for Achieving SDGs

- **Enhances Socio-Economic Growth**
- **Supports Sustainable Land Use**
- **Promotes Social Stability**

Key Challenges in Monitoring SDGs

Target 1.4: By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance

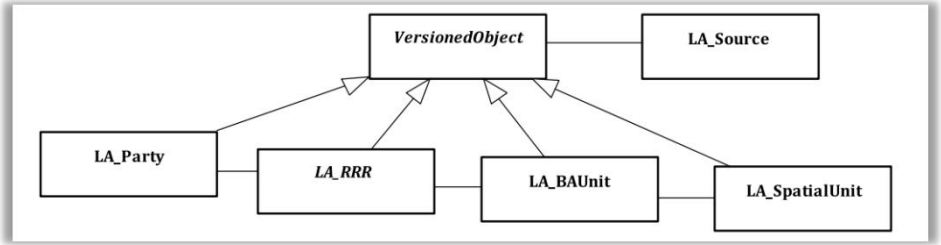
- **Indicator 1.4.1:** Proportion of population living in households with access to basic services
  See metadata :
- **Indicator 1.4.2:** Proportion of total adult population with secure tenure rights to land, (a) with legally recognized documentation, and (b) who perceive their rights to land as secure, by sex and type of tenure
  See metadata :



- **Lack of Data and Inconsistency**
- **Disparity Between Global and Local Indicators**
- **Text-based Metadata document**
- **Lack of harmonized monitoring tools**

Introducing LADM as a Solution for SDG Monitoring

ISO 19152 Land Administration Domain Model



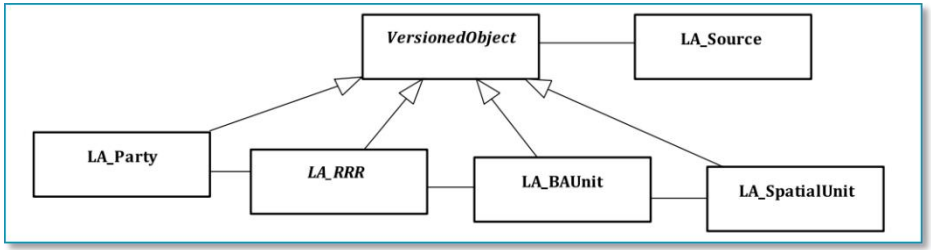
Basic classes of the core LADM

Enhances the efficiency and interoperability of land administration systems by providing a unified structure for managing land-related information across various jurisdictions.

- **Shared Vocabulary —— Provides terms**
- **Customization —— Can be extended**

Introducing LADM as a Solution for SDG Monitoring

ISO 19152 Land Administration Domain Model



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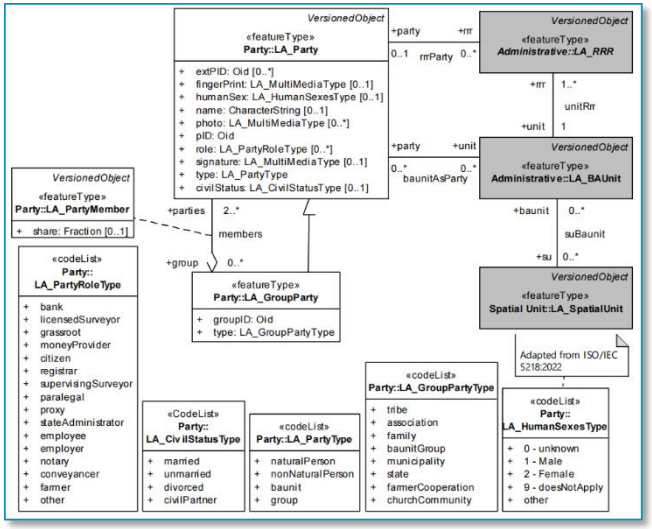
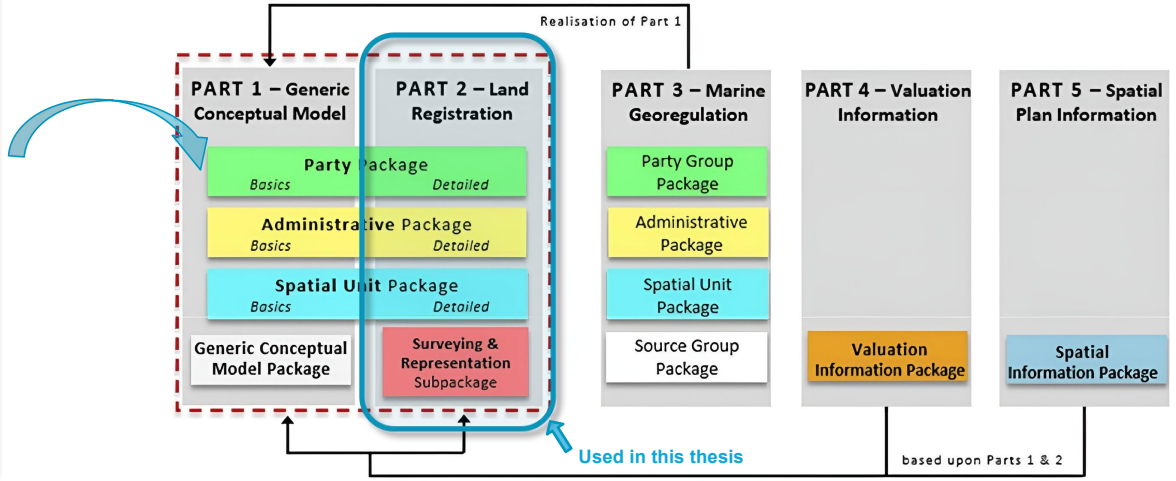


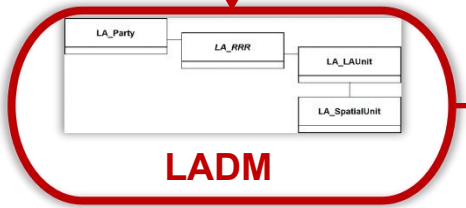


LADM Edition II Parts 1-5

Importance of Land Administration for SDGs

Land administration for sustainable development

Specific implementation pathways



LADM

- **Standardization**
- **Efficiency**
- **Accuracy**
- **Scalability**
- **Interoperability**

Formalizing SDG land-related indicators by using LADM

SDG

SDGs Indicator

- Lack of Data and Inconsistency
- Lack of harmonized monitoring tools
- Text-based Metadata document
- Disparity Between Global and Local Indicators

Research Questions

How can the ISO 19152 Land Administration Domain Model (LADM) be implemented to formalize and standardize land-related SDG indicators?

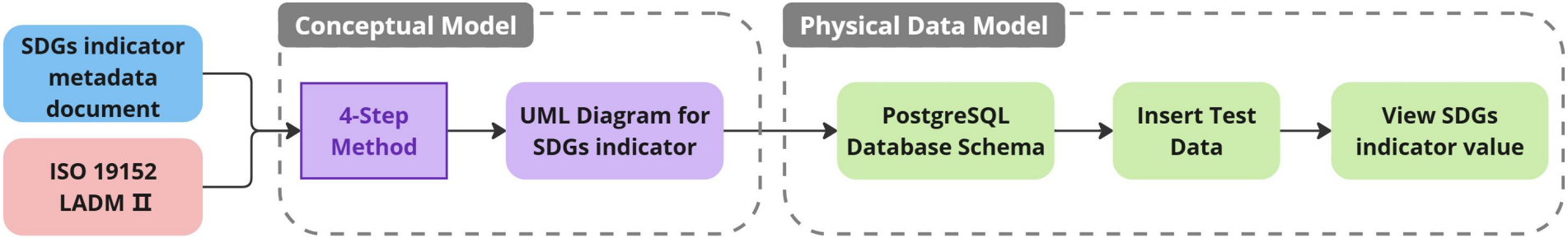
Subquestions:

1. How can the **conceptual model** for SDG 1.4.2 be **developed** based on its metadata?
2. How can the **conceptual model** for SDG 1.4.2 be effectively **translated** into a physical database implementation?
3. What **added value** does this approach bring to the overall monitoring and evaluation of SDG indicators?

Methodology

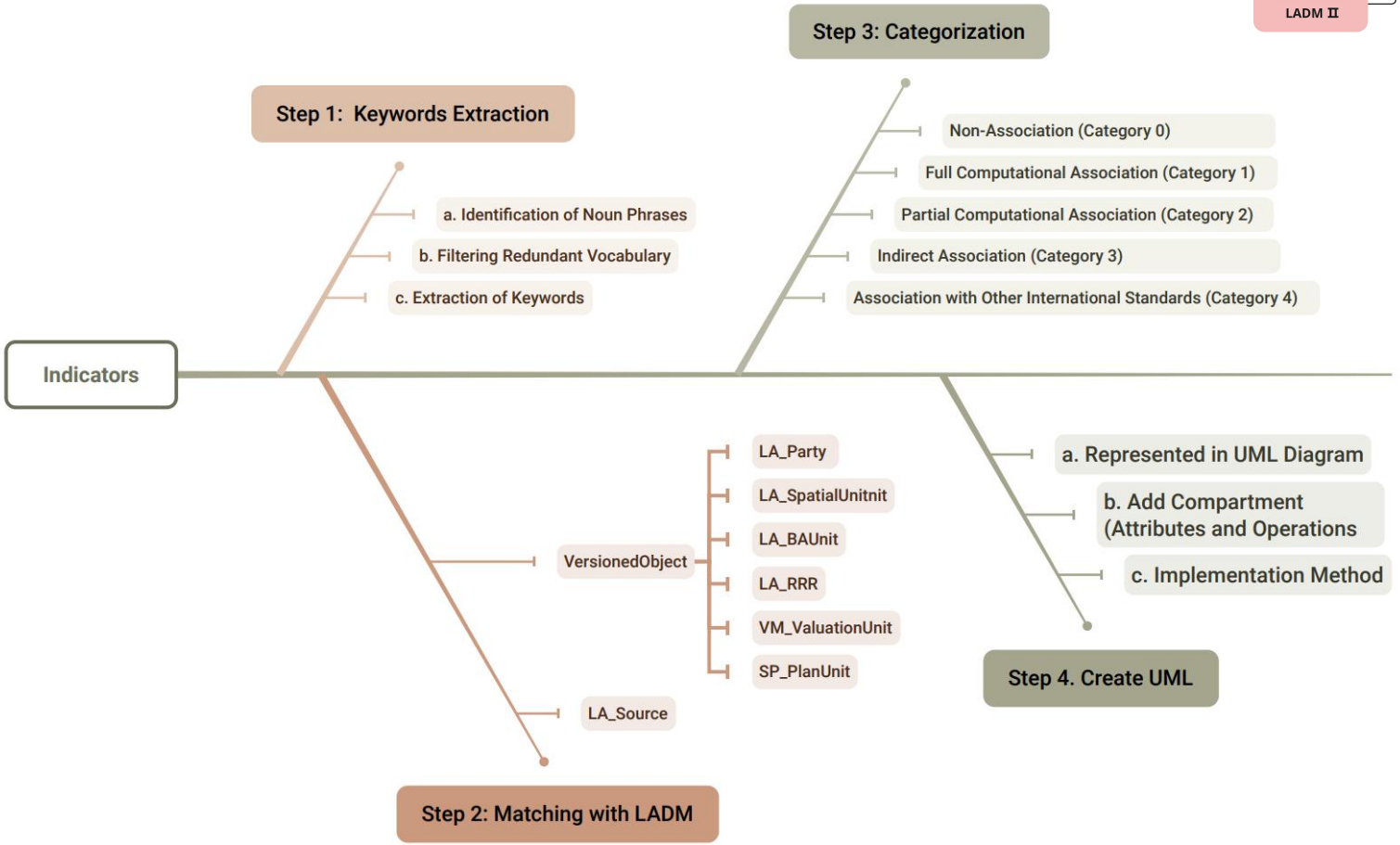
How to formalize?

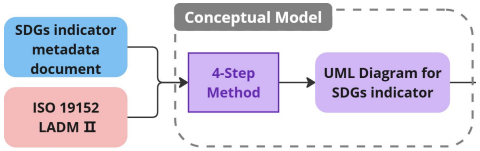
Research Approach Overview



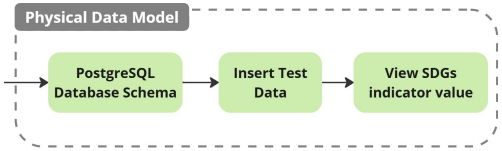
1. *Linking LADM and SDGs Using the Four-Step Method*
2. *Transition from Conceptual to Physical Model*

Linking LADM and SDGs Using the Four-Step Method





Transition from Conceptual to Physical Model



Physical Model Requirements

- **Data Consistency**

Ensures reliable data during operations (insert, update, delete).Includes constraints and validation to maintain accuracy.

- **Standardization**

Aligns with ISO 19152 LADM for global compatibility.Uses standardized data types for seamless integration with LADM systems.

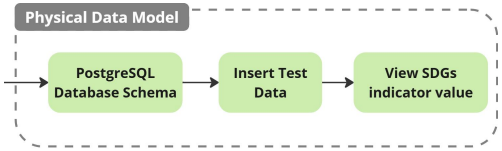
- **Scalability**

Designed for flexible expansion to support new data and future needs.Can handle data growth without major structural changes.

- **Operability**

Implements abstract concepts from the conceptual model.Supports efficient data storage, retrieval, and computation.

Transition from Conceptual to Physical Model



Model Transformation Strategy

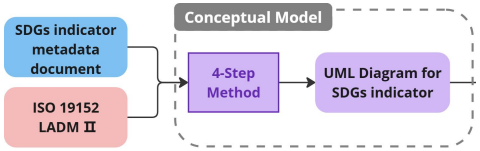
- **Class-to-Table Mapping:**
Translates LADM classes (e.g., LA Party, LA SpatialUnit) into database tables.Maintains integrity of relationships using foreign key constraints.

- **Attribute-to-Column Mapping:**
Maps attributes to database fields with standard data types; custom data types for specialized needs.

- **Normalization:**
Reduces redundancy and ensures data integrity through database normalization.

- **Hierarchical Mapping:**
Implements class hierarchies (e.g., versioned objects) using hierarchical table structures.

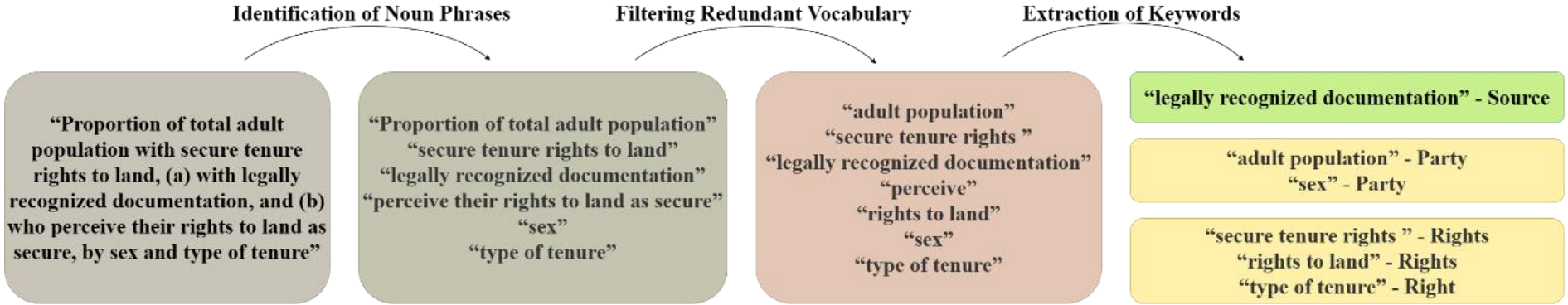
Conceptual Model for SDG Indicator 1.4.2



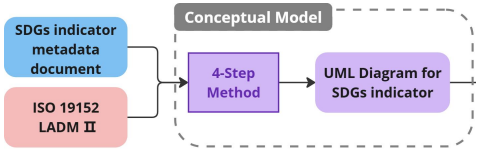
CASE

the SDG Indicator 1.4.2 ***"Proportion of total adult population with secure tenure rights to land, (a) with legally recognized documentation, and (b) who perceive their rights to land as secure, by sex and type of tenure"***

Step 1: Keywords Extraction



Conceptual Model for SDG Indicator 1.4.2



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Step 2: Matching with LADM

from a cadaster system compliant with LADM

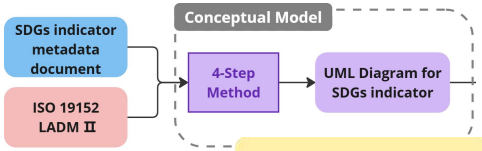
$$\text{Part (A):} \frac{People\ (adult)\ with\ legally\ recognized\ documentation\ over\ land}{Total\ adult\ population} \times 100$$

from censuses or inter-censual projections

$$\text{Part (B):} \frac{People\ (adult)\ who\ perceive\ their\ rights\ as\ secure}{Total\ adult\ population} \times 100$$

household survey

Conceptual Model for SDG Indicator 1.4.2



LA_RRR

CASE

the SDG Indicator 1.4.2 ***"Proportion of total adult population with secure tenure rights to land, (a) with legally recognized documentation, and (b) who perceive their rights to land as secure, by sex and type of tenure"***

LA_Party

Step 2: Matching with LADM

LA_Source, LA_Party

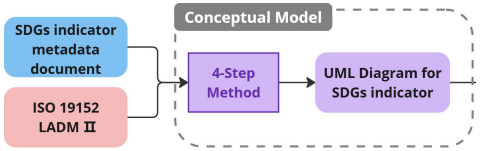
$$\text{Part (A):} \frac{\textit{People (adult) with legally recognized documentation over land}}{\textit{Total adult population}} \times 100$$

$$\text{Part (B):} \frac{\textit{People (adult) who perceive their rights as secure}}{\textit{Total adult population}} \times 100$$

External: Population

External: SecureLandRightsAdult

Conceptual Model for SDG Indicator 1.4.2



CASE

the SDG Indicator 1.4.2 *"Proportion of total adult population with secure tenure rights to land, (a) with legally recognized documentation, and (b) who perceive their rights to land as secure, by sex and type of tenure"*

Step 3: Classification

External: Population

External: SecureLandRightsAdult

LA_Party

LA_RRR

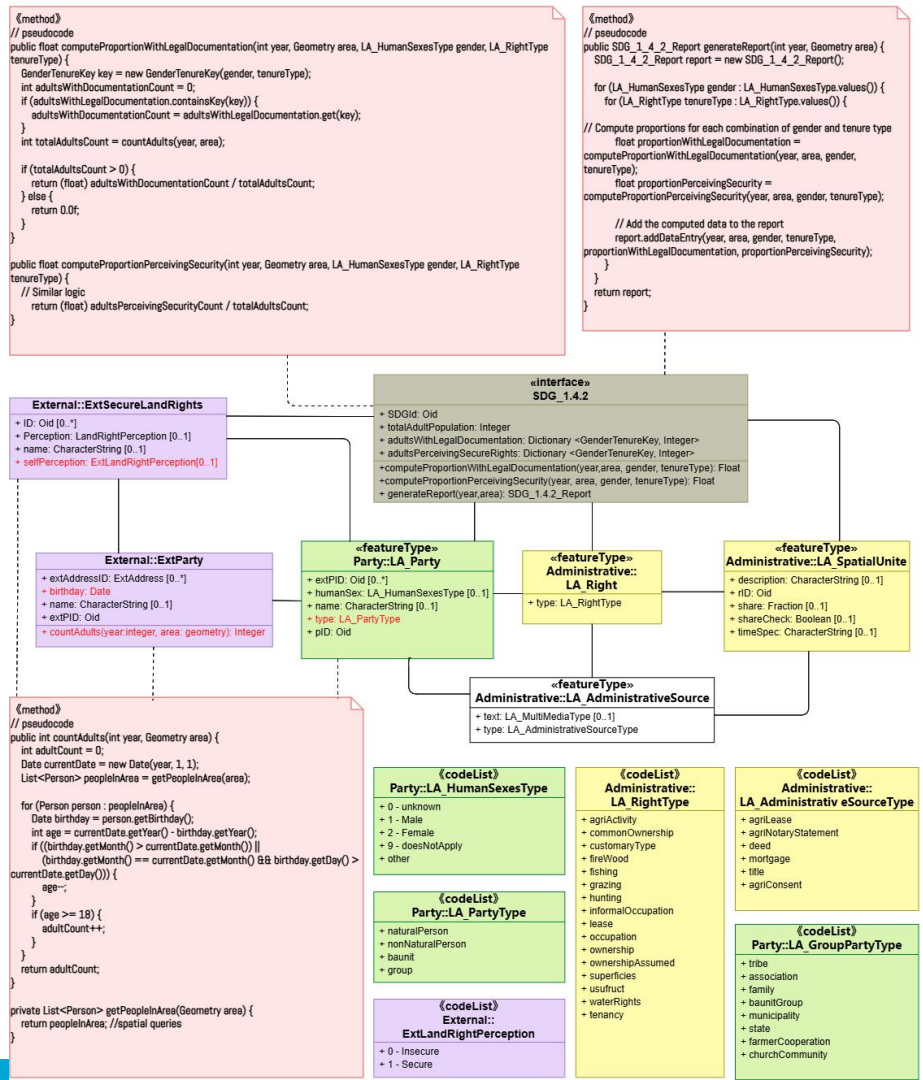
LA_Source, LA_Party

→ **Category 2**
Partial Computational Association

Conceptual Model for SDG Indicator 1.4.2

Step 4: Create UML

Existing LADM Class	Attributes Used in the Case	Notes
LA_Party	+gender:LA_HumanSexesType[0..1]	Highlighted to facilitate gender-based classification and calculation.
LA_Right	LA_RightType	Delineating various land tenure types, echoing the "type of tenure" parameter in the indicator. The specific right types are detailed in the "Code List."
LA_AdministrativeSource	+type:LA_AdministrativeSourceType	Signifying "Legally recognized documentation." Its code list meticulously enumerates the possible values, such as agriLease, deed, and title.
LA_BAUnit		While not the focal point, it is outlined to underscore the indicator's emphasis on rights over land.



Implementation

Tools Used

PostgreSQL
open-source relational database used to store and manage spatial and non-spatial data.

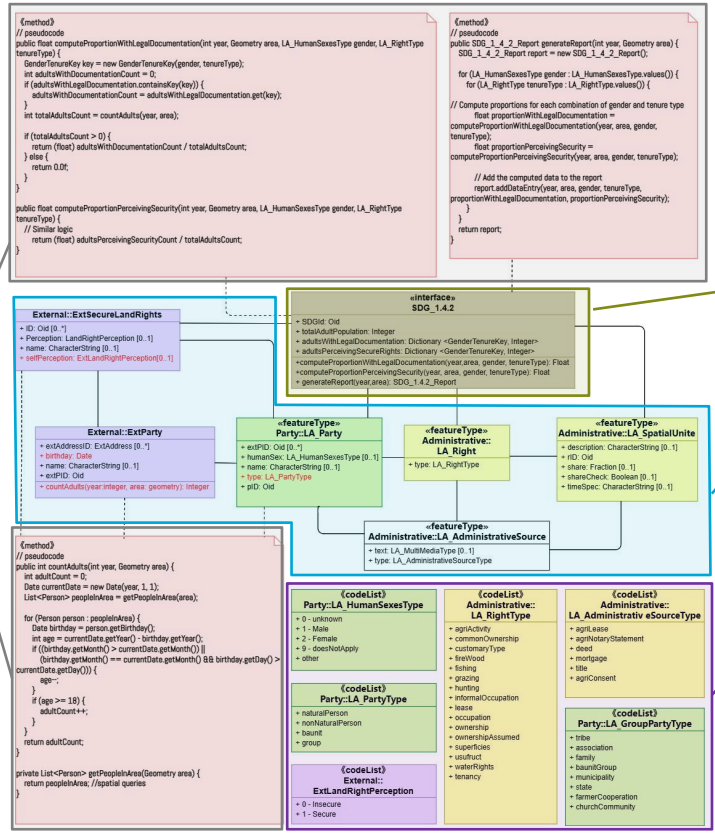
PostGIS
a spatial database extender for PostgreSQL, enabling advanced geographic queries and spatial data processing.

QGIS
- Open-source Geographic Information System used for spatial data visualization, analysis, and mapping.
- Can link to PostgreSQL/PostGIS

Enterprise Architect

UML structure

SDG Indicator 1.4.2 ***"Proportion of total adult population with secure tenure rights to land, (a) with legally recognized documentation, and (b) who perceive their rights to land as secure, by sex and type of tenure"***



Method to Function

Interface to View

Class to Table

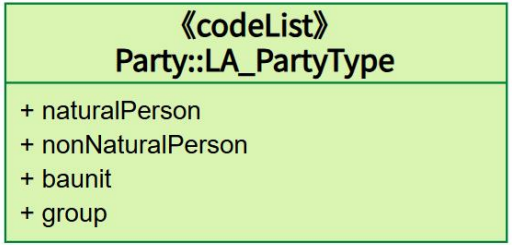
Codelist to Table

Codelist to Table

Fixed Code List

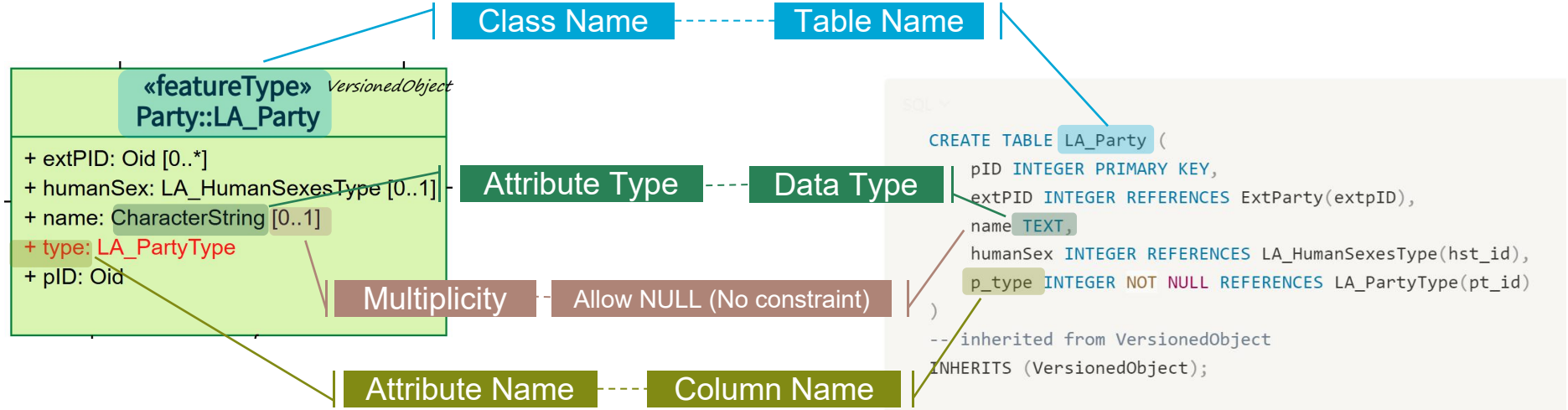

```
CREATE TABLE LA_HumanSexesType (
    hst_id INTEGER UNIQUE NOT NULL,
    hst_description TEXT NOT NULL UNIQUE
);
INSERT INTO LA_HumanSexesType (hst_id, hst_description ) VALUES
(0, 'unknown'),
(1, 'Male'),
(2, 'Female'),
(9, 'doesNotApply'),
(99, 'other');
```

Flexible Code List

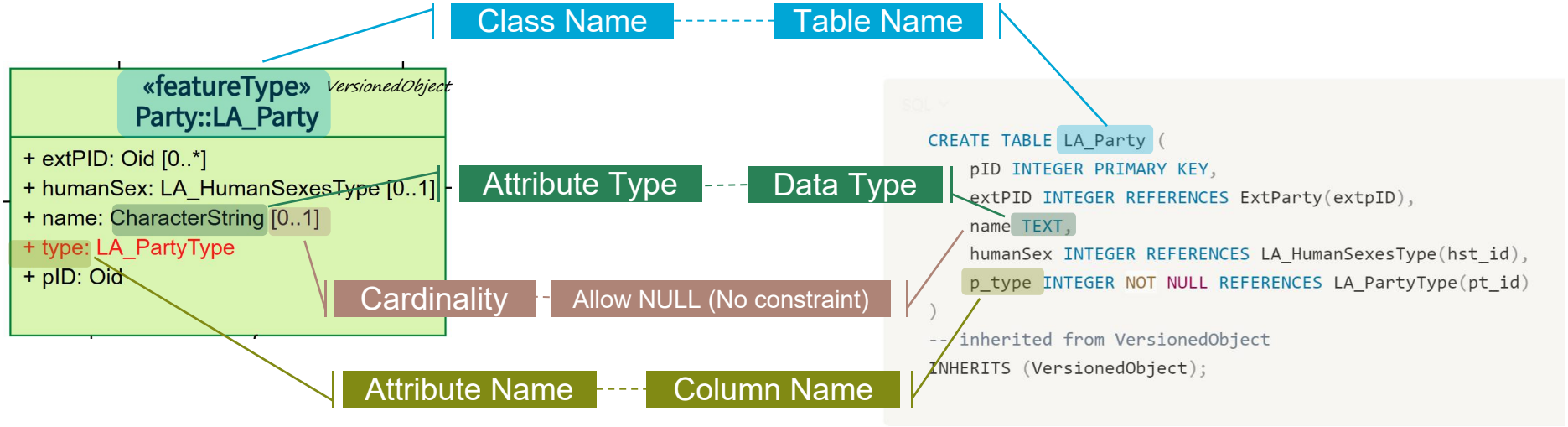



```
CREATE TABLE LA_PartyType (
    pt_id SERIAL PRIMARY KEY,
    pt_description TEXT NOT NULL UNIQUE
);
INSERT INTO LA_PartyType (pt_description ) VALUES
('naturalPerson'),
('nonNaturalPerson'),
('baunit'),
('group');
```

Class to Table



Class to Table

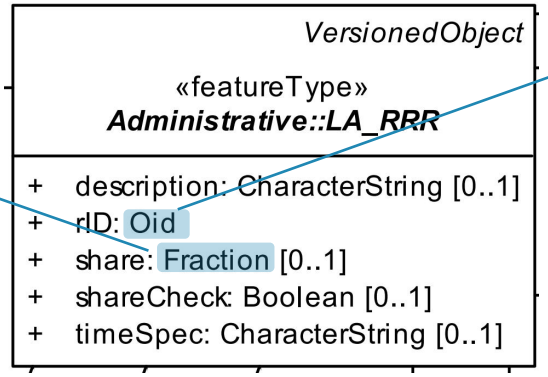


UML Component	SQL Representation	Example
Class Name	Table Name	UML Class: LA_Party → SQL Table: LA_Party
Attribute Name	Column Name	UML Attribute: name → SQL Column: name
Attribute Type	Data Type	UML Type: CharacterString → SQL Type: TEXT
Multiplicity: 1	NOT NULL Constraint	UML Multiplicity: 1 → SQL Constraint: name TEXT NOT NULL
Multiplicity: 0..1	Allow NULL (No constraint)	UML Multiplicity: 0..1 → SQL Column: name TEXT
Multiplicity: 0..*	Many-to-Many Relationship, Association Table	UML Multiplicity: 0..* → Requires a join table
unique identifier	PRIMARY KEY Constraint	UML Attribute: pID → SQL: pID INTEGER PRIMARY KEY
Inheritance(usually in italics in the upper right corner)	INHERITS keyword (for PostgreSQL)	UML: LA_Party inherits VersionedObject → SQL: INHERITS (VersionedObject)
Visibility (public/private/protected)	Ignored in SQL, all attributes accessible	N/A
Initial Value	DEFAULT Clause	UML availabilityStatus: LA AvailabilityStatusType = documentAvailable → SQL: availabilityStatus INTEGER DEFAULT 1(the id of documentAvailable)

Class to Table: special Data Type

Fraction

```
CREATE TYPE Fraction AS (
    numerator INTEGER,
    denominator INTEGER
);
```



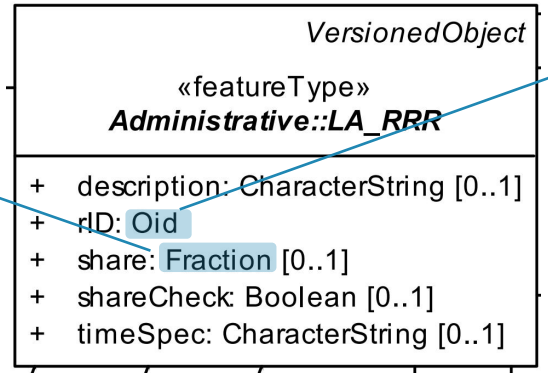
Oid

```
CREATE TYPE Oid AS (
    localId VARCHAR,
    namespace VARCHAR
);
```

Class to Table: special Data Type

Fraction

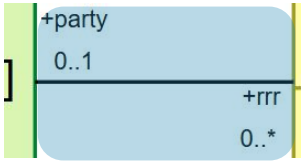
```
CREATE TYPE Fraction AS (
    numerator INTEGER,
    denominator INTEGER
);
```



Oid

```
CREATE TYPE Oid AS (
    localId VARCHAR,
    namespace VARCHAR
);
```

Class to Table: Relationships Between Tables

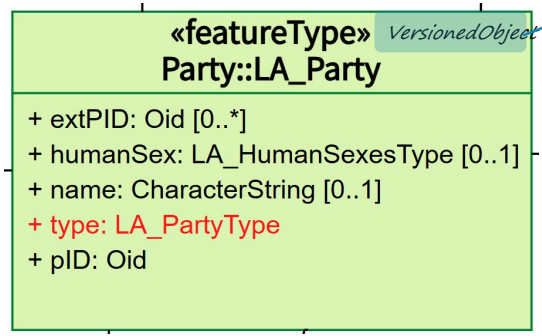


Association

```
CREATE TABLE LA_Right (
    rID INTEGER PRIMARY KEY,
    r_type INTEGER NOT NULL REFERENCES LA_RightType (rt_id),

    -- inherited from LA_RRR
    suID INTEGER REFERENCES la_spatialunit(suid),
    pID INTEGER REFERENCES la_party(pid),
```

Use foreign keys



Inheritance

```
CREATE TABLE LA_Party (
    pID INTEGER PRIMARY KEY,
    extPID INTEGER REFERENCES ExtParty(extpID),
    name TEXT,
    humanSex INTEGER REFERENCES LA_HumanSexesType(hst_id),
    p_type INTEGER NOT NULL REFERENCES LA_PartyType(pt_id)
)
-- inherited from VersionedObject
INHERITS (VersionedObject);
```

Use INHERITS keyword

Class to Table: Constraints

- **Primary Key: id**
- **Foreign Key: relationship between tables(Class to Class/ codelist to Class)**
- **NOT NULL/ UNIQUE/CHECK: simple logic**


```
CREATE TABLE LA_Right (
    rID INTEGER PRIMARY KEY,
    r_type INTEGER NOT NULL REFERENCES LA_RightType (rt_id),

    -- inherited from LA_RRR
    suID INTEGER REFERENCES la_spatialunit(suid),
    pID INTEGER REFERENCES la_party(pid),
```

Functions and Triggers for Complex Constraints

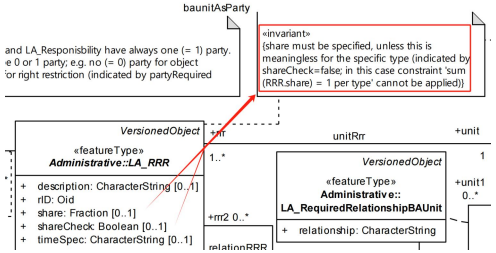
check version lifespan continuity

«featureType»
Generic Conceptual Model::VersionedObject

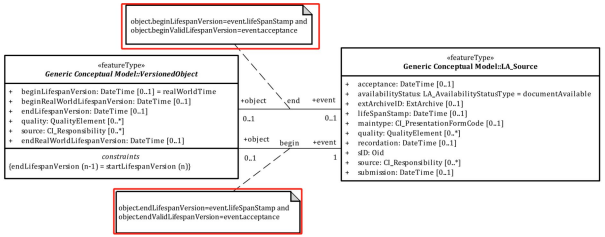
+ beginLifespanVersion: DateTime [0..1] = realWorldTime
+ beginRealWorldLifespanVersion: DateTime [0..1]
+ endLifespanVersion: DateTime [0..1]
+ quality: QualityElement [0..*]
+ source: CI_Responsibility [0..*]
+ endRealWorldLifespanVersion: DateTime [0..1]

constraints
{endLifespanVersion (n-1) = startLifespanVersion (n)}

check share sum



check source constraints



check fraction validity

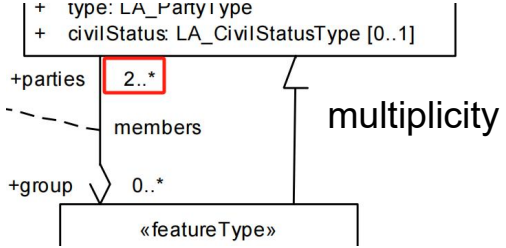
«dataType»
Generic Conceptual Model::Fraction

+ denominator: Integer
+ numerator: Integer

+ equals(Fraction): Boolean
  [a.equals(b)] = [a.numerator*b.denominator = b.numerator*a.denominator]
+ real(): Real
  a.real() = a.numerator/a.denominator

constraints
{denominator > 0}
{numerator > 0}
{numerator <= denominator}

check minimum group members



Example: check version lifespan continuity

«featureType** ***Generic Conceptual Model::VersionedObject*
+ beginLifespanVersion: DateTime [0..1] = realWorldTime + beginRealWorldLifespanVersion: DateTime [0..1] + endLifespanVersion: DateTime [0..1] + quality: QualityElement [0..*] + source: CI_Responsibility [0..*] + endRealWorldLifespanVersion: DateTime [0..1]
constraints {endLifespanVersion (n-1) = startLifespanVersion (n)}

- For each version of a record, the end time of the previous version must match the start time of the next.
- Prevents gaps in historical data, preserving data integrity and consistency.

```
1  select * from la_party
```

Data Output | Messages | Notifications

	beginlifespanversion timestamp with time zone	endlifespanversion timestamp with tim	beginrealworldlifespanversion timestamp with time zone	endrealworldlifespanversion timestamp with time zone	pid [PK] integer	extpid integer	name text
1	2000-01-01 14:37:22+01	[null]	2000-01-01 00:00:00+01	[null]	10001	110001	M1

Example: check version lifespan continuity

```
IF NEW.endLifespanVersion IS NULL THEN
    query := format(
        'SELECT EXISTS (SELECT 1 FROM %I WHERE suid = $1)',
        TG_TABLE_NAME
    );
    EXECUTE query INTO suid_exists USING NEW.suid;
    IF suid_exists = FALSE THEN
        RETURN NEW;
    END IF;
```

If no previous record exists for suid, skips the continuity check since it's the first entry for this suid.

Example: check version lifespan continuity

```
    IF NEW.endLifespanVersion IS NULL THEN
        query := format(
            'SELECT EXISTS (SELECT 1 FROM %I WHERE suid = $1)',
            TG_TABLE_NAME
        );
        EXECUTE query INTO suid_exists USING NEW.suid;
        IF suid_exists = FALSE THEN
            RETURN NEW;
        END IF;
```

If no previous record exists for suid, skips the continuity check since it's the first entry for this suid.

```
        query := format(
            'SELECT endLifespanVersion FROM %I WHERE suid = $1 AND endLifespanVersion IS
NOT NULL ORDER BY endLifespanVersion DESC LIMIT 1',
            TG_TABLE_NAME
        );

        EXECUTE query INTO prev_endLifespanVersion USING NEW.suid;
```

Retrieves the endLifespanVersion of the most recent record for the same suid if it exists.

Example: check version lifespan continuity

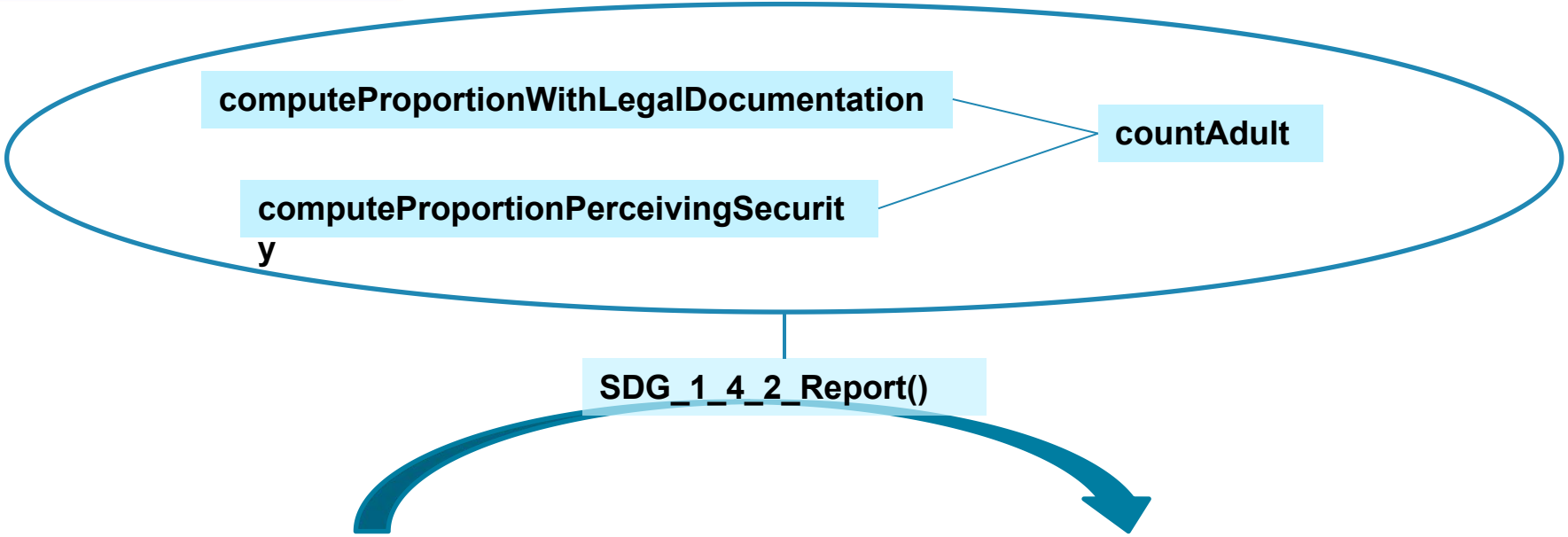
```
    IF NEW.endLifespanVersion IS NULL THEN
        query := format(
            'SELECT EXISTS (SELECT 1 FROM %I WHERE suid = $1)',
            TG_TABLE_NAME
        );
        EXECUTE query INTO suid_exists USING NEW.suid;
        IF suid_exists = FALSE THEN
            RETURN NEW;
        END IF;
```

If no previous record exists for suid, skips the continuity check since it's the first entry for this suid.

```
        IF prev_endLifespanVersion IS NOT NULL AND prev_endLifespanVersion <> NEW.beginL
ifespanVersion THEN
            RAISE EXCEPTION 'Lifespan continuity error in table % for suid %: previous e
ndLifespanVersion % does not match new beginLifespanVersion %',
                            TG_TABLE_NAME, NEW.suid, prev_endLifespanVersion, NEW.beginL
ifespanVersion;
        END IF;
```

Raises an exception if they don't match, preventing data inconsistency.

Method to Functions




```
SELECT *
FROM SDG_1_4_2_Report(
  '2000-01-01 00:00:00',
  '2001-01-01 00:00:00',
  (SELECT geom FROM test_area WHERE id = 1)
);
```

	report_region geometry	report_category text	report_subcategory text	report_totaladultscount integer	report_proportionperceivingsecurity double precision	report_proportionwithlegaldocumentation double precision
1	01030000204071...	total	[null]	17	0.47058823529411764	0.47058823529411764
2	01030000204071...	gender	9	17	0	0
3	01030000204071...	gender	2	17	0.23529411764705882	0.23529411764705882
4	01030000204071...	gender	1	17	0.23529411764705882	0.23529411764705882
5	01030000204071...	tenure_type	11	17	0.47058823529411764	0.47058823529411764

Input: time period and area

Output: proportion by category

Interface to View

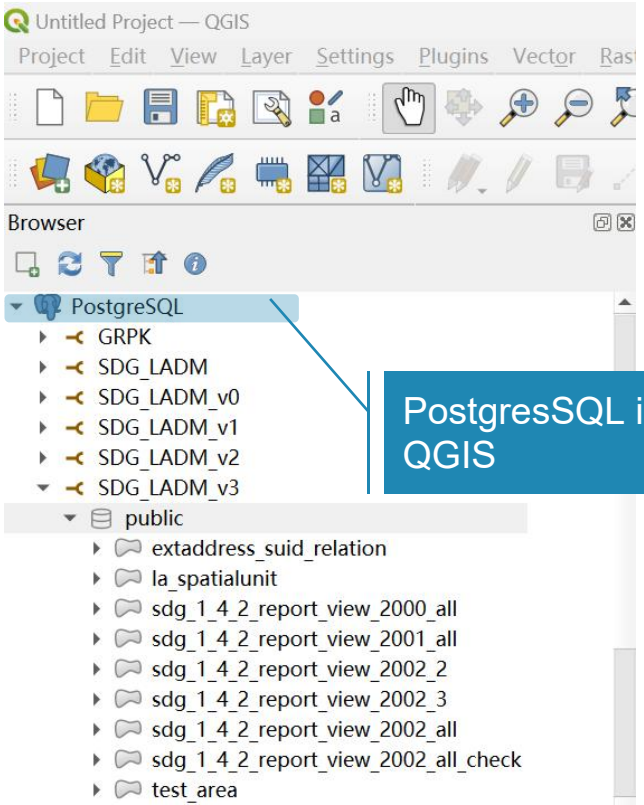
SDG_1_4_2_Report()

	report_region geometry	report_category text	report_subcategory text	report_totaladultscount integer	report_proportionperceivingsecurity double precision	report_proportionwithlegaldocumentation double precision
1	01030000204071...	total	[null]	17	0.47058823529411764	0.47058823529411764
2	01030000204071...	gender	9	17	0	0
3	01030000204071...	gender	2	17	0.23529411764705882	0.23529411764705882
4	01030000204071...	gender	1	17	0.23529411764705882	0.23529411764705882
5	01030000204071...	tenure_type	11	17	0.47058823529411764	0.47058823529411764

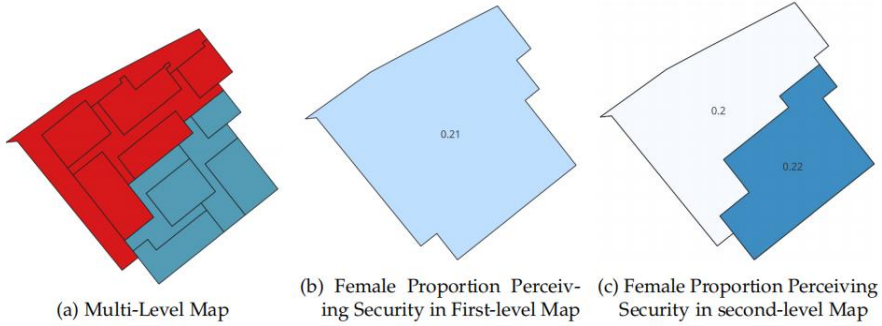
VIEW SDG_1_4_2_Report_View_2000_all

	report_begindate timestamp with time zone	report_enddate timestamp with time zone	report_ geome	report_category text	report_subcategory text	report_totaladultscount integer	report_proportionperceivingsecurity double precision	report_proportionwithlegaldocumentation double precision
1	2000-01-01 00:00:00+01	2001-01-01 00:00:00+01	01030000...	gender	Male	17	0.23529411764705882	0.23529411764705882
2	2000-01-01 00:00:00+01	2001-01-01 00:00:00+01	01030000...	tenure_type	ownership	17	0.47058823529411764	0.47058823529411764
3	2000-01-01 00:00:00+01	2001-01-01 00:00:00+01	01030000...	gender	Female	17	0.23529411764705882	0.23529411764705882
4	2000-01-01 00:00:00+01	2001-01-01 00:00:00+01	01030000...	gender	doesNotApply	17	0	0
5	2000-01-01 00:00:00+01	2001-01-01 00:00:00+01	01030000...	total	[null]	17	0.47058823529411764	0.47058823529411764

QGIS visualization



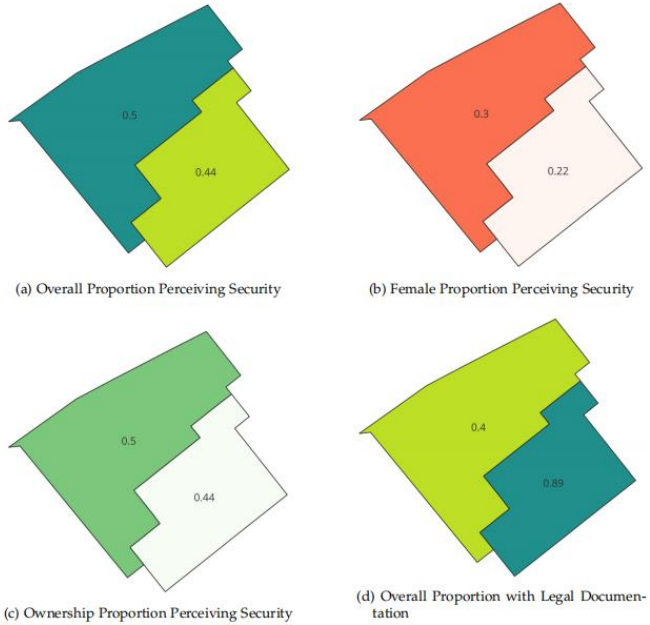
PostgresSQL in QGIS



(a) Multi-Level Map

(b) Female Proportion Perceiving Security in First-level Map

(c) Female Proportion Perceiving Security in second-level Map



(a) Overall Proportion Perceiving Security

(b) Female Proportion Perceiving Security

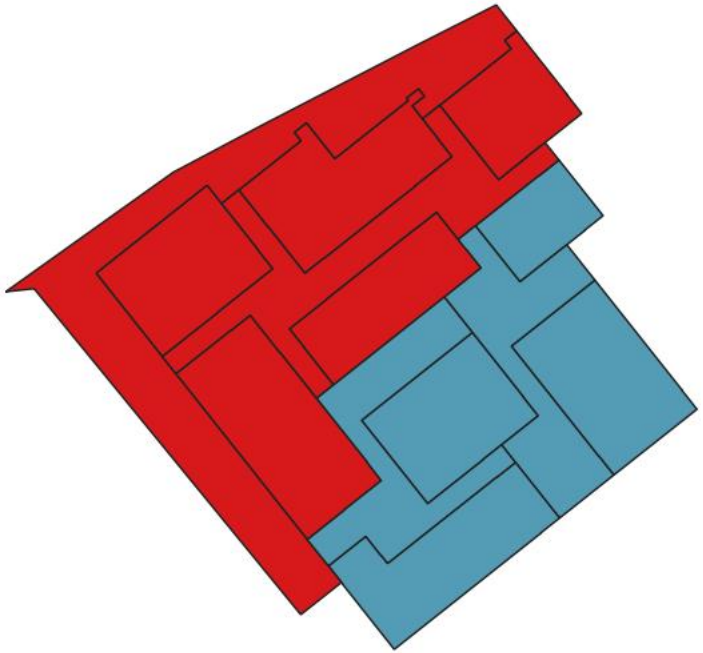
(c) Ownership Proportion Perceiving Security

(d) Overall Proportion with Legal Documentation

Figure 5.7.: Key SDG Report Maps for Regions 50001 and 50002

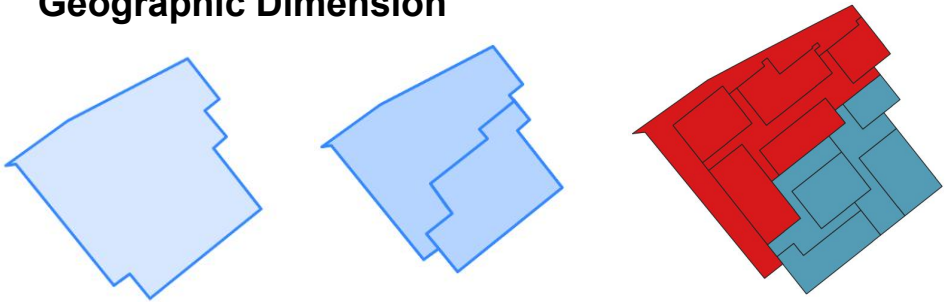
Testing

Test data set design



Test area(LA_SpatialUnit)

Geographic Dimension



Temporal Dimension

Year 1: System Initialization

- used as the baseline dataset

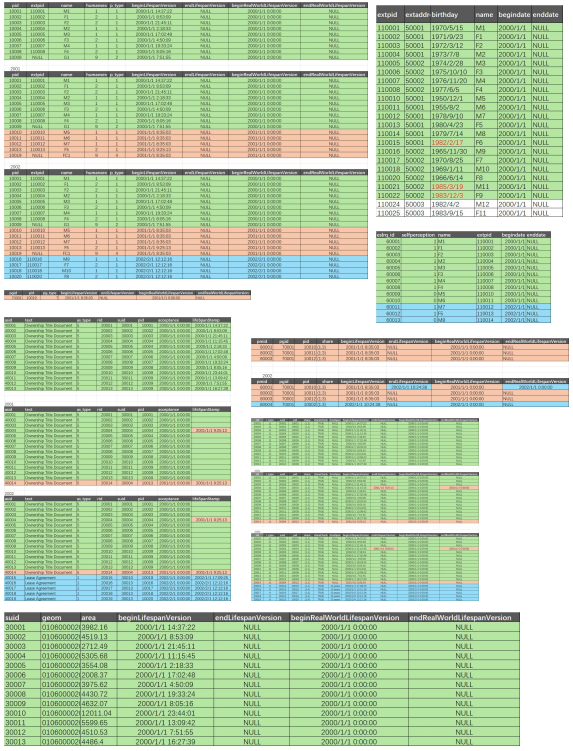
Year 2:

- Land Rights Transfer
- Formation of a Cooperative
- Some people become adults

Year 3:

- Lease and ownership exist together
- Party have RRR on parcel as a group
- External dataset update

Test data set design



manual calculation

	report_begindate timestamp with time zone	report_enddate timestamp with time zone	report_ geome	report_category text	report_subcategory text	report_totaladultscount integer	report_proportionperceivingsecurity double precision	report_proportionwithlegaldocumentation double precision
1	2000-01-01 00:00:00+01	2001-01-01 00:00:00+01	01030000...	gender	Male	17	0.23529411764705882	0.23529411764705882
2	2000-01-01 00:00:00+01	2001-01-01 00:00:00+01	01030000...	tenure_type	ownership	17	0.47058823529411764	0.47058823529411764
3	2000-01-01 00:00:00+01	2001-01-01 00:00:00+01	01030000...	gender	Female	17	0.23529411764705882	0.23529411764705882
4	2000-01-01 00:00:00+01	2001-01-01 00:00:00+01	01030000...	gender	doesNotApply	17	0	0
5	2000-01-01 00:00:00+01	2001-01-01 00:00:00+01	01030000...	total	[null]	17	0.47058823529411764	0.47058823529411764

	report_begindate timestamp with time zone	report_enddate timestamp with time zone	report_ geome	report_category text	report_subcategory text	report_totaladultscount integer	report_proportionperceivingsecurity double precision	report_proportionwithlegaldocumentation double precision
1	2001-01-01 00:00:00+01	2002-01-01 00:00:00+01	01030000...	gender	Male	18	0.2222222222222222	0.2222222222222222
2	2001-01-01 00:00:00+01	2002-01-01 00:00:00+01	01030000...	tenure_type	ownership	18	0.5	0.4444444444444444
3	2001-01-01 00:00:00+01	2002-01-01 00:00:00+01	01030000...	gender	Female	18	0.2777777777777778	0.2222222222222222
4	2001-01-01 00:00:00+01	2002-01-01 00:00:00+01	01030000...	gender	doesNotApply	18	0	0
5	2001-01-01 00:00:00+01	2002-01-01 00:00:00+01	01030000...	tenure_type	lease	18	0	0
6	2001-01-01 00:00:00+01	2002-01-01 00:00:00+01	01030000...	total	[null]	18	0.5	0.4444444444444444

	report_begindate timestamp with time zone	report_enddate timestamp with time zone	report_ geome	report_category text	report_subcategory text	report_totaladultscount integer	report_proportionperceivingsecurity double precision	report_proportionwithlegaldocumentation double precision
1	2002-01-01 00:00:00+01	2003-01-01 00:00:00+01	01030000...	gender	Male	19	0.21052631578947367	0.42105263157894735
2	2002-01-01 00:00:00+01	2003-01-01 00:00:00+01	01030000...	tenure_type	ownership	19	0.4736842105263158	0.42105263157894735
3	2002-01-01 00:00:00+01	2003-01-01 00:00:00+01	01030000...	gender	Female	19	0.2631578947368421	0.21052631578947367
4	2002-01-01 00:00:00+01	2003-01-01 00:00:00+01	01030000...	gender	doesNotApply	19	0	0
5	2002-01-01 00:00:00+01	2003-01-01 00:00:00+01	01030000...	tenure_type	lease	19	0	0.21052631578947367
6	2002-01-01 00:00:00+01	2003-01-01 00:00:00+01	01030000...	total	[null]	19	0.47368421052631576	0.631578947368421

automated calculation

Validation of constraints

Use of invalid data to test whether the system can accurately recognise and report errors

Example: check_version_lifespan_continuity

```
UPDATE LA_Right
SET
    endLifespanVersion = '2001-01-01 08:35:03',
    endRealWorldLifespanVersion = '2001-01-01 00:00:00'
WHERE
    rID = 20004;
```

```
INSERT INTO LA_Right (rID, r_type, suID, pID, share, shareCheck, timeSpec, beginLifespan
Version, endLifespanVersion, beginRealWorldLifespanVersion, endRealWorldLifespanVersion)
VALUES
(20014, 11, 30004, 10013, '(1,1)', TRUE, NULL, '2001-01-02 08:35:03', NULL, '2001-01-01
00:00:00', NULL);
```

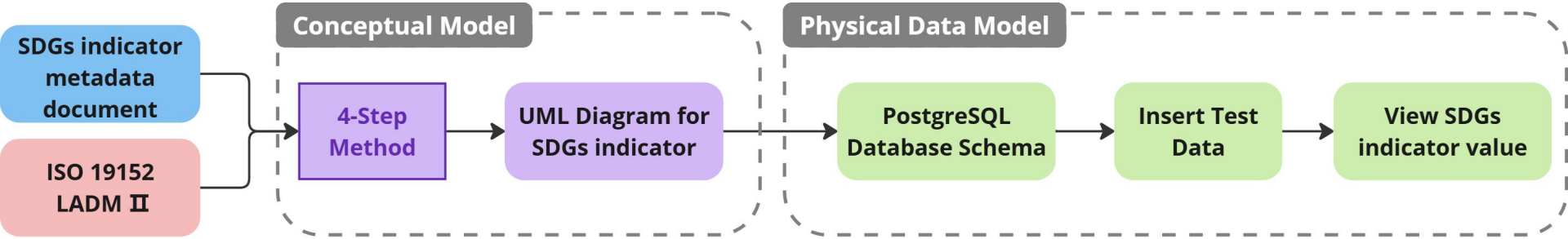
Data Output | Messages | Notifications

```
ERROR:  Error occurred in check_version_lifespan_continuity: Lifespan continuity error in table la_right for suid 30004: previous
endLifespanVersion 2001-01-01 08:35:03+01 does not match new beginLifespanVersion 2001-01-02 08:35:03+01
CONTEXT:  在RAISE的第45行的PL/pgSQL函数check_version_lifespan_continuity()
```

Conclusion

Answers to research questions

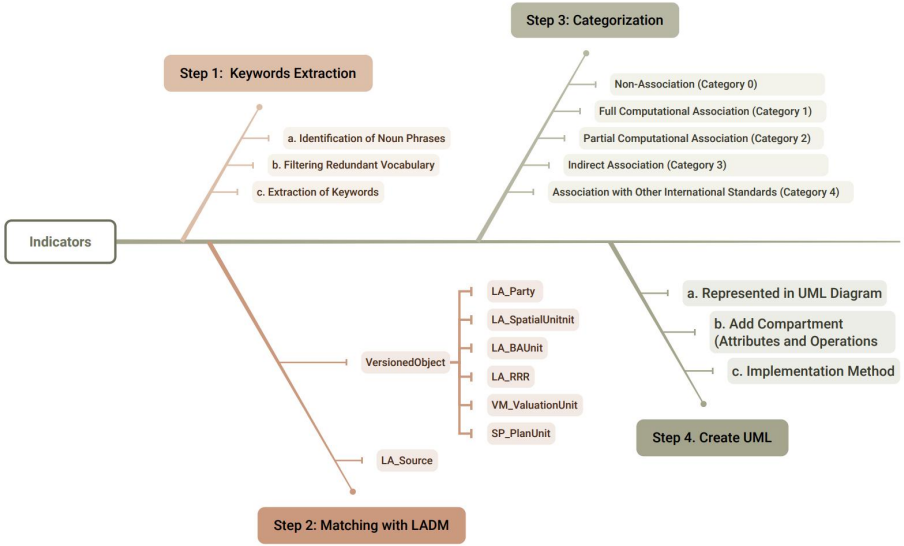
How can the ISO 19152 Land Administration Domain Model (LADM) be implemented to formalize and standardize land-related SDG indicators?



1. ***Linking LADM and SDGs Using the Four-Step Method***
2. ***Transition from Conceptual to Physical Model***

Answers to research questions

How can the conceptual model for SDG 1.4.2 be developed based on its metadata?



- adding necessary attributes
- supporting SDG 1.4.2 indicator calculations
- reducing the reliance on manual data collection
- ensuring consistency

Answers to research questions

How can the conceptual model for SDG 1.4.2 be effectively translated into a physical database implementation?

Physical Model Requirements

- **Data Consistency**
- **Standardization**
- **Scalability**
- **Operability**

Model Transformation Strategy

- **Class-to-Table Mapping:**
  Translates LADM classes (e.g., LA Party, LA SpatialUnit) into database tables.Maintains integrity of relationships using foreign key constraints.
- **Attribute-to-Column Mapping:**
  Maps attributes to database fields with standard data types; custom data types for specialized needs.
- **Normalization:**
  Reduces redundancy and ensures data integrity through database normalization.
- **Hierarchical Mapping:**
  Implements class hierarchies (e.g., versioned objects) using hierarchical table structures.

Answers to research questions

What added value does this approach bring to the overall monitoring and evaluation of SDG indicators?

- **Reduces Manual Work:**
Minimizes reliance on manual data collection and calculations by integrating cadastral systems.

- **Enhances Accuracy:**
Formalizes and automates calculations, reducing errors associated with manual methods.

- **Consistent Reporting:**
Supports standardized reporting across time periods, regions, and governance levels.

- **Timely Data for Policymakers:**
Provides reliable data for assessing trends and evaluating policy impacts.

- **Scalable & Adaptable:**
Applicable across diverse legal frameworks, supporting SDG monitoring in various land administration contexts.

Contributions

- **Standardized Solution for SDG Calculation**:
  - Utilizes ISO 19152 LADM for systematic, standardized calculation of SDG indicators in land administration.
  - Promotes global standardization and consistency.

- **Automated System for Dynamic Data Processing**:
  - Efficiently processes land rights changes, population dynamics, and administrative updates.
  - Enhances accuracy and efficiency in monitoring SDG 1.4.2.

- **Foundation for Future Research and Applications**:
  - Validates feasibility with simulated data, setting groundwork for real-world applications.
  - Provides a reference for expanding to other SDG indicators and for policy development.

Limitations

- **Use of Synthetic Data:**

Testing relied on simulated data, which may not capture the full complexity of real-world land administration. Performance may vary in practical applications.

- **Focus on a Single SDG Indicator (SDG 1.4.2):**

The study focused solely on tenure security; other SDG indicators were not explored, limiting the assessment of the LADM framework's broader applicability.

- **Limited Regional and Legal Context Analysis:**

The system's adaptability across diverse legal and regional land administration frameworks was not evaluated, affecting generalizability.

- **Concurrency and Multi-User Access:**

The study did not address multi-user access, meaning data consistency and integrity issues could arise in real-world, concurrent-use environments.

Future work

- **Application to Other SDG Indicators:**

Extend the system to support additional land-related SDGs, such as:

SDG 11: Sustainable Cities and Communities

SDG 15: Life on Land

Adapt the current model for a more comprehensive sustainable land management solution.

- **Integration of Real-World Data:**

Validate the system with real-world land administration data from various regions.

Collaborate with governments and organizations to test in diverse legal and administrative contexts.

- **Enhancement of User Interface and Reporting:**

Develop a more user-friendly interface for non-technical users.

Expand reporting capabilities to support diverse formats and tailored data visualizations.

- **Further Performance Optimization:**

Continue optimizing for larger datasets and complex queries.

Assess system performance in high-concurrency, multi-user environments to ensure stability.

Formalizing land indicators for SDGs: Implementation and evaluation using international standards

Thanks !

Mengying Chen

TU Delft