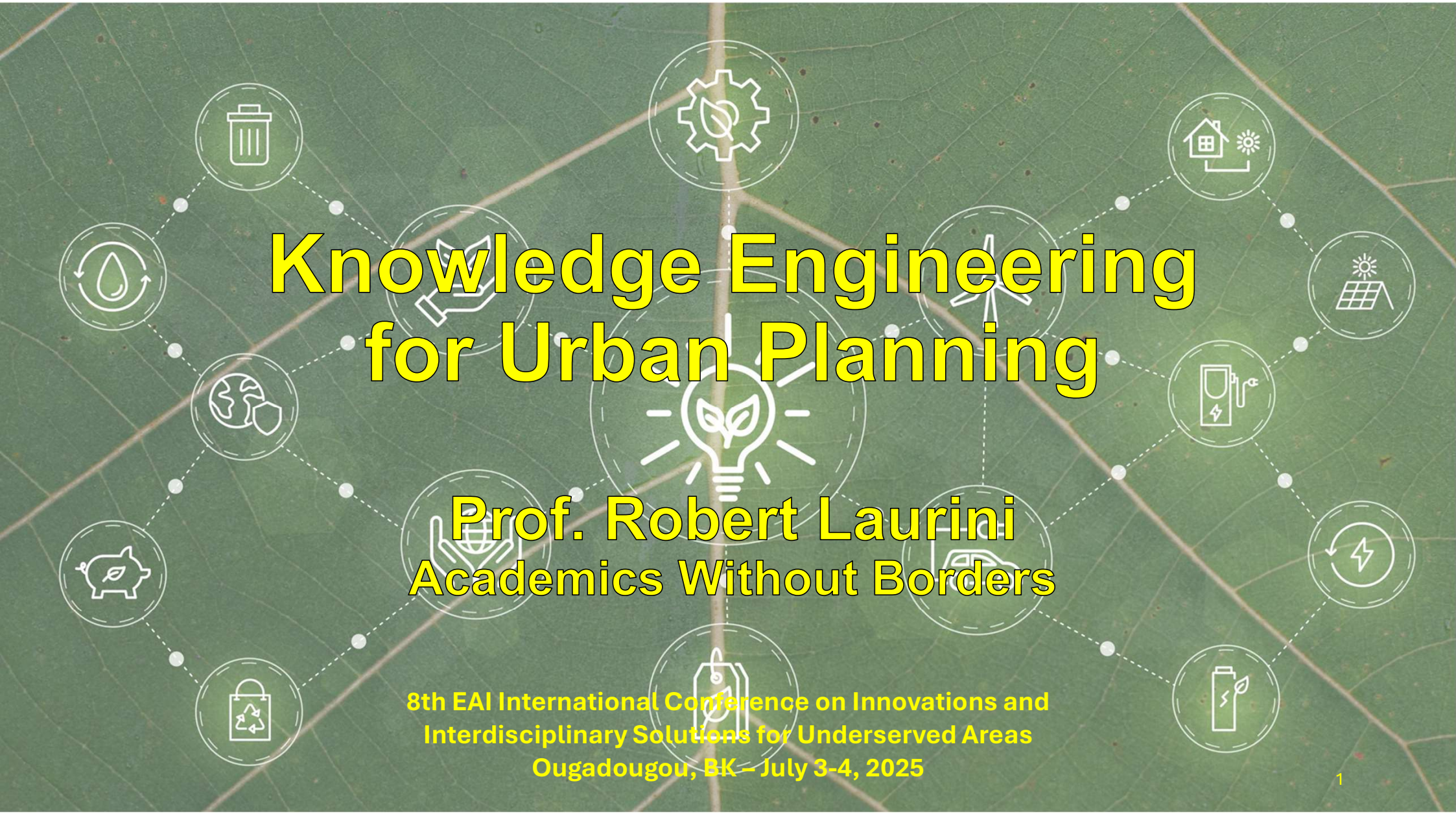


Knowledge Engineering for Urban Planning

Prof. Robert Laurini

Academics Without Borders

8th EAI International Conference on Innovations and Interdisciplinary Solutions for Underserved Areas

Ougadougou, BK – July 3-4, 2025

Dr. Robert Laurini

- Doctorates in computing (1973 and 1980), University of Lyon, France
- Distinguished professor at INSA-Lyon
- Extra positions
  - University of Cambridge, UK; University of Maryland CP, USA; University of Venice, Italy.
- Research specialty:
  - computing (AI) for urban planning
  - 10+ books, 250+ papers
  - (co)-supervisor of 44 PhD; Member of PhD committees in 19 countries
- Now,
  - Professor Emeritus at KSI,
  - IARIA fellow
  - Honorary president of « Urban Data Management Society »
  - Honorary president of « USF/Academics Without Frontiers »
  - Volunteer in an association for helping international students in Lyon

Knowledge Engineering for Urban Planning

1 – Introduction

Generalities, Objectives,

Smart cities, City Digital Twins

2 – Structure of a UKB

Geographic objects, relations, ontologies, rules, gazetteers

Multimedia documents, graphs

3 – Modeling Urban knowledge

Urban objects, rules and feedforward rules

Projects and knowledge

4 – Conclusions

1 – Introduction

Characteristics of urban planning

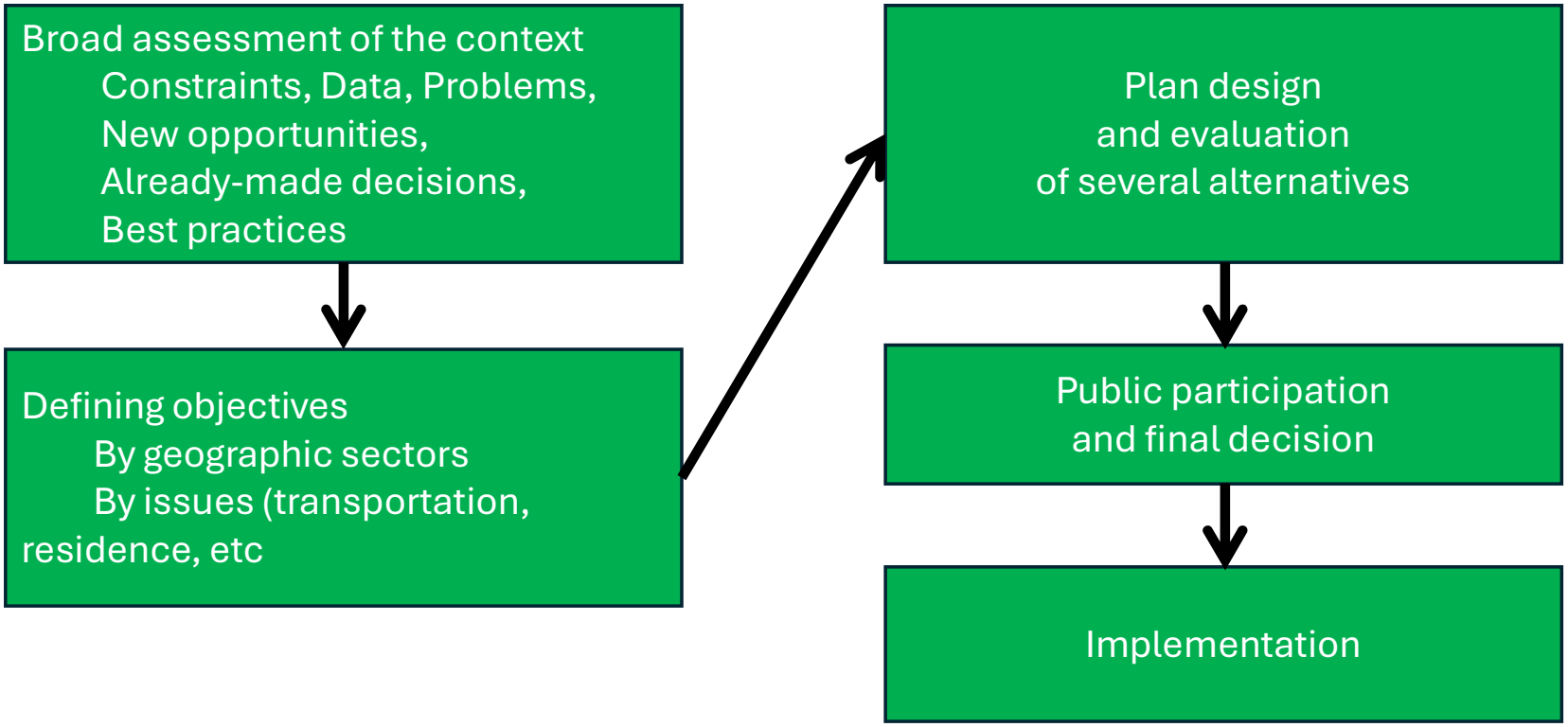
Objectives of this talk

Smart cities

City Digital Twins

Knowledge engineering

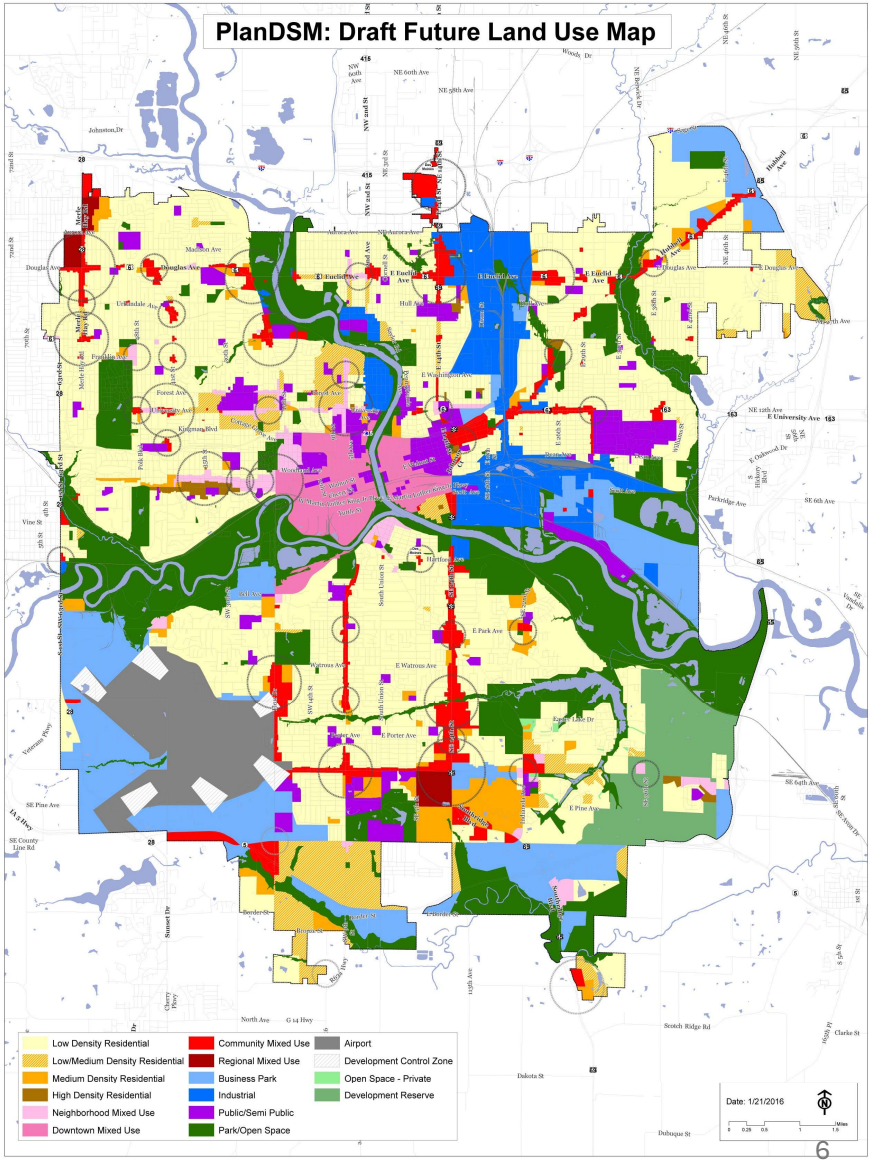
Planning as a Groupware Activity



Own elaboration

Example of Land Use Plan

https://plandsm.dsm.city/future-land-use-map-designations-draft



Planning as a feedforward activity

- Feedforward refers to using predictions, projections, and future-oriented data to guide present actions. In contrast to feedback, which reacts to past outcomes, feedforward is about shaping the future by anticipating it.
- Urban planners use this principle when they design cities or neighborhoods not just for current needs, but for how populations, technologies, climates, and economies are likely to evolve.
- **Knowledge and feedforward**

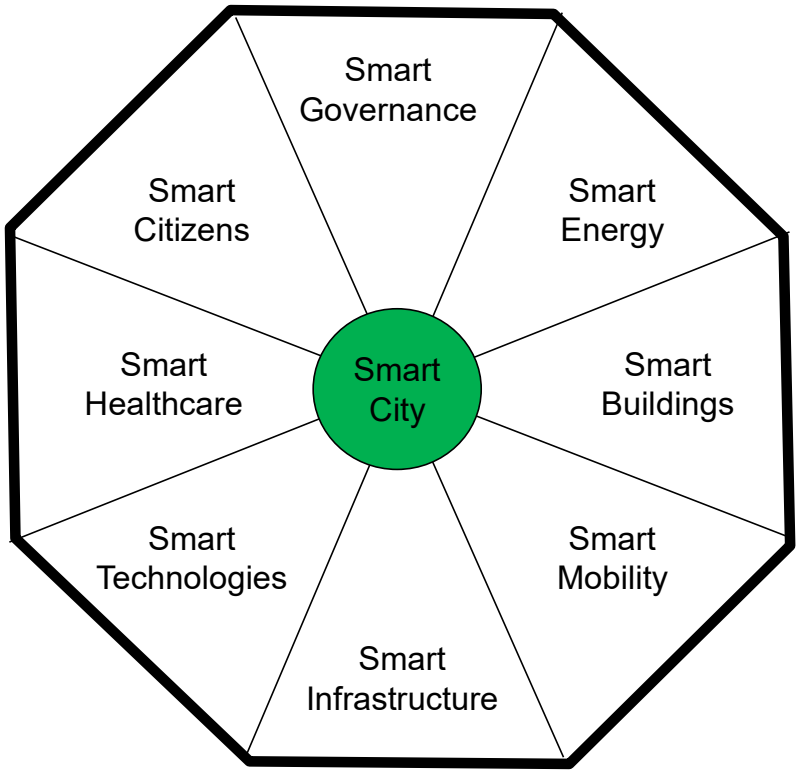
About Knowledge

- Knowledge Society
- Basis for governance
  - Smart Cities
  - Territorial Intelligence
- Difference between data, information and knowledge
- Neighboring concepts
  - Smart People
  - Smart Governance

Several Definitions of « Smart Cities »

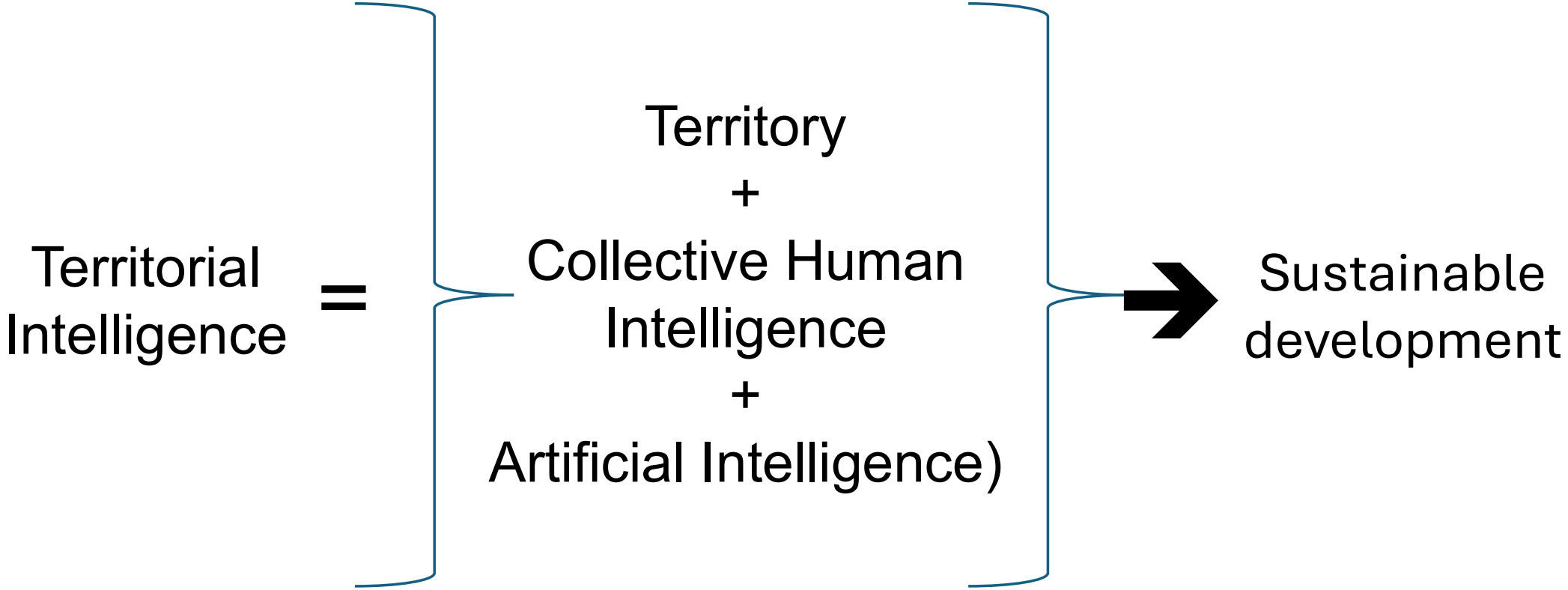
- Common features
  - Importance of technologies
  - Sustainable development
  - Public participation

Mathew's Diamond for Smart Cities



Own elaboration with modification from J. Mathew (2013) "City as a Customer". http://www.frost.com/c/10046/blog/blog-display.do?id=2377335. Visited March 4, 2017.

Definition of Territorial Intelligence



Definition of Geographic Knowledge

- Geographic knowledge corresponds to information potentially useful to
  - explain
  - manage
  - monitor
  - and plan a territory.

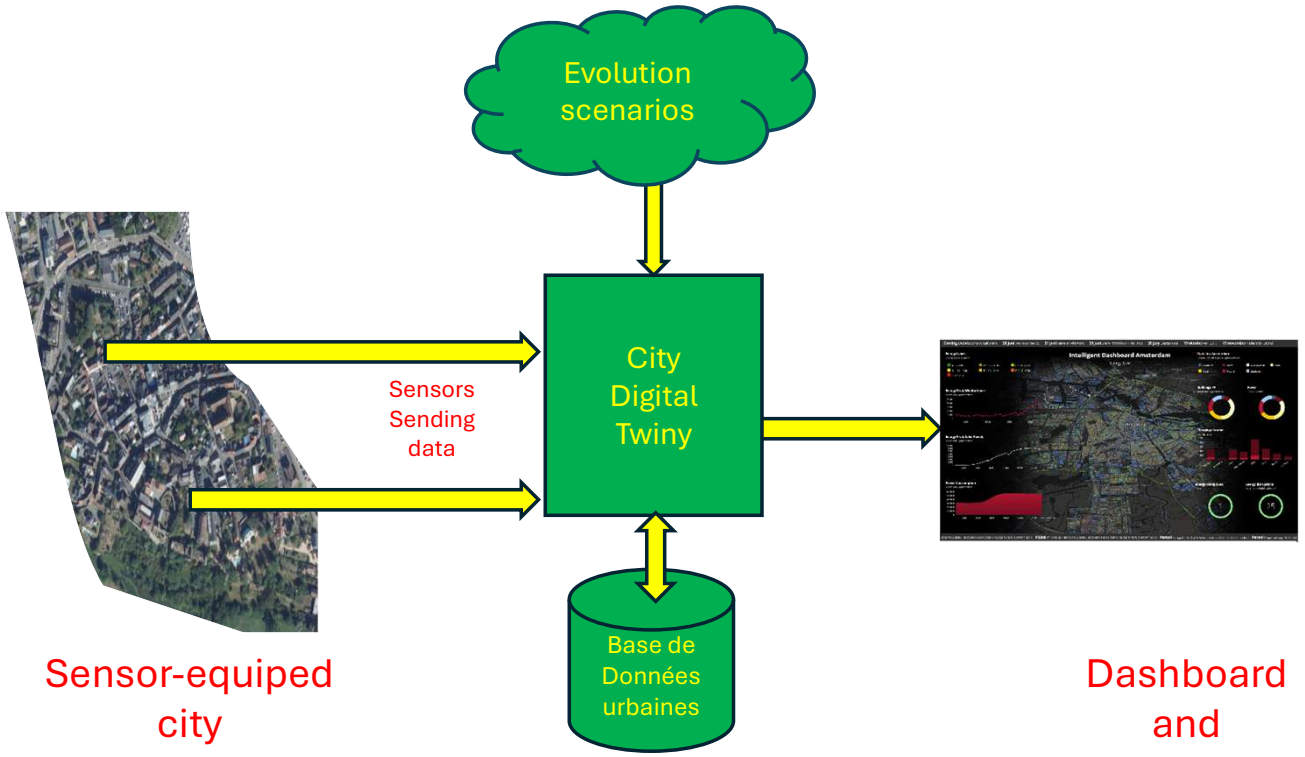
Geographic Rules

- RULES as first-class citizens in IT
  - IF-THEN-Fact
  - IF-THEN-Actions
- Business intelligence (1st order logic)

- Territorial Intelligence
  - Rewrite geoprocessing based on rules
  - Renovate concepts
  - Feedforward Knowledge

- New types for geographic rules

Principle of City Digital Twin Systems



Own elaboration

2 – Structure of an Urban Knowledge Base

- Objects
  - geographic shape
  - coordinates
- Relations
  - topology
- Complex structures
- Ontologies
- Rules

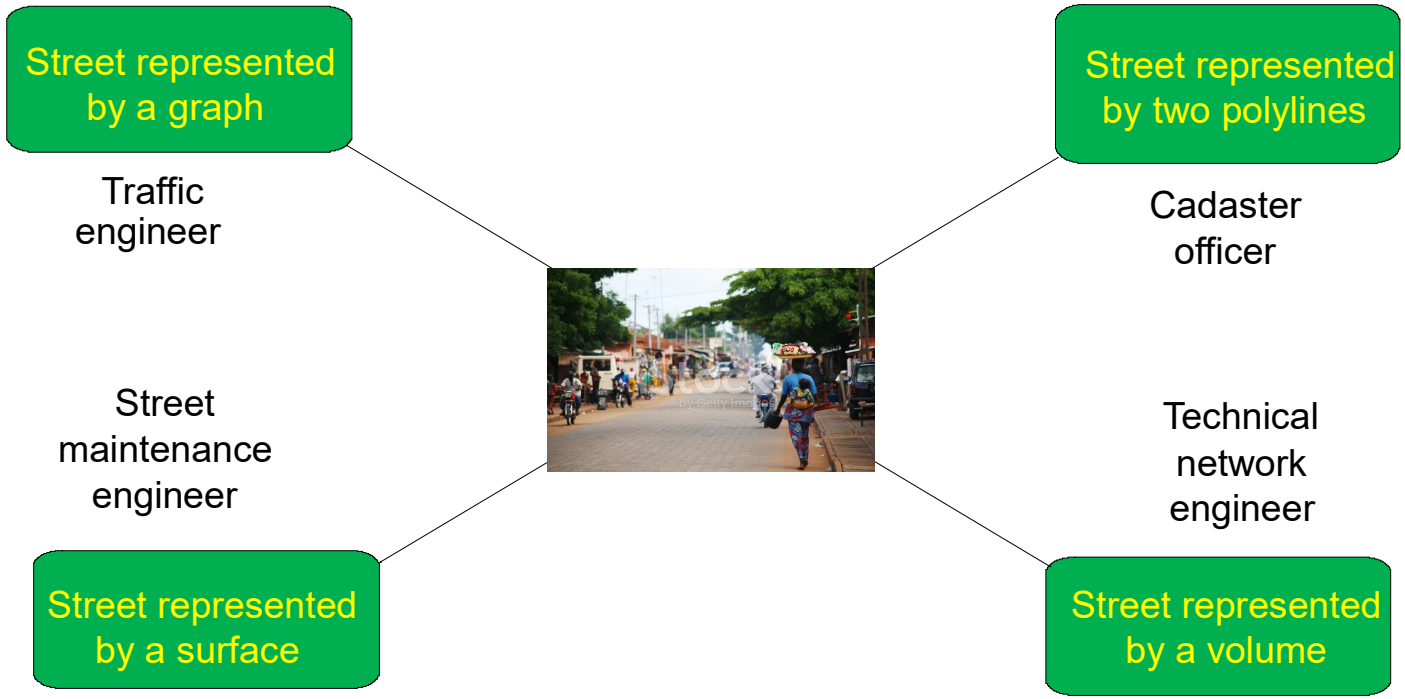
- Gazetteers
  - sometimes multilingual
- Multimedia documents
  - aerial photos
  - satellites images
- Knowledge graphs

➔ Reasoning

Specific Characteristics of Urban Objects

- Space 2D, 3D, 3D+T ➔ coordinates
- Computational geometry, topology
- Cartography and geovisualization
- Spatial analysis
- Features and geographic objects
  - Measurement accuracy
  - Multiple representations
  - Acquisition devices

Example of a Street



Own elaboration

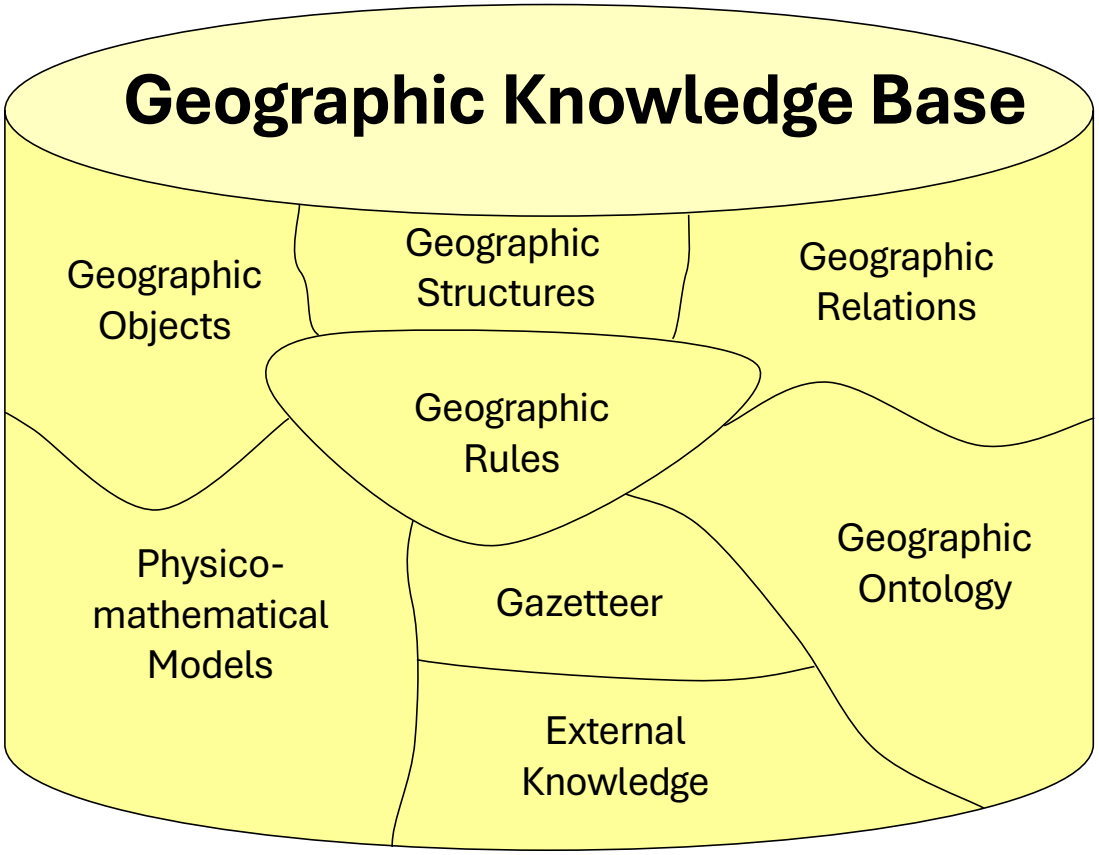
Geographic Projects

- Where to put a new airport, a new hospital, a new stadium, etc.?
- Is this new construction project compliant with planning rules?
- What is the best mode or the best way to get from *A* to *B*?
- How to organize a plan for green spaces in a city?
- How to reorganize common transportation?
- etc.

Repository for Multimedia Documents

- Text (urban planning laws, legal written statements, other reports, etc.)
  - Metadata
  - Key-words
- Maps
  - Working maps
  - Legal maps
- Images
  - Satellite images
  - Aerial photos

Structure of a Geographic Knowledge Base

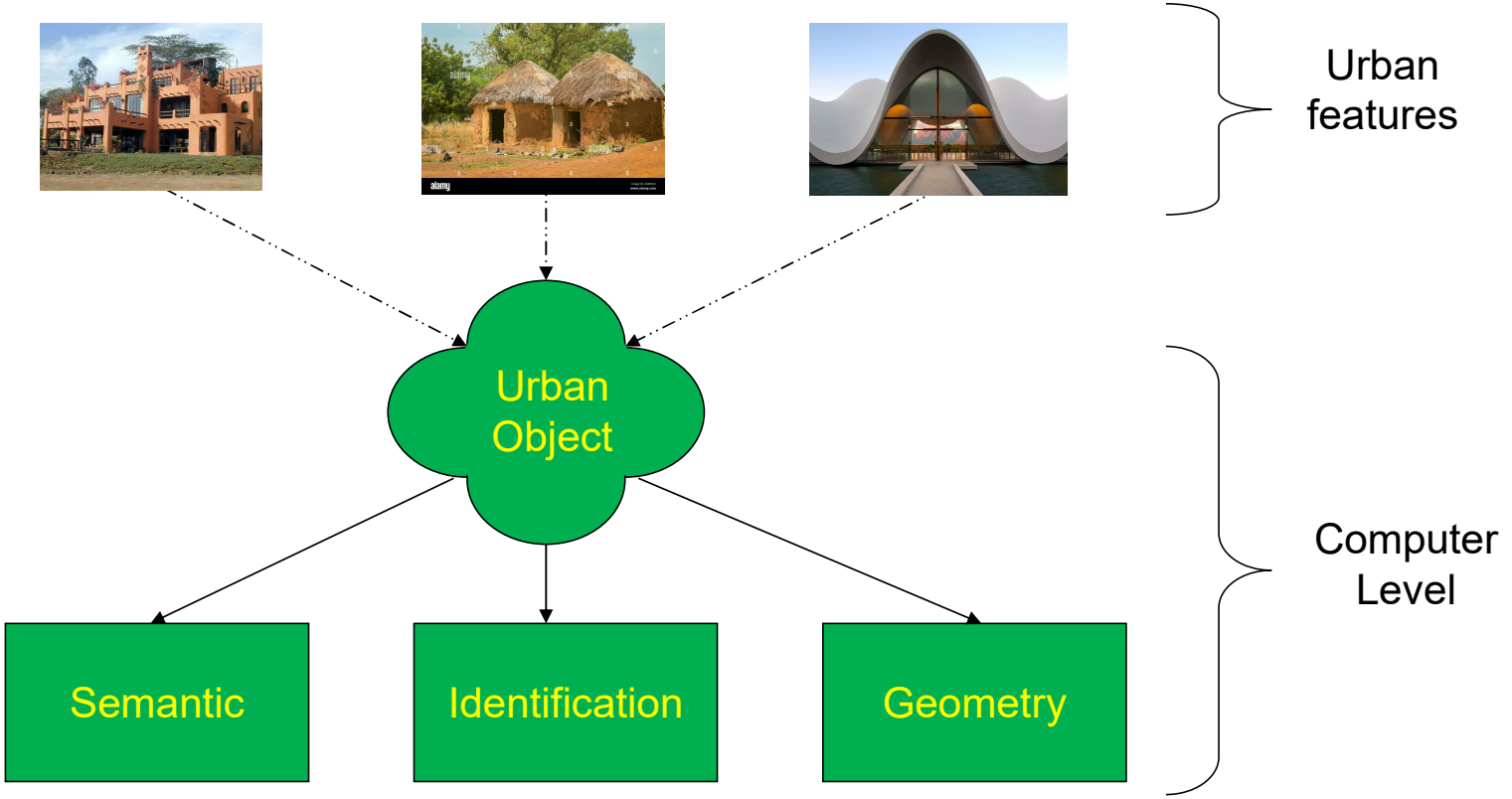


Own elaboration

Urban Objects

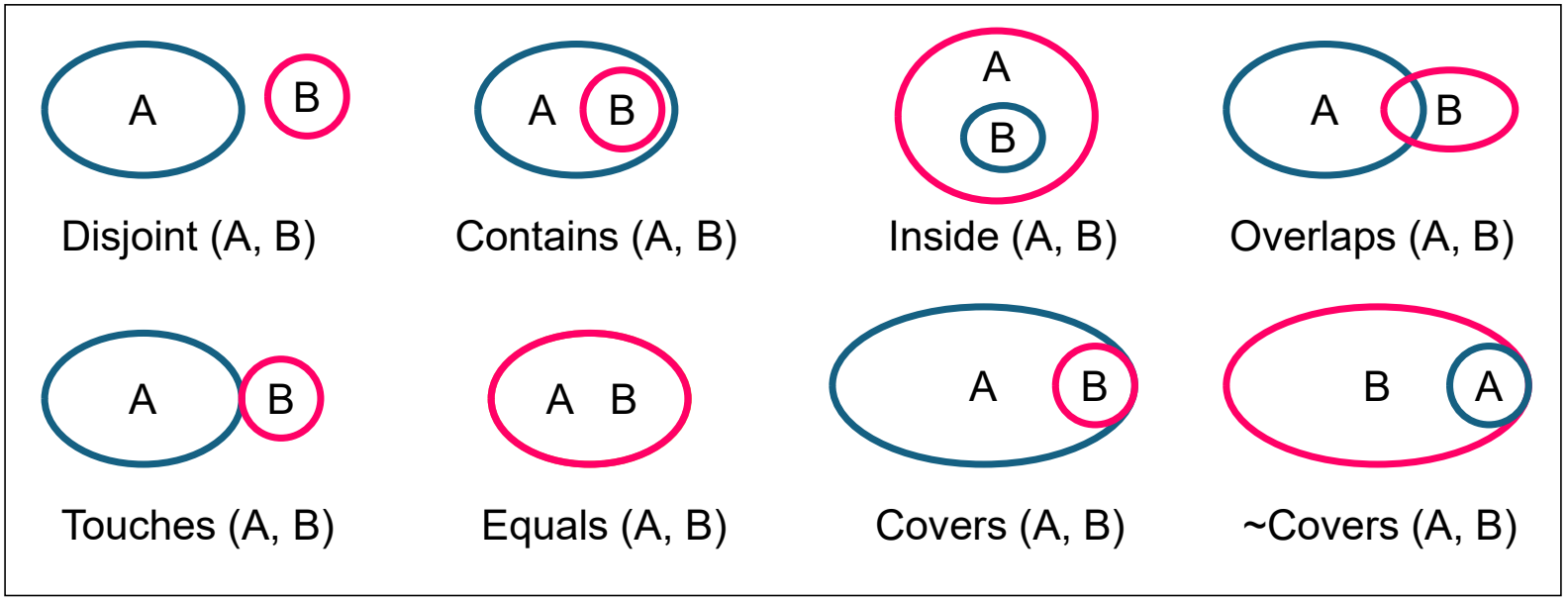
- Administrative divisions, buildings, streets, etc.
  - Manmade objects (crisp boundaries)
  - Euclidean Geometry
- Natural objects (mountains, rivers, etc.)
  - With fuzzy boundaries
  - Fractal geometry
- Continuous fields (temperature, pollution, etc.)

Characteristics of Geo Objects



Own elaboration

Egenhofer Topological Relations

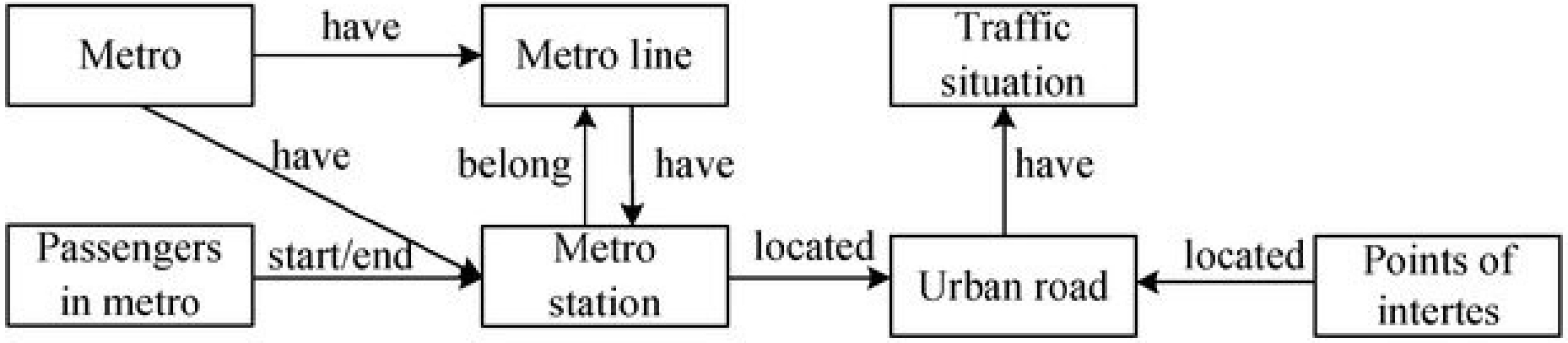


Own elaboration

Urban Ontologies

- Organizations of geo features
- In addition to relations “*is_a*”, “*has_a*”, “*whole_part*”
  - Necessity of spatial relations
- The Towntology project

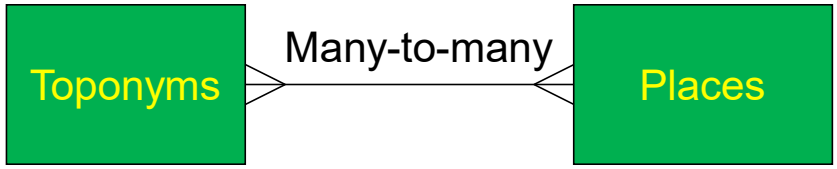
Example of an Urban Ontology



https://www.mdpi.com/2071-1050/13/6/3191

Gazetteers

- Placenames / toponyms
- Can change over time
- Multiple translations
- Different places can have same name

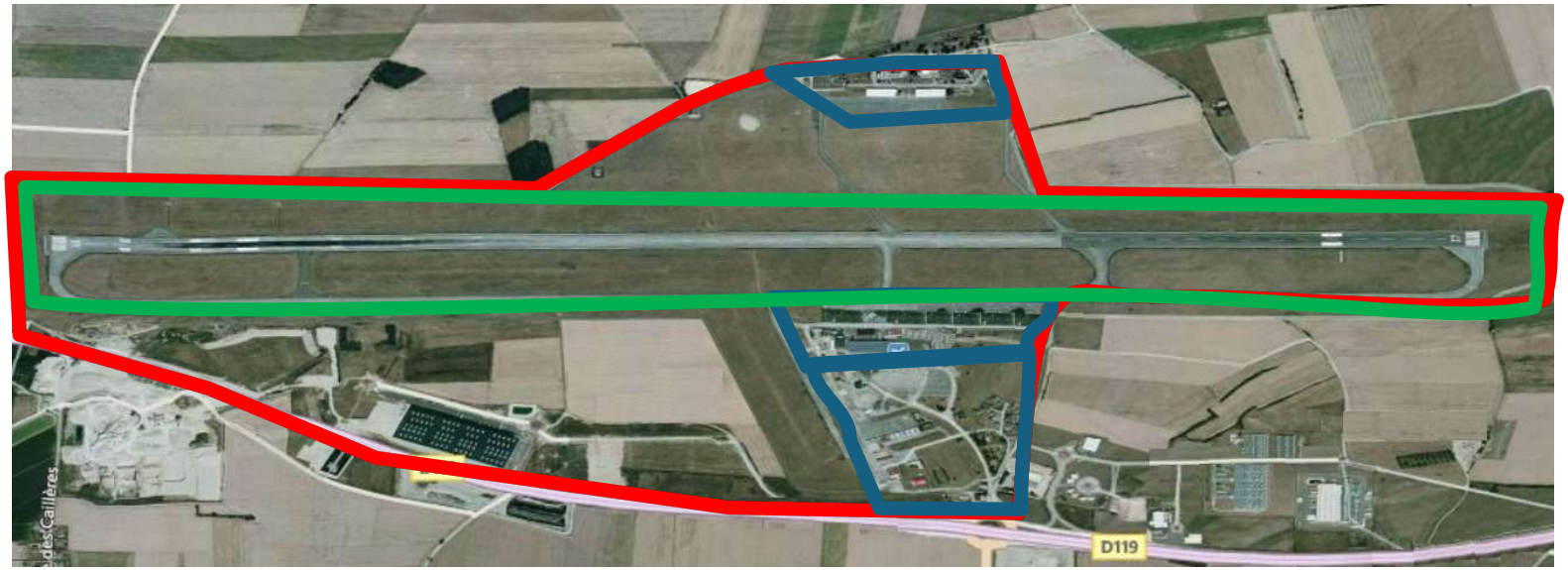


- Not only city's names, but also streets and landmarks

Own elaboration

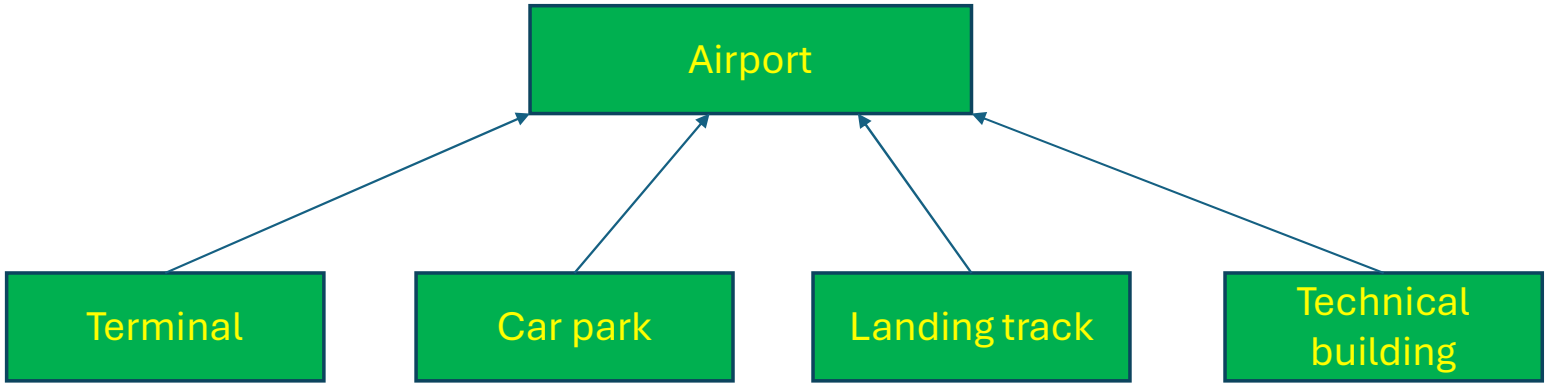
Ontology-driven Aggregation

- Ex: a small airport
  - Terminal, car park, landing track, technical building



Own elaboration

Fragment of the Ontology

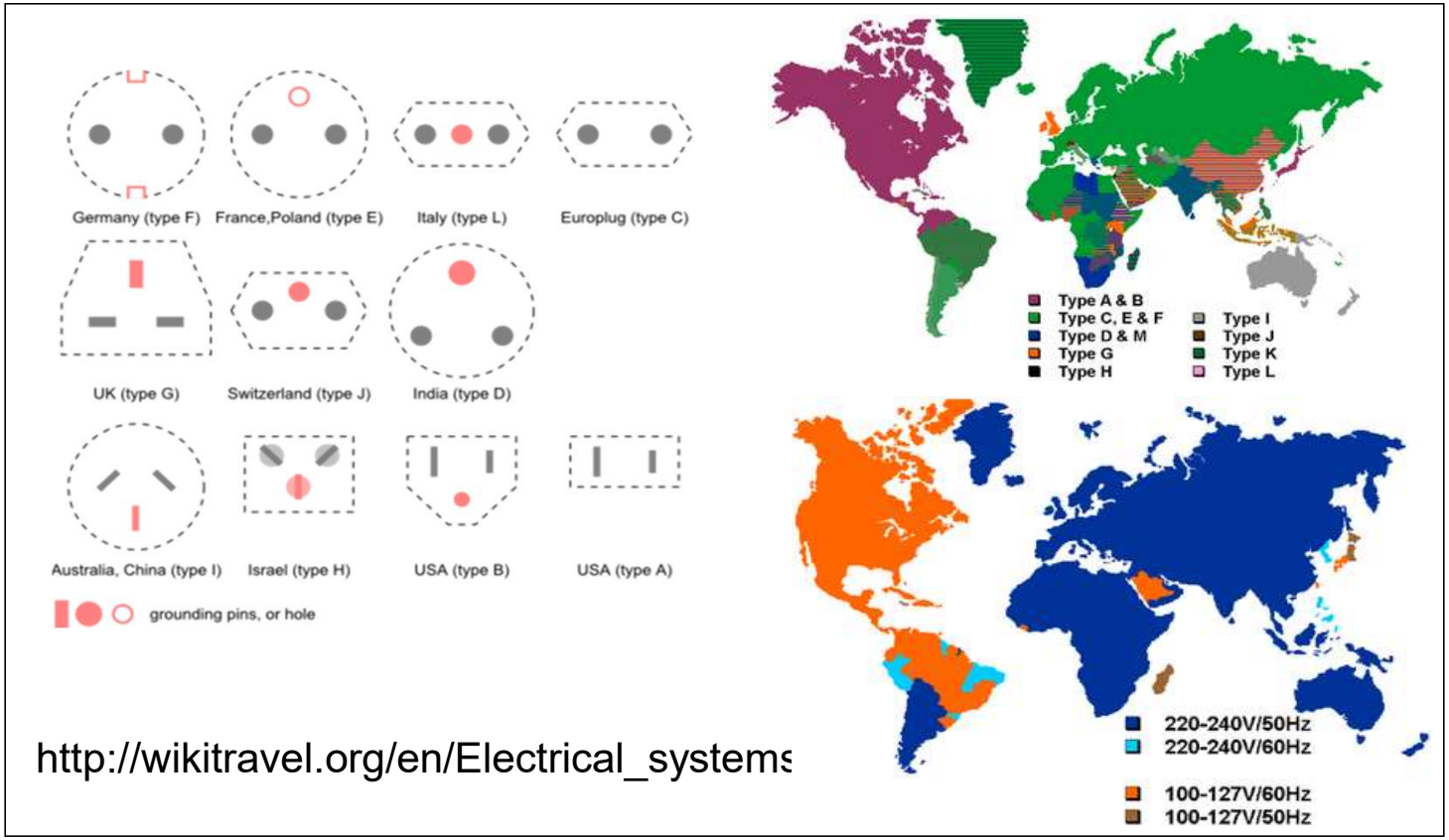


Geographic ontology: *has_a* with components with geometric type;

$has\_a \equiv contains \vee covers$

Own elaboration

Example of multimedia located rules



http://wikitravel.org/en/Electrical_systems

Geographic and Urban Rules

- in the United Kingdom, we drive on the left;
- in Canada, the majority of the population lives along the border with the United States;
- each capital city has an international airport nearby;
- between the two capital cities, in general, there are direct flights;
- in the Northern Hemisphere, the more you are going to the north, the colder (but locally this is not always true).

Other Examples of Geographic Rules

- the more you climb a mountain, the colder
- heavy rain upstream, downstream flooding
- mosques are oriented towards Mecca
- if a zone is a swamp, it is necessary to prohibit construction
- if there is unemployment, the creation of companies or industrial areas must be encouraged

Different Types of Spatial Rules

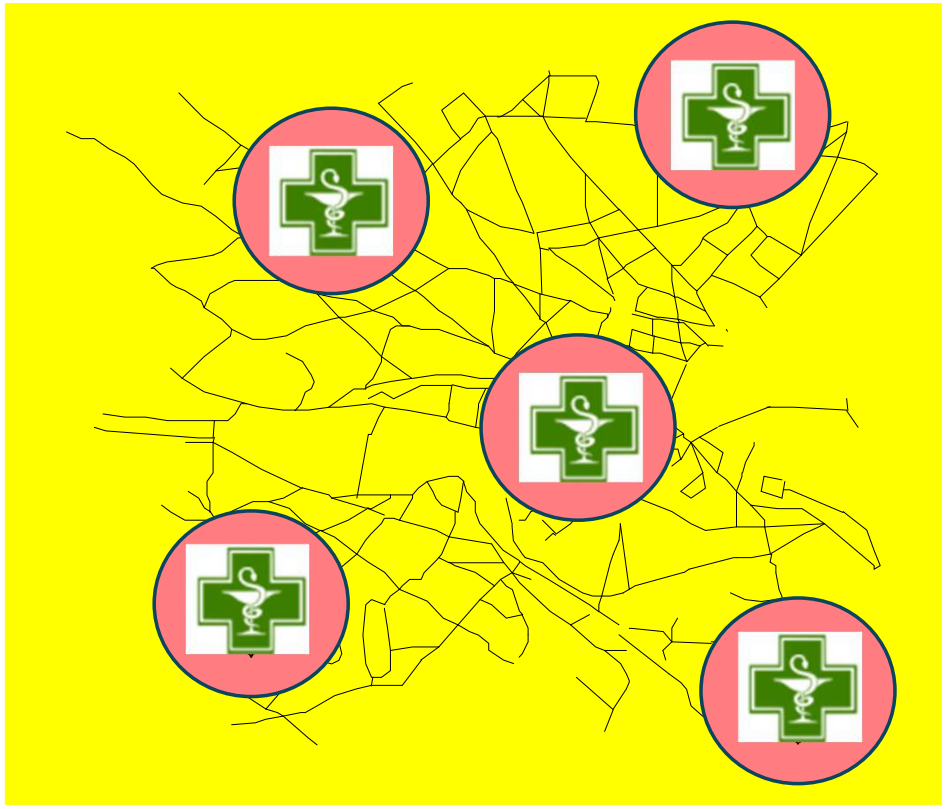
- Applicative rules once planning decision are made
  - Urban and Environmental Planning
  - Residential activities
  - Economic development
  - Commerce
  - Transportation
  - Tourism,
  - etc

Other Ancillary Spatial Rules

- Generic rules (to ensure reasoning robustness)
  - Quality control
  - Independence from data acquisition devices
  - Taking human languages and reasoning into account

- Cartographic rules
  - Variation according scales (mutation of shapes, relations, etc.)
  - Generalization (simplification) of shapes
  - Cartographic disappearance of smaller objects (< 0.1 mm)

Pharmacy Location in France



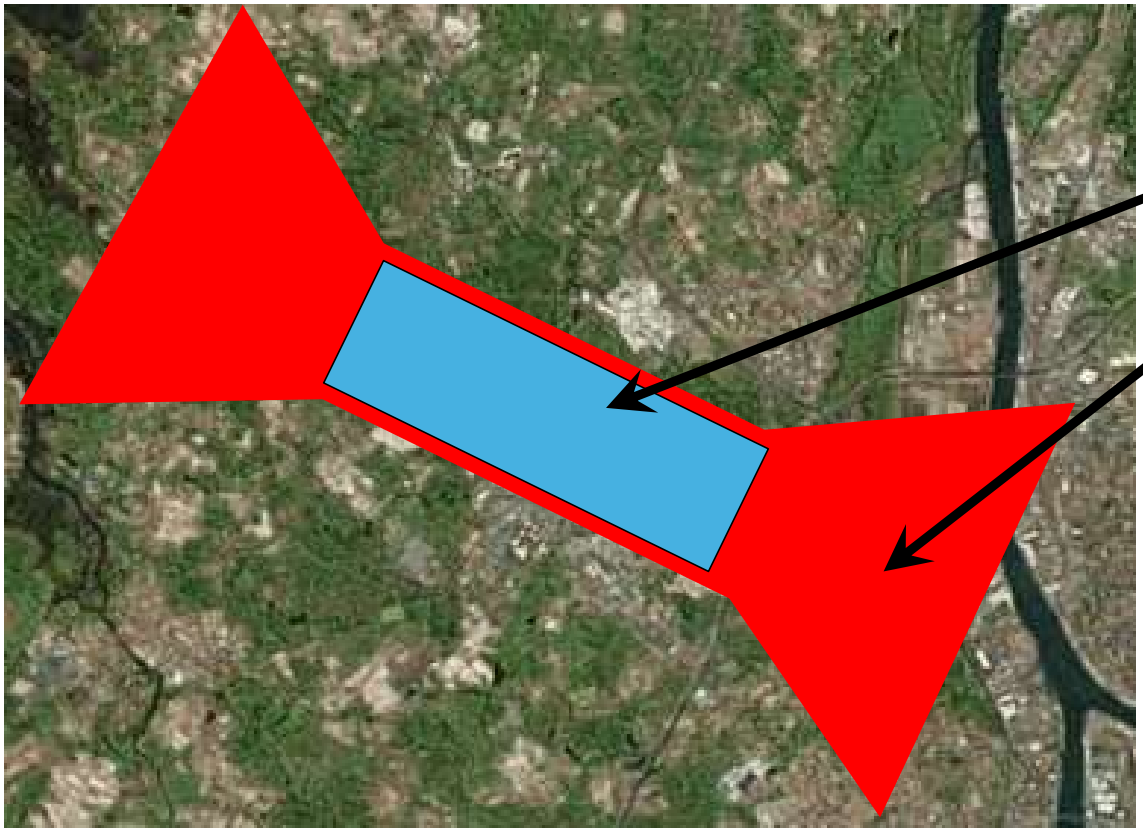
Pharmacy

Where it is forbidden to open a new pharmacy

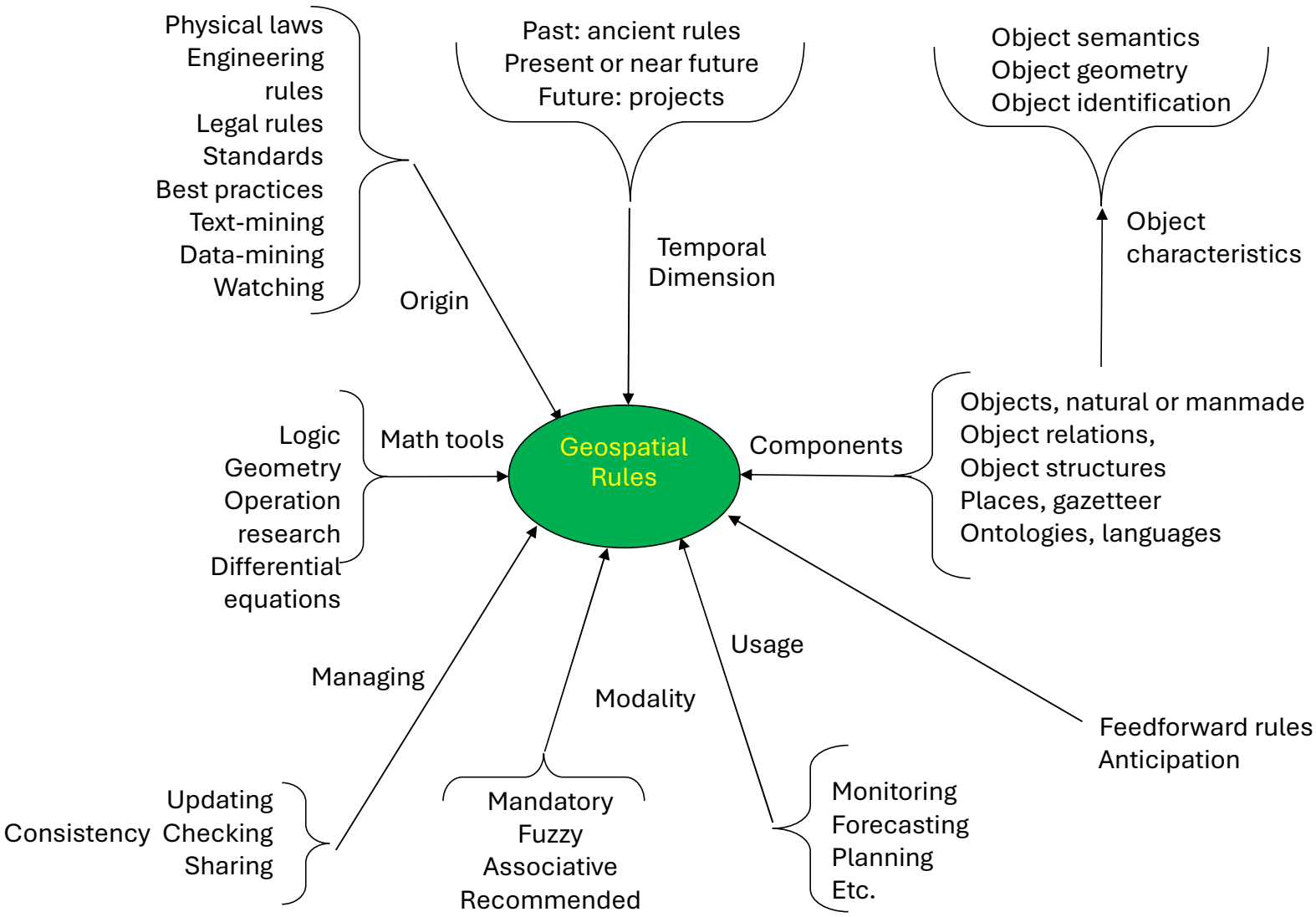
Where it is authorized

Own elaboration

At the Vicinity of an Airport



Own elaboration

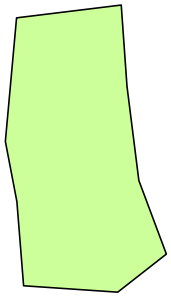
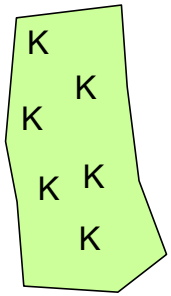
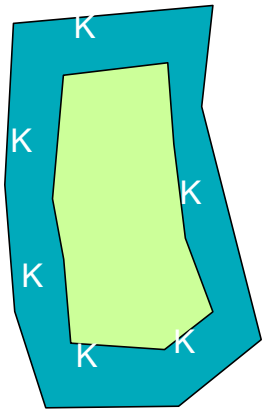
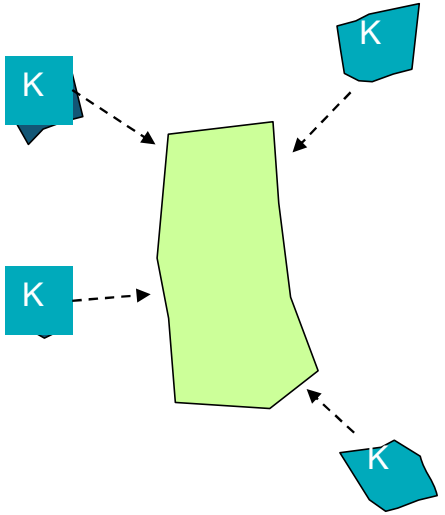


Own elaboration

External Knowledge

- In GIS, usually coverage = spatial extension of the jurisdiction of the owning entity
- Importance of the vicinity (sometimes outside objects have more importance than some inside objects)
- Two kinds of external knowledge
  - At the vicinity of the jurisdiction
  - Technology watching
- “intra muros” and “extra muros” knowledge

External Knowledge

			
A City	Internal Knowledge	External Neighboring Knowledge	External Outside Knowledge

Own elaboration

3 – Modeling Urban Knowledge

Rule modeling

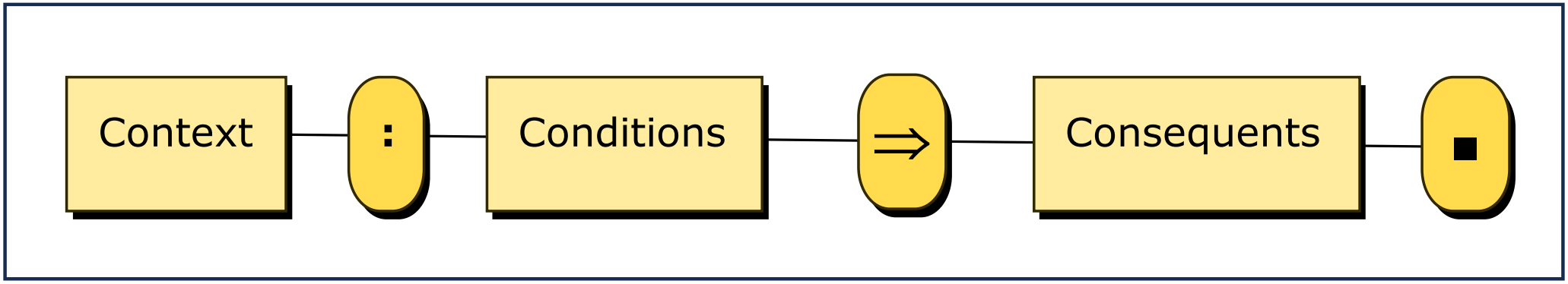
Knowledge Graph

Project repository

Geovisualization

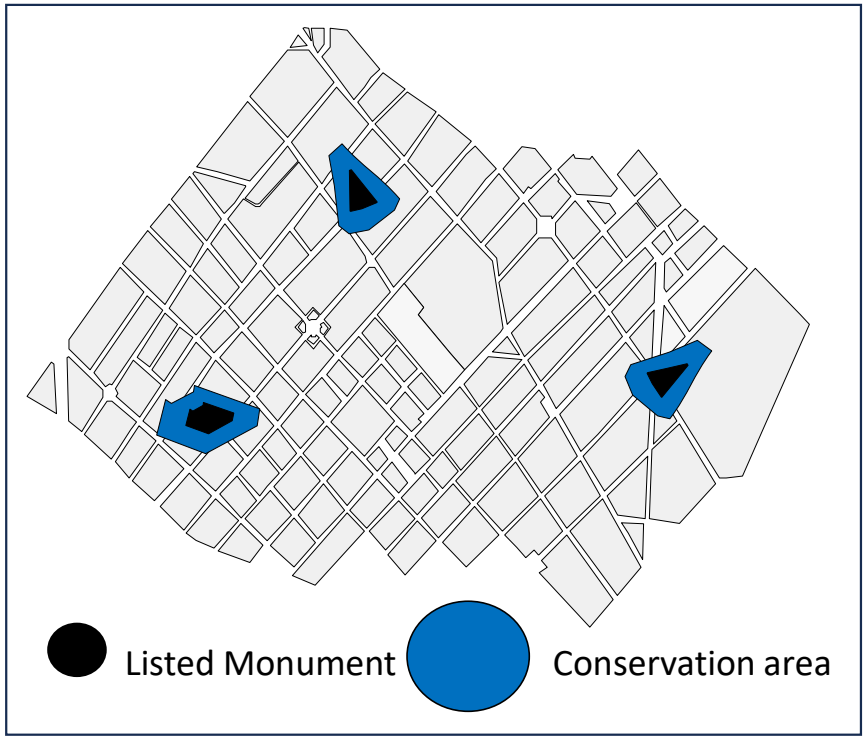
Grammar for Spatial Rule encoding

- Context (definitions of objects, relationships between them)
- Boolean conditions (including geometry and topology
- Consequence



Own elaboration

Example for Listed Monuments



Own elaboration

$\forall\ T \in Earth, \forall\ B \in PROJECT, \exists\ M \in Geo\text{-}Objects,$

Type (B) = “Building”,

Type (M) = “Listed_Monument”,

$\vDash$ *Inside* (*Geom* (B), T), *Inside* (*Geom* (M), T)

:

Disjoint (Geom(B), *Union* (*Buffer* (*Geom* (M), 100)))

$\Rightarrow$

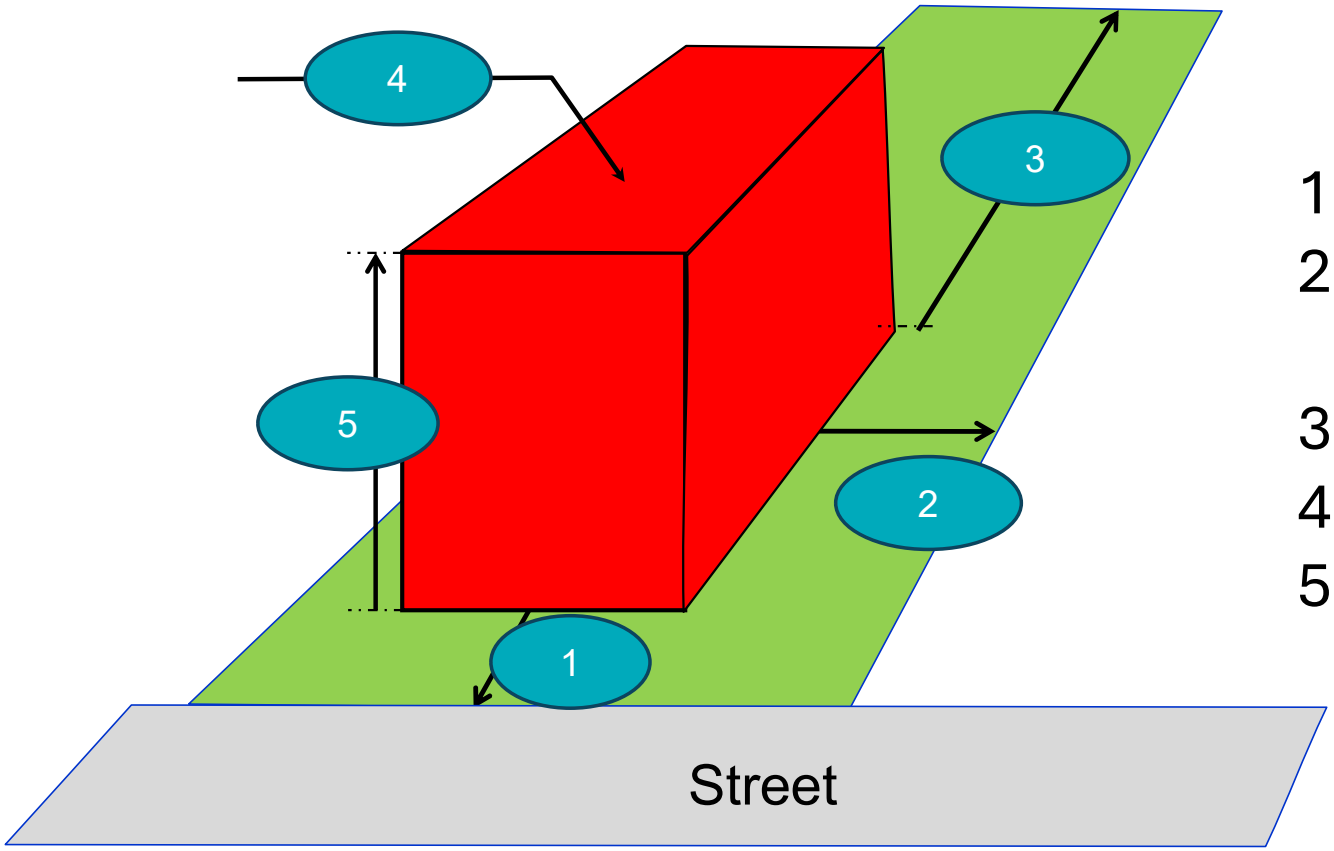
State (B) = “LM_Approved”

Context

Boolean Conditions

Consequence

Urban Planning Rules Concerning New Buildings



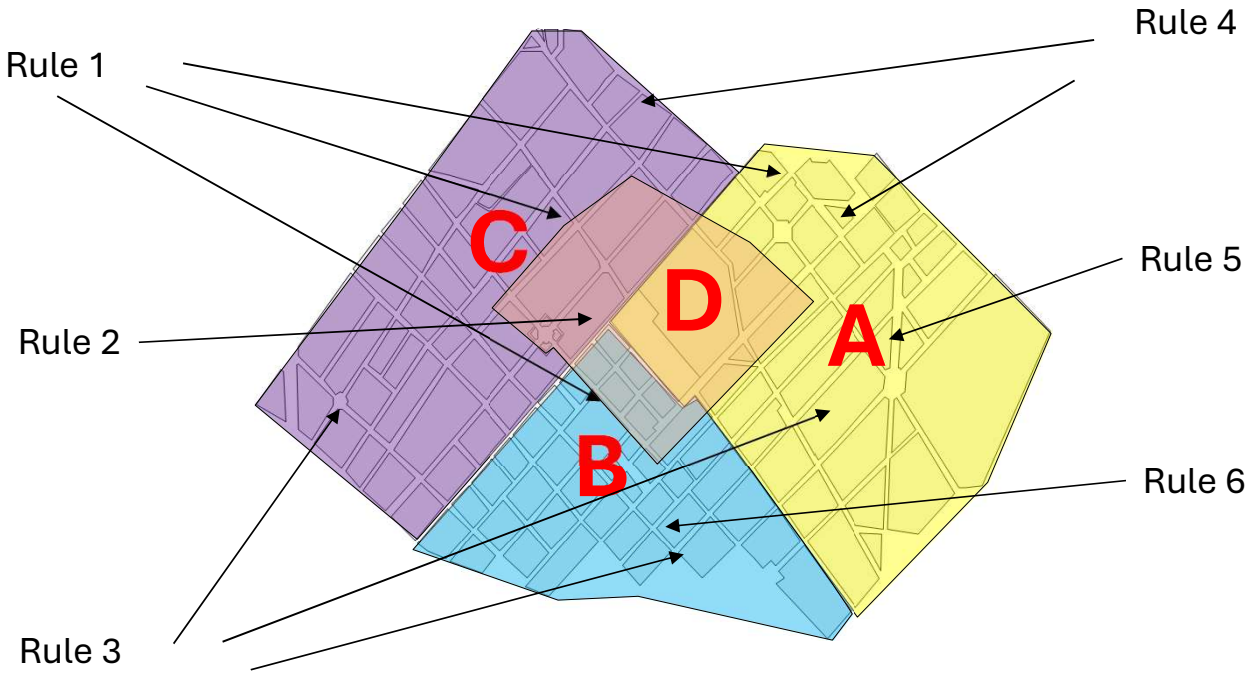
1 – distance from the street
2 – distance to neighboring buildings
3 – distance of the backyard
4 – shape of roof
5 – height of the building

Own elaboration

Encoding

$\forall\ B \in PROJECT, \exists\ P \in\ GO$ $\Omega\text{-}Type\ (B) =$ "Building", $\Omega\text{-}Type\ (P) =$ "Parcels", $Contains\ (Geom\ (P), Geom\ (B))$: $Height\ (B) < 10$ $\wedge Street\_distance\ (B, P) > 3$ $\wedge Neighbor\_distance\ (B, P) > 3$ $\Rightarrow$ $UP\text{-}Allowed\ (B, P)$	Rule 10.9-10.13

Located rules




```
IF Object Z Belongs to ZoneA
Then Apply Rules 1, 3 and 5
```

Own elaboration

Conclusion about rules

- More than `IF-Then-fact` and `IF-Then-Action`

- Other types of rules
  - Located rules
  - Bi-location rules

Feedforward Rules

- Consider two rules:

1 - If it rains, I get wet

- ***Cause-effect chain***

2 - If it rains, I take my umbrella

- ***Result of an anticipation to buy an umbrella***

- This is a Feedforward rule

Definition of Feedforward Rules

- A feedforward rule refers to a control or decision-making process in which outputs are determined based on preset inputs, without relying on feedback from past results.

- They are linked to anticipation processes:
  - ex budget
  - Disaster management

General Model of Feedforward Rules

- General framework in two steps

Pre-rule	Since it frequently rains, Consequently I will buy an umbrella
Post-rule	Whenever it rains, Then I take my umbrella.

Ex1: Monitoring Pollution

Dissemination of sensors

Pre-rule	Since pollution must be monitored, Consequently adequate sensors are distributed throughout the city.
Post-rule	Whenever a threshold is exceeded, Then an alert is triggered.

Ex2: Disaster Management

Mitigation, preparedness
response, recovery

Pre-rule	Since a risky event is recurring, Consequently define actions to mitigate it and to be prepared.
Post-rule	Whenever the risky event occurs, Then organize response and recovery.

Ex3: Technology Watch

Pre-rule	Since another city puts in place a clever device, and this one is a success Consequently examine it carefully.
Post-rule	Whenever the context is favorable Then this device can be imported into my city.

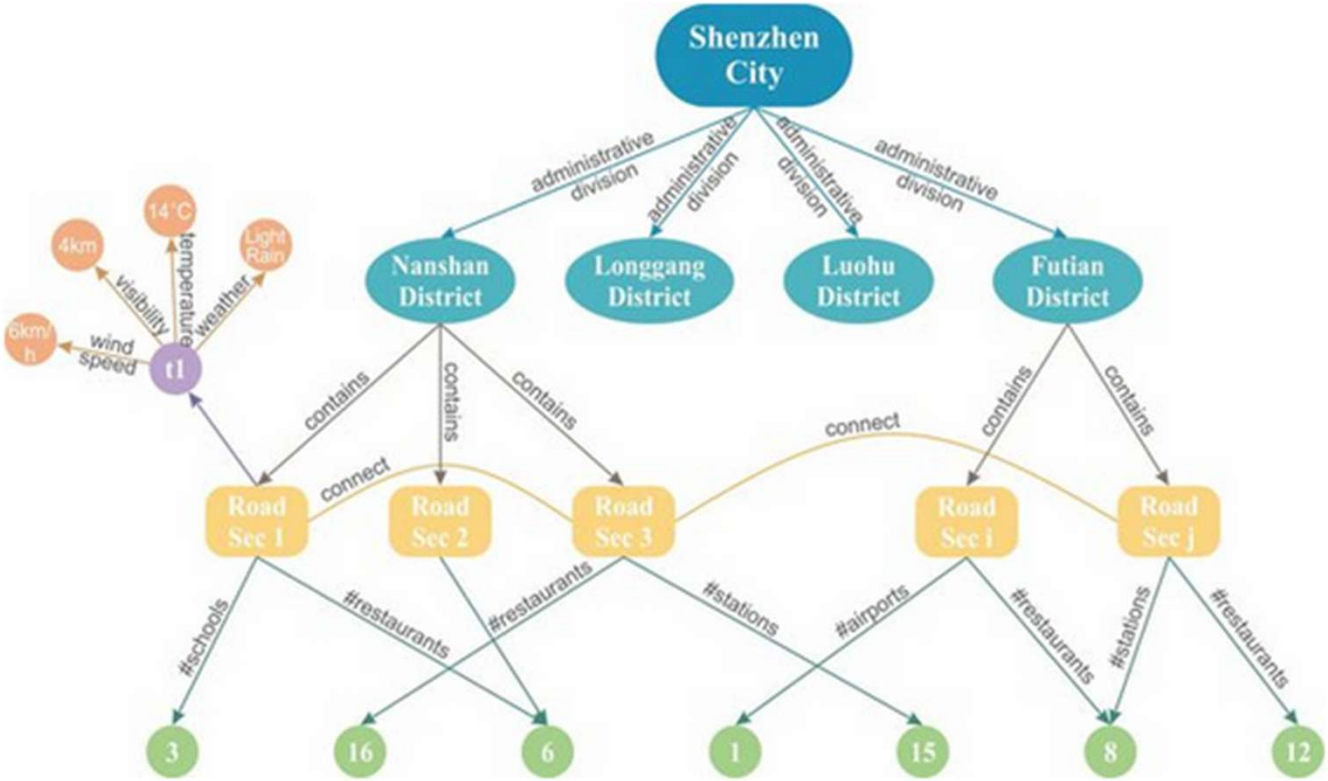
Ex4: Public Participation

Pre-rule	Since public participation is mandatory for any urban plan or project, Consequently organize it to be efficient.
Post-rule	Whenever a plan or a project is designed, Then collect public opinions and synthesize them.

Ex5: Urban Planning as a Whole Process

Pre-rule	Since the State wants to modernize cities Consequently each city must design its own plan
Post-rule	Whenever the objectives are set Then design the plan accordingly.

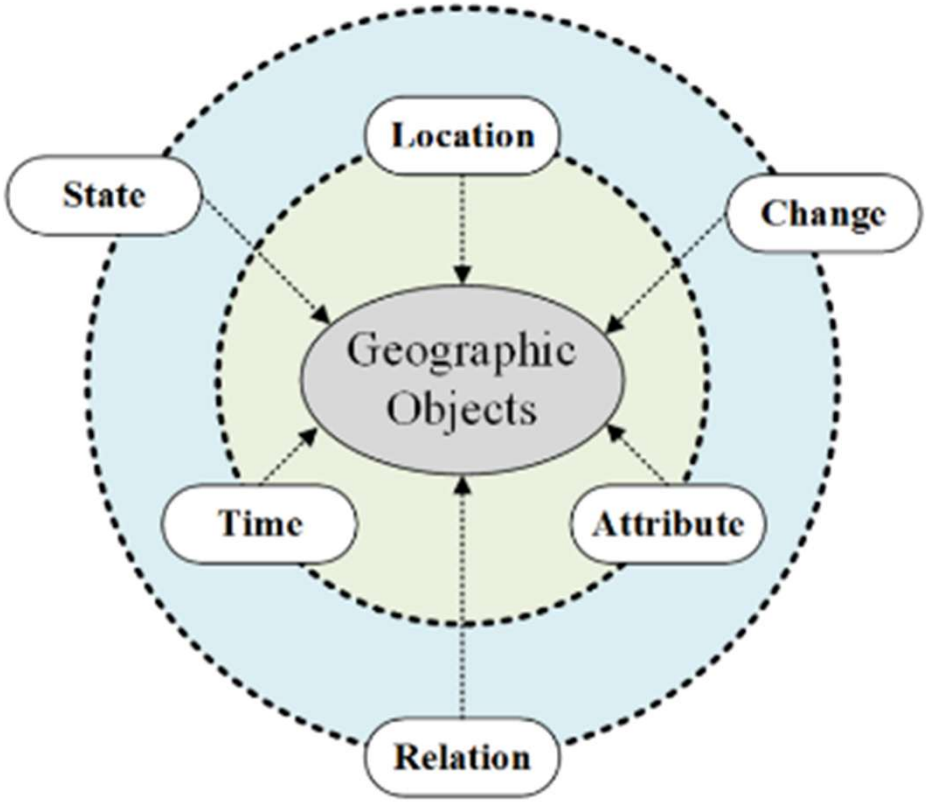
Knowledge Graph for the City of Shenzhen



From Jiawei Zhu et al. 2020

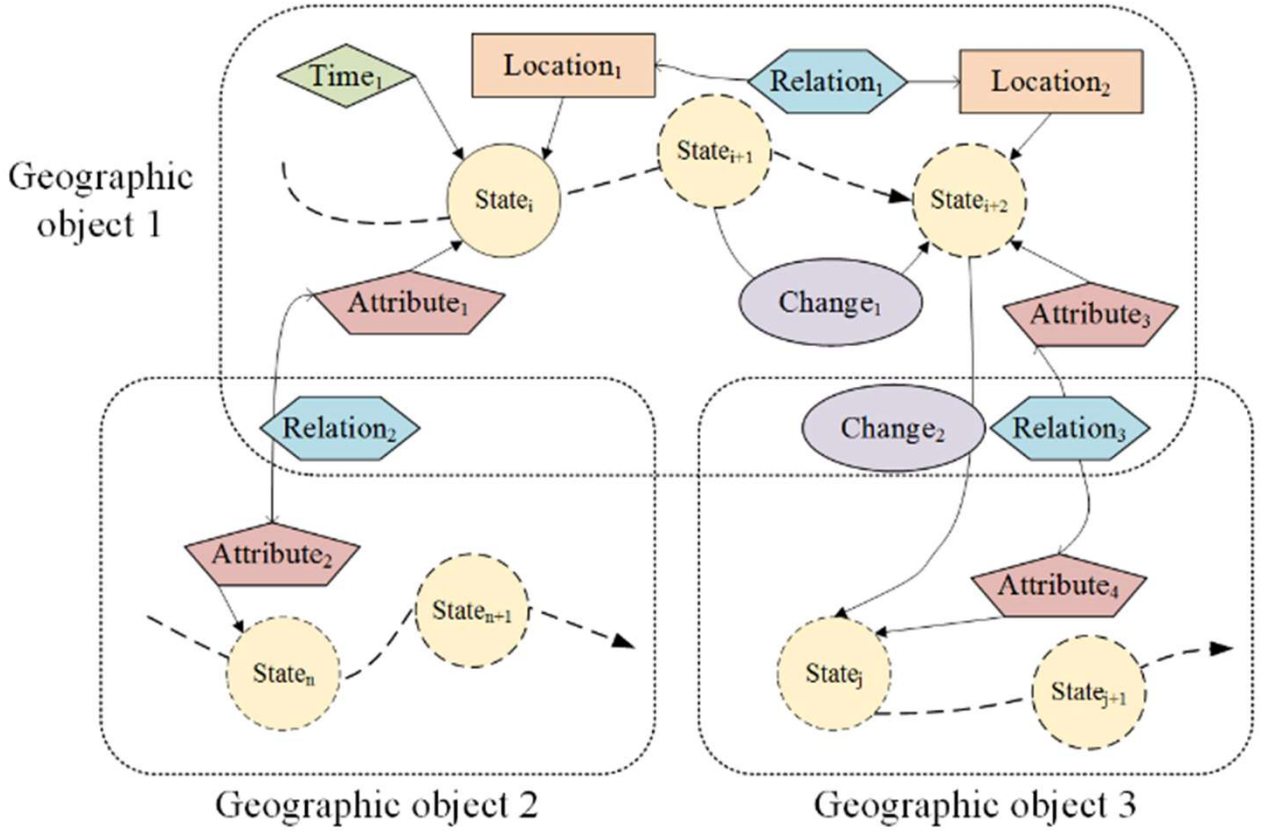
https://www.researchgate.net/publication/346555799_KST-GCN_A_Knowledge-Driven_Spatial-Temporal_Graph_Convolutional_Network_for_Traffic_Forecasting/figures?lo=1

Geo-KG (Shu Wang 2019)



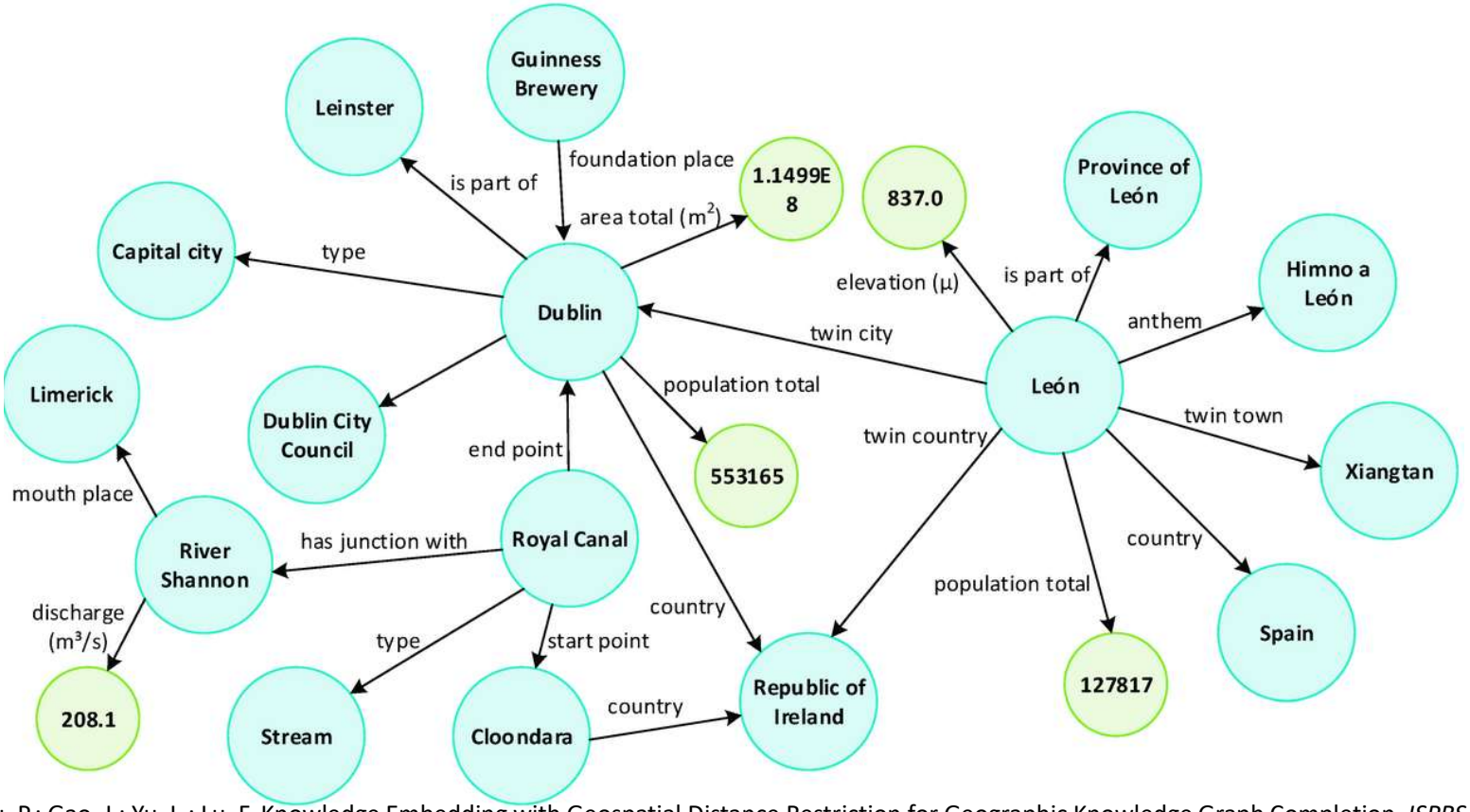
https://www.mdpi.com/2220-9964/8/4/184

Large interactions between urban objects with Geo-KG (Shu Wang 2019)



https://www.mdpi.com/2220-9964/8/4/184

Knowledge Graph for Dublin



Qiu, P.; Gao, J.; Yu, L.; Lu, F. Knowledge Embedding with Geospatial Distance Restriction for Geographic Knowledge Graph Completion. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 254. https://doi.org/10.3390/ijgi8060254

Knowledge from geovisualization

- Geovisualization: much more than cartography
- Idea:

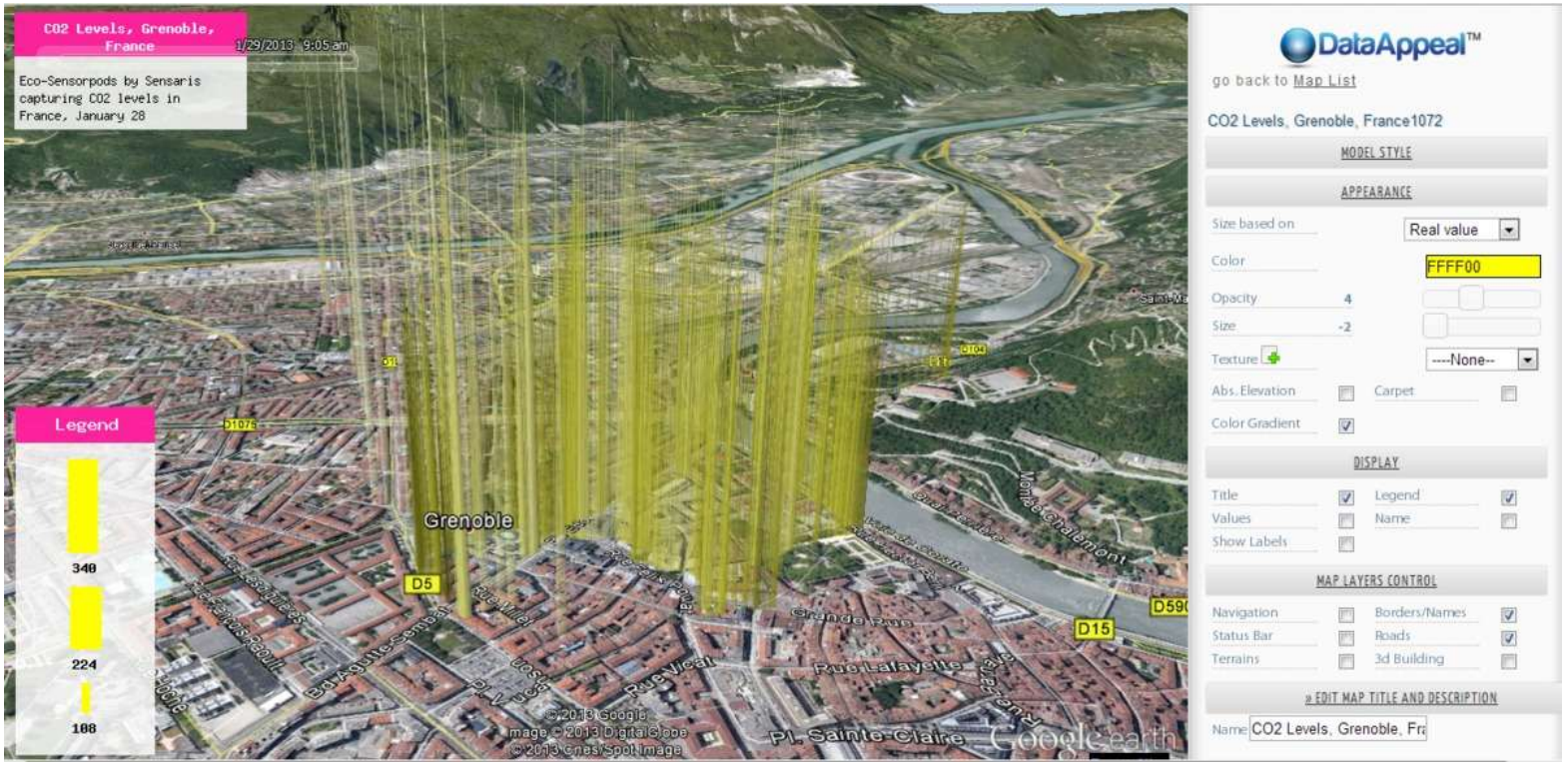
- Trying to extract knowledge from new novel visual layouts

- Visual reasoning

3D Example

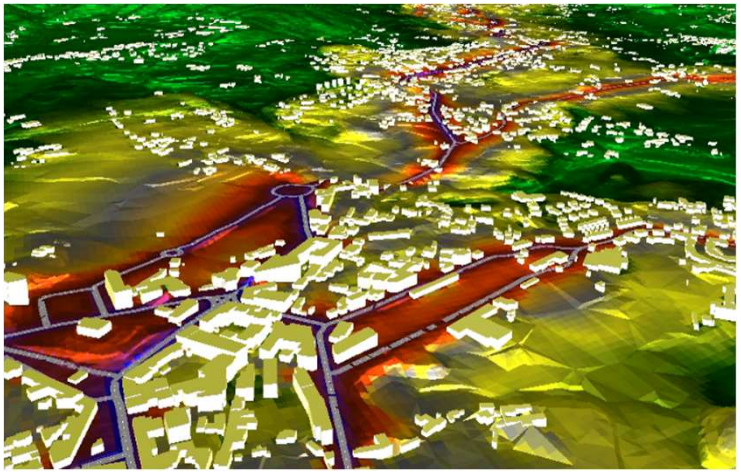
https://www.artstation.com/artwork/JeQAr0

Air pollution in Grenoble

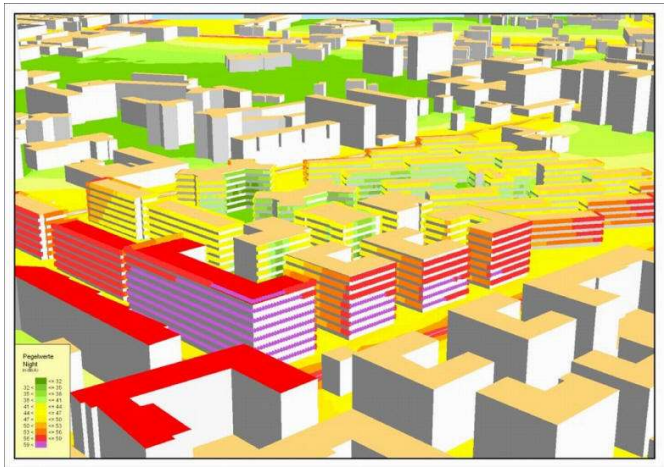


https://www.nadiaamoroso.com/creative-cartography

Noise visualization



https://apambiente.pt/sites/default/files/_Ar_Ruido/Ruido/SituacaoNacional/MapasRuidoMunicipais/Lousada_RNT.pdf



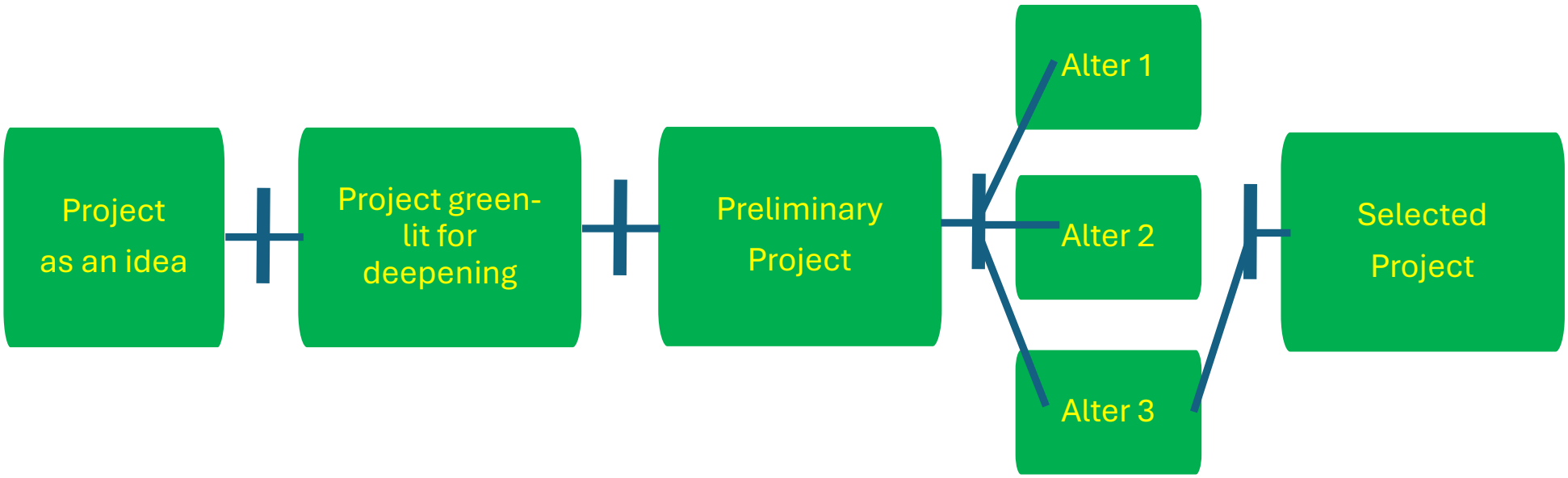
https://www.adamsengg.com/expansion-modules/

Knowledge for/from Projects

- Knowledge is the base for the design of new urban projects

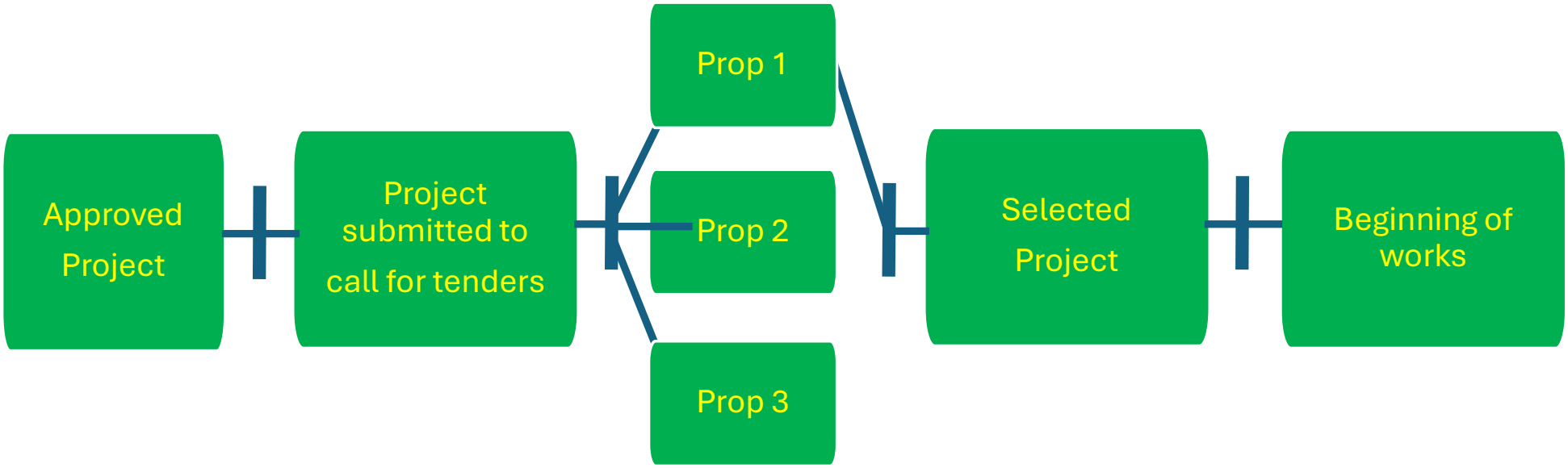
- Lessons learnt from projects
  - Completed projects
  - On-going projects
  - Abandoned projects

Urban Project Management – Phase 1
From idea to project



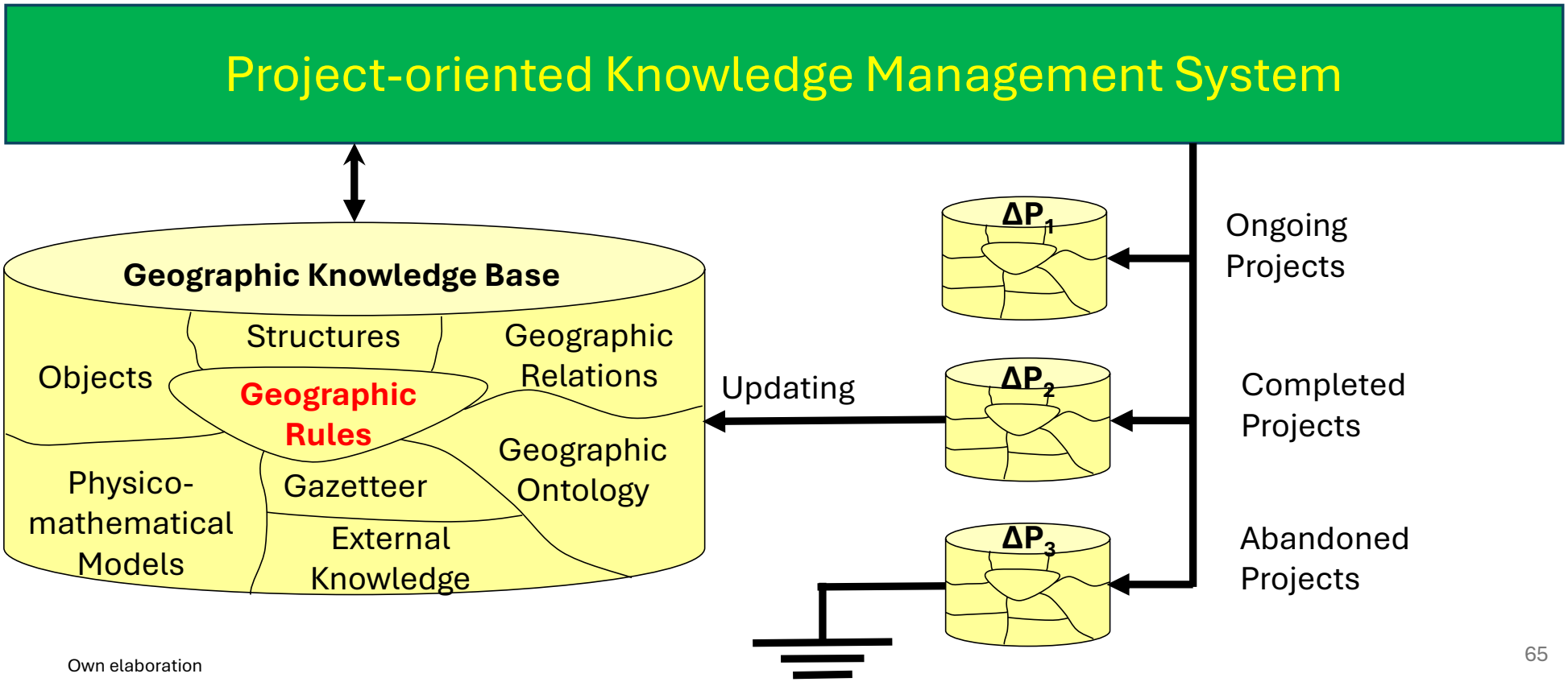
Own elaboration

Urban Project Management – Phase 2
From project to implementation



Own elaboration

Architecture for Project Management



Own elaboration

Conclusion

- Urban planning is a complex activity involving several specialties
  - In the past, based on data
  - Now on, based on knowledge
- Only a rapid presentation of geographic knowledge in urban planning
- Importance of feedforward rules
- Territorial intelligence more complex than business intelligence
- Many additional aspects must be developed to get operational systems

Special issue of the “AI Journal”
RL Guest Editor

Special Issue

AI-Powered Smart Cities: Towards Sustainable Urban Environments

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Universitaires Sans Frontières/ Academics Without Borders

- From 2009, an NGO devoted to assist universities in their development
- Examples
  - Bachelor courses in Bobo Dioulasso in Civil Engg
  - Schools of engineering in Douala, in Ouagadougou
  - Master courses in Togo and Benin
  - Courses for Doctoral Schools in Tunisia, Morocco, Colombia, in course Cameroon
- Bimonthly newsletter (8000+ French, 3000+ English, 2000+ Spanish)

  - Contact: Jean.Ruffier@usf-awb.net
  - www.univ-sf.org

Tanks for your attention!

Prof. Robert Laurini

Robert.Laurini@usf-awb.net
www.laurini.net/robert

Can be downloaded from www.laurini.net/ftp/ouaga1.pdf