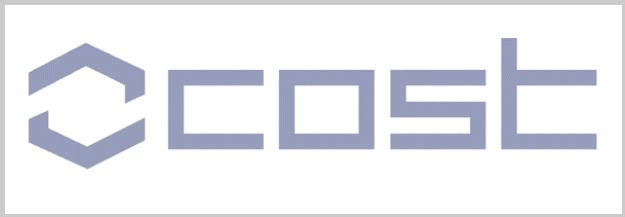
Theoretical approach to urban ontology:
a contribution from urban system analysis

University of Pisa
Department of Civil Engineering

Polytechnic of Milan
Department of Architecture and Planning

ing. Caglioni Matteo

prof. Rabino Giovanni



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Definition of Ontology

- *Guidelines to built ontology: A bibliography study.* (C. Roussay, 2005)

- *"An ontology is a formal and explicit specification of a shared conceptualization"* (Studer, 1998)

Formal language

- **Natural languages** aren't able to describe in a powerful way concept definitions and relationships.

- **Syntactical machine readable languages** such as HTML or XML are limited because they are only intended for human consumption.

Formal language

- We need to make the information not only machine readable but machine-understandable.
- In order to gain machine understanding we need **semantic languages** which are able to define meaning for the stored information.

Formal language

- Requirements for ontology language
  - Easy to use and comprehend
  - Compatible with existing standards
  - Formally specified
  - Adequately expressive
  - Possibility to perform an automate reasoning

Formal language

- ***OIL*** (Ontology Inference Layer)
- ***DAML*** (DARPA Agent Mark-up Language)
- ***DAML+OIL***
- ***OWL*** (Ontology Web Language)
  - OWL lite (First Order Logic)
  - OWL DL (Descriptive Logic)
  - OWL Full

Shared and reusable ontologies

- Ontology building is an iterative process characterized by an high cost.
- There are databases with ontologies already developed, but these resources are limited.
- Formal structure and formal language allow to re-use ontology in another application.
- Re-using ontologies allows to share knowledge contained inside them.

The object

- **physical** object, which are entities limited in space and in time.
- **social** object, which are entities just limited in time (i.e. a contract, or a promise)
- **ideal** object, which are entities not limited in space and in time.

(Casati, 1998; Ferraris, 2005; Varzi 2005)

Semantic relationships

- The most common way to represent objects in an ontology is using semantic relationships between concepts, which give a **hierarchical structure** to the whole system.

Semantic relationships

- **Taxonomy** (Hiperonomy, Hiponomy)

  X is a kind of Y (o Y has a kind of X).

  characterize relationship between classes and subclasses, where subclasses inherit all proprieties of the their class (flat, detach house, cinema, theatre are kinds of buildings).

- **Partonomy** (Meronimy, Olonimy)

  X is a part of Y (o Y has a part X).

  the sum of parts of an object constitute the object itself (window, door, roof are parts of a house).

Semantic relationships

- Semantic relationship between verbs
  - **Toponimy**: a verb is a troponym of another one, when the first expresses a particular manner of the second (march - walk).
  - **Implication**: an action implies another one, when the first action can't be performed without to perform also the second (snore - sleep).

Semantic relationships

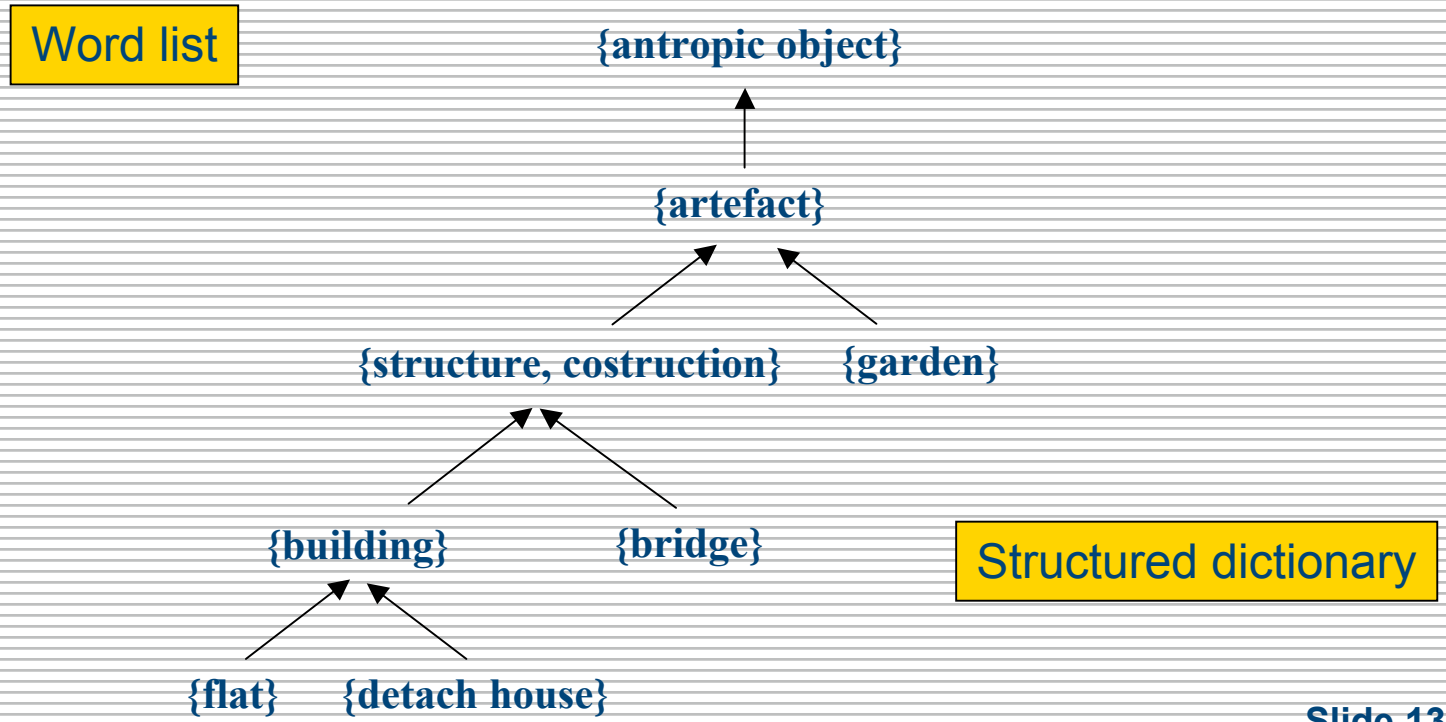
- Lexical relationships are important relations between concepts that depend by phrases in which they are
  - **Synonymy**: two concepts are synonyms, if substituting one concept with the other one inside a phrase, the value of truth of phrase doesn't change.
  - **Antinomy**: the antonym (or contrary) is a concept having a meaning opposite to that of another concept.
  - **Polysemy**: the polysemous is a concept with more than one meaning.

Semantic relationships

- Semantic relationships are easy to use, also because we already know their proprieties and their formal representation…
- …there are other kinds of relationships we can add to ontology, but we need to define them and characterize them in a formal way.

Semantic relationships

<detach house, artefact, flat, garden, construction, building, structure, bridge, antropic object>



Semantic relationships

1 define theory: buildings

2 define class: building(x)

a instance-of(White House,building)

b instance-of(Louvre,building)

c instance-of(Scala,building)

3 define relationship: kind-of(x,b)

a kind-of(theatre,building)

b kind-of(hospital,building)

c kind-of(house,building)

4 define relationship: constitute-by(b,x)

a constitute-by(building,doors)

b constitute-by(building,windows)

c constitute-by(building,walls)

Semantic relationships

1 define theory: buildings

2 define class: building(x)

3 define relationship: made-of(e,material)

a ∀ e,m: made-of(e,m) -> instance-of(e,building) & (m = concrete or m = steel)

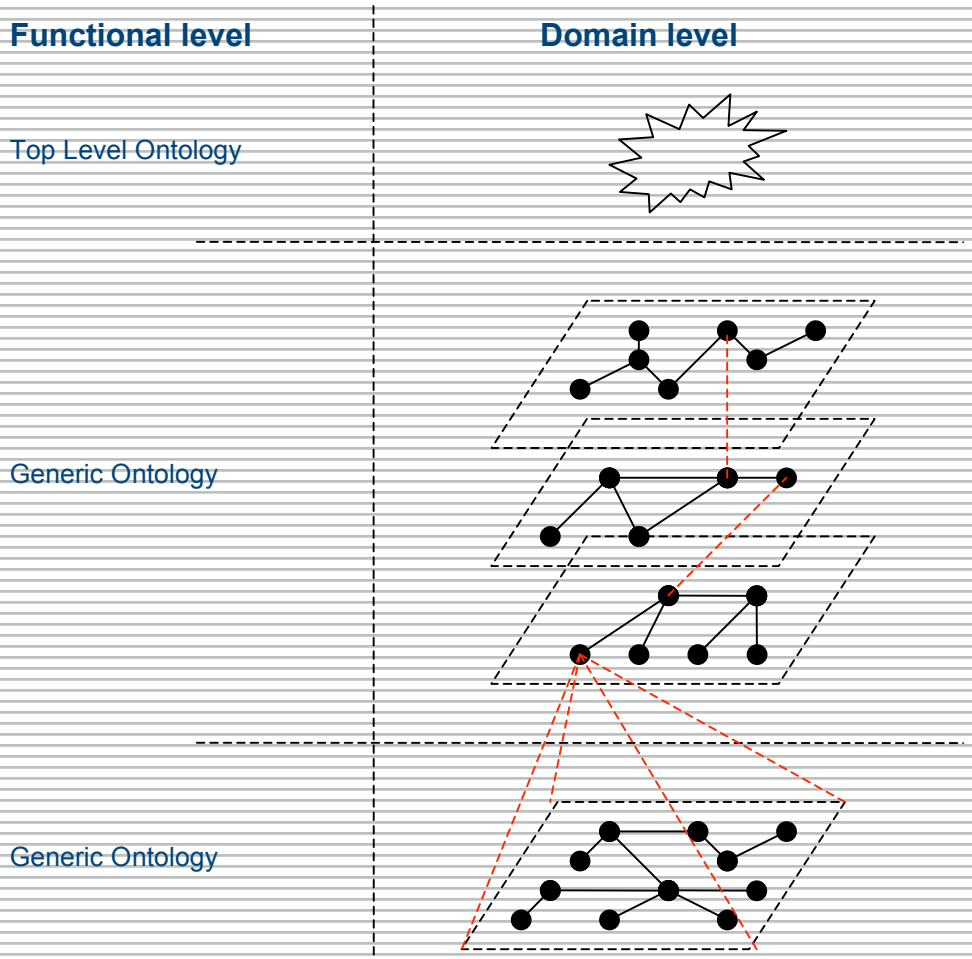
4 define relationship: kind-of(e,structure)

a kind-of(e,steel) ↔ instance-of(e,building) & made-of(e,steel) & ¬ made-of(e,concrete)

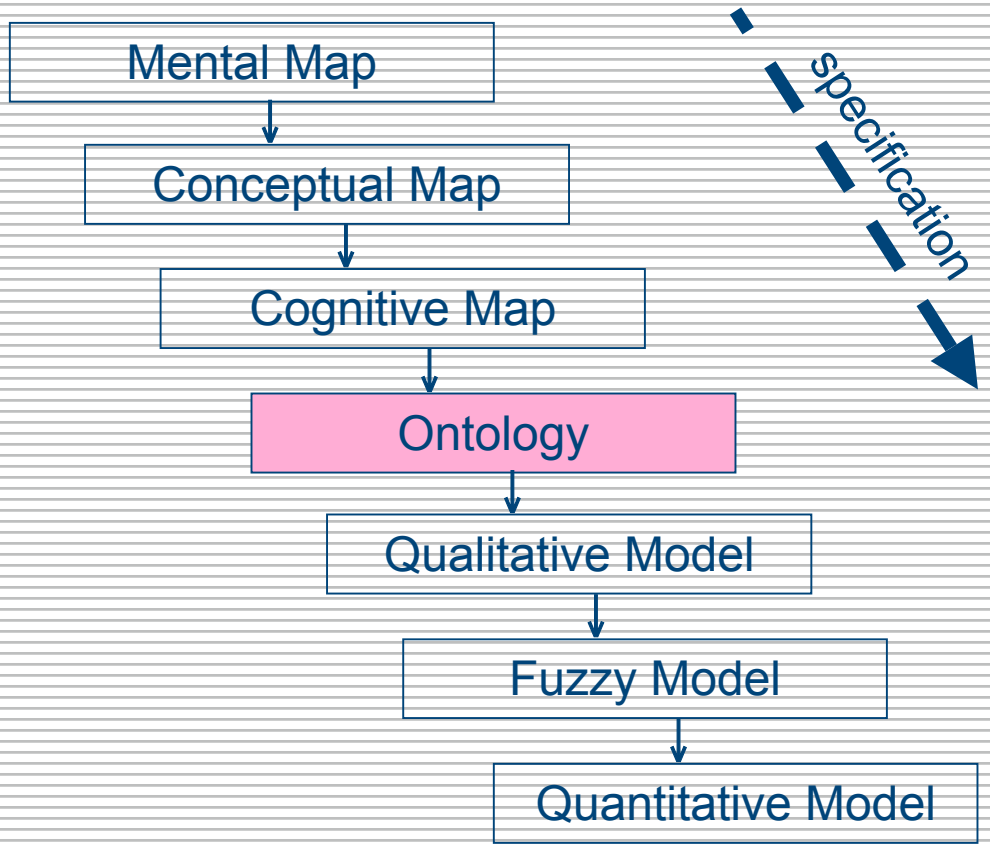
b kind-of(e,con) ↔ instance-of(e,building) & made-of(e,concrete) & ¬ made-of(e,steel)

c kind-of(e,r_con) ↔ instance-of(e,building) & made-of(e,concrete) & made-of(e,steel)

Ontology and representation

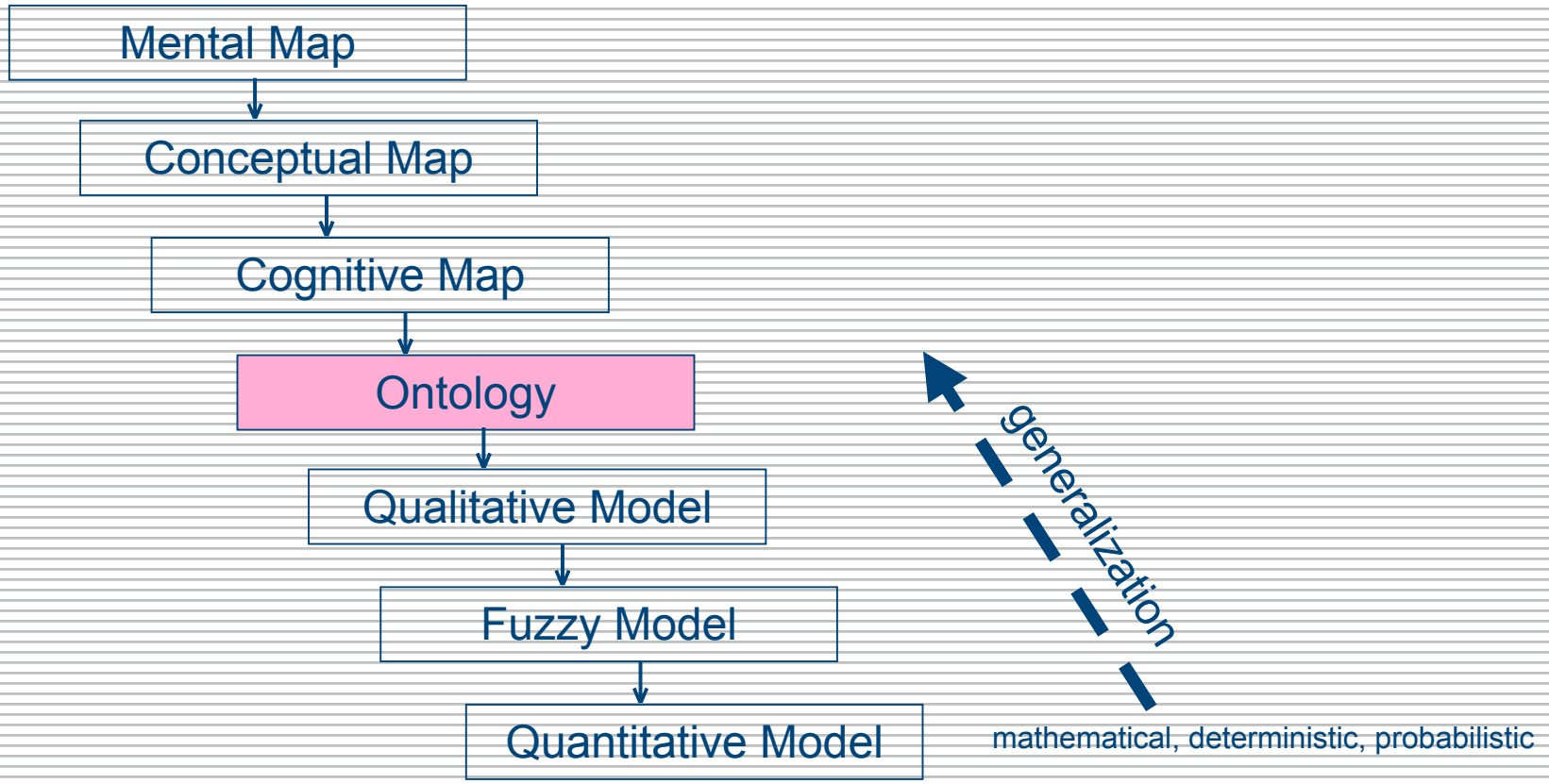


Model building levels

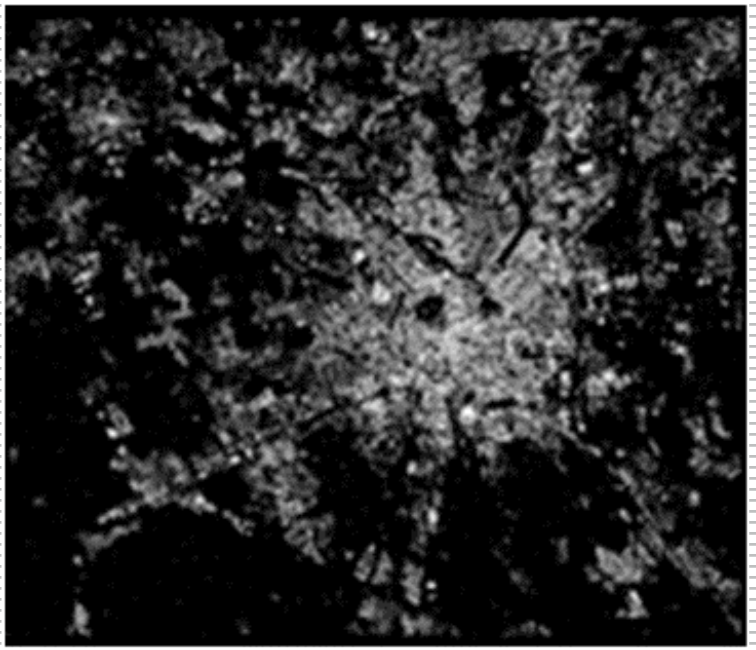


mathematical, deterministic, probabilistic

Model building levels

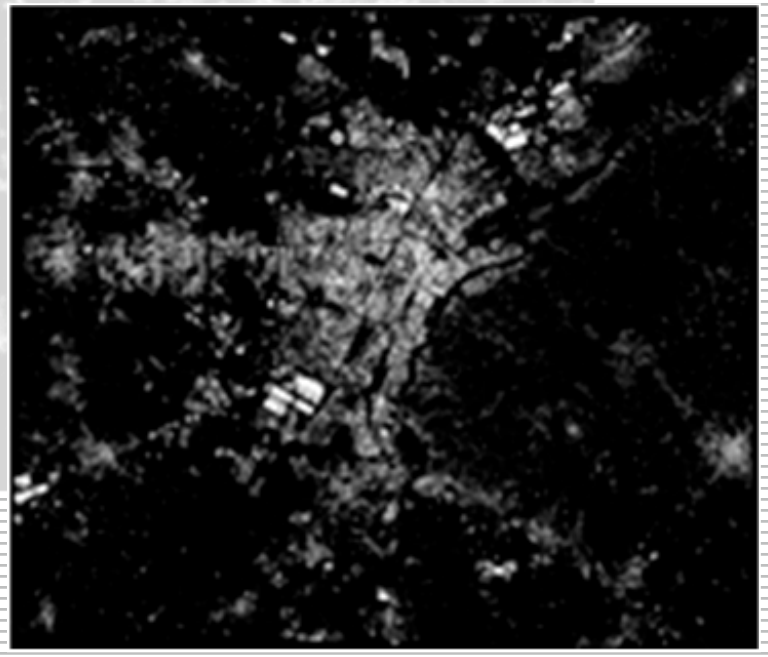


Urban sprawl



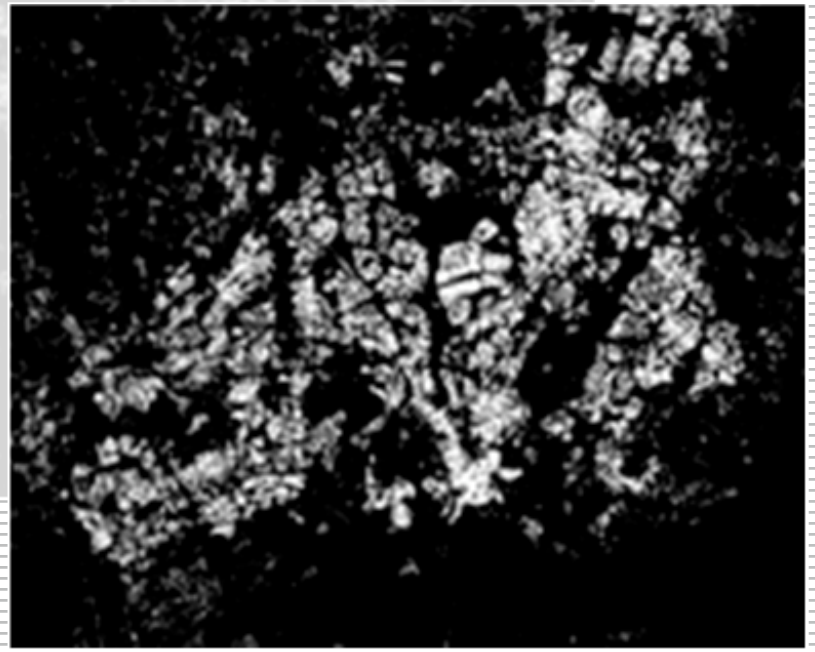
MILAN

Urban sprawl



TURIN

Urban sprawl



HELSINKI

Urban sprawl

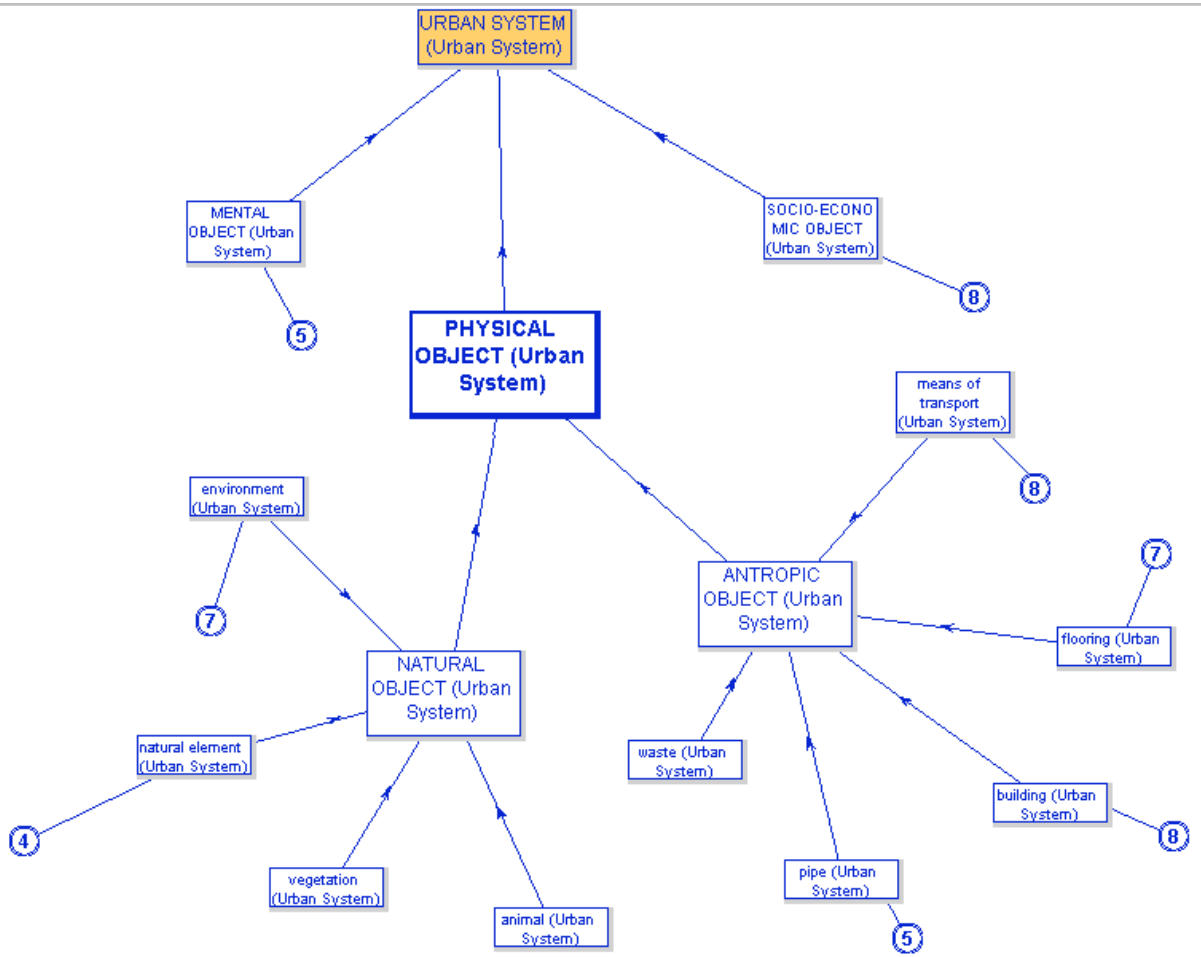
- Urban sprawl, an uncontrolled and ungovernable growth of low density urbanized areas, is the result of a localization process, determined by complex urban dynamics acting on territory.

→ We need a systemic view of the city.

Urban ontology

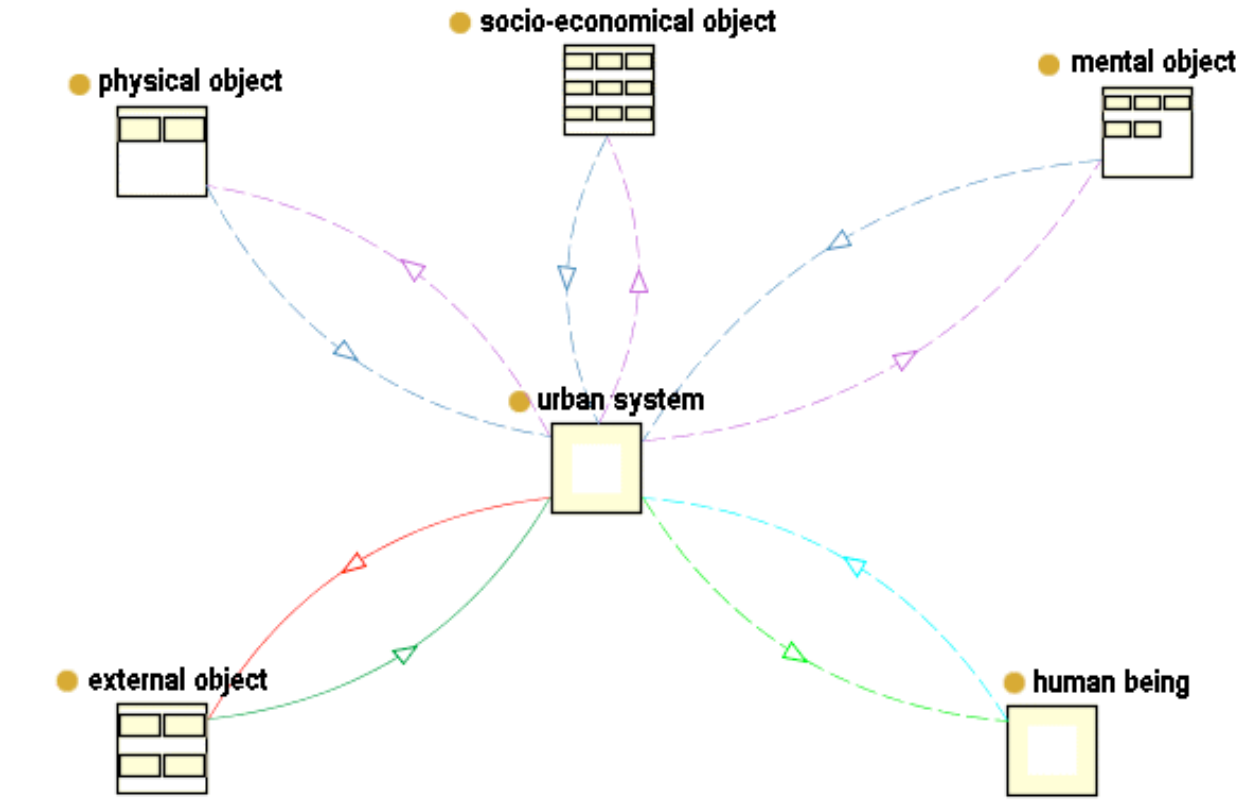
- **Domain**: urban system
- **Definition**: ‘city’ has seen like a ‘machine’, a system therefore, modified by man, inside of which he lives, where for living we mean the performance of all those activities which characterize human being (i.e. eating, sleeping, working, having social relationships, thinking, and having opinions and emotions).

Urban ontology



Towntology

Urban ontology



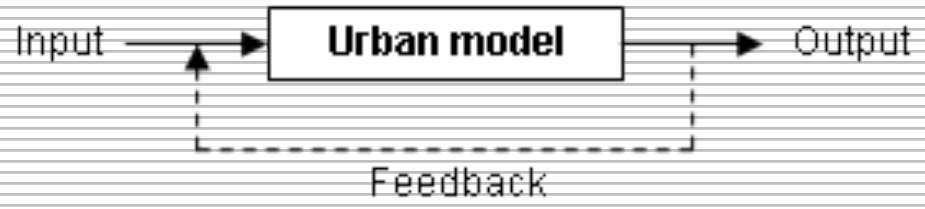
Protégé

Urban ontology

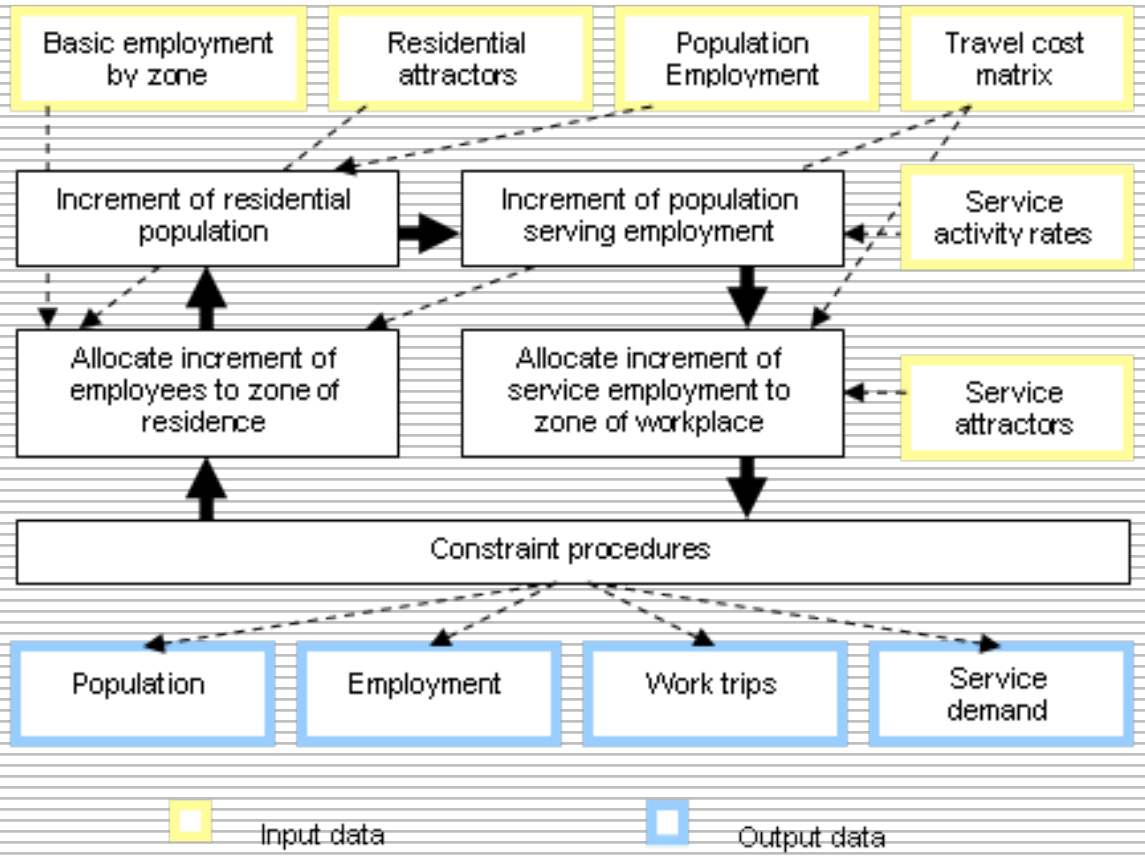
- It's possible to identify an isomorphism between concepts in ontology and entities in a model…
- …also between relationships, defined and represented in ontology, and equations which connect different entities using a mathematical form.

Urban ontology

- According with our systemic view of the city, we propose to represent ontology using a classic **input-output structure** of the urban system.



The Lowry Model



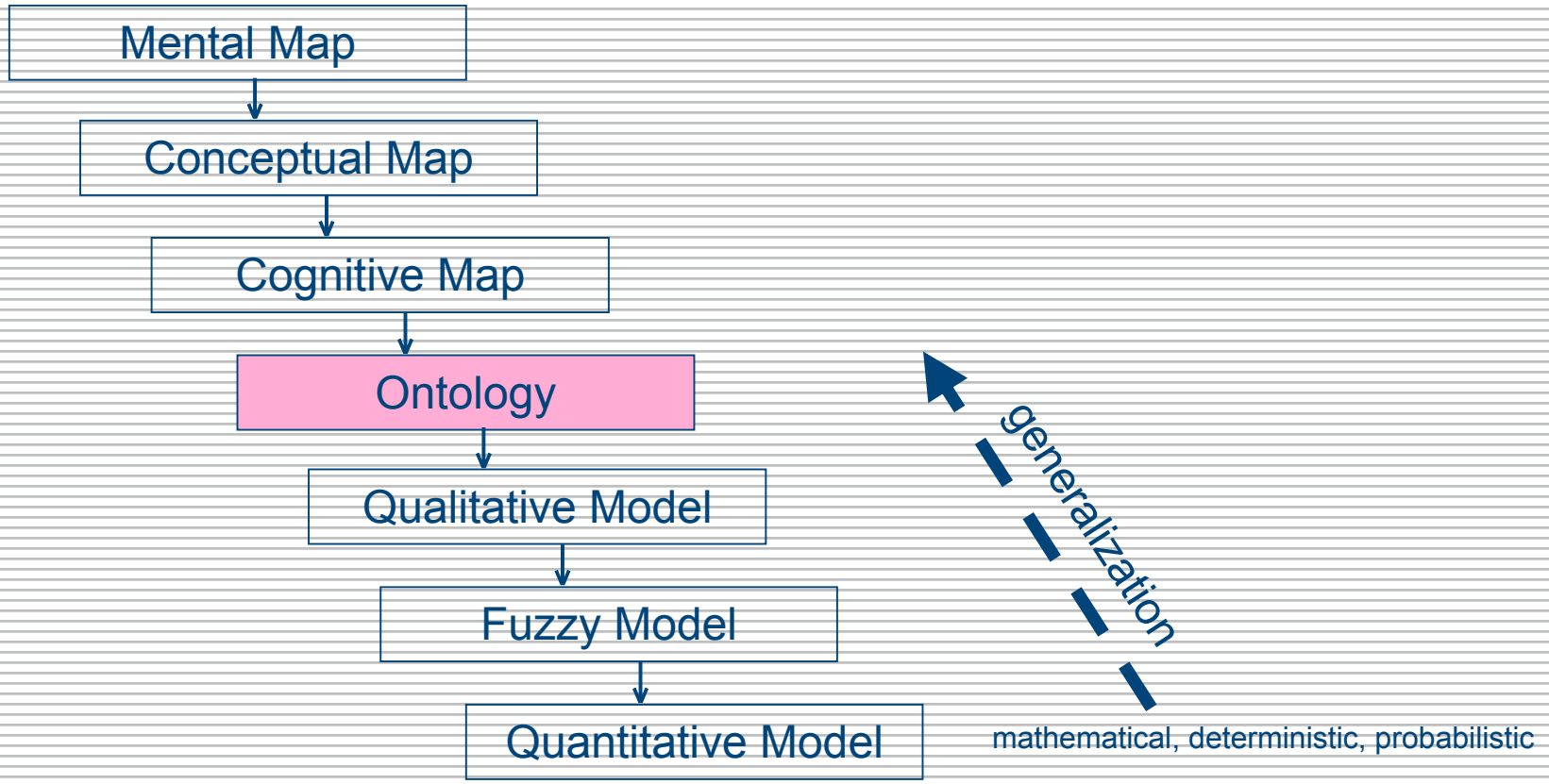
The Lowry Model

- The Lowry model was one of the first transportation / land use model to be developed in 1964.
- Even if its formulation is rather simple, it provides the relationships between transportation and land use.
- The core assumption of the Lowry model is that regional and urban growth (or decline) is a function of the expansion (or contraction) of the basic sector.

The Lowry Model

- To build an ontology following a top-down process is an ambitious and rather complex project…
- we purpose to start from already existing mathematical models, building ontology through a **generalization** process.

Model building levels



The Lowry Model

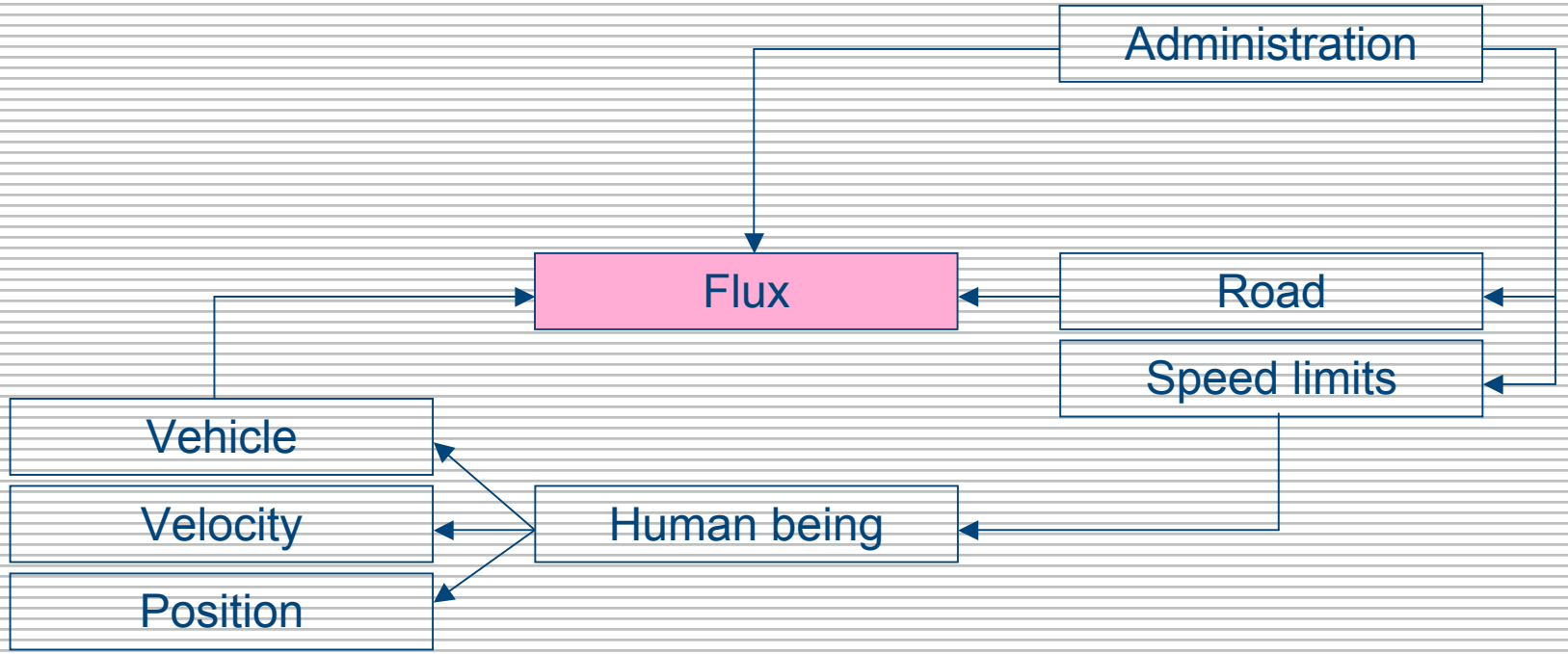
$$F_{ij} = \frac{L_i^b \cdot W_i \cdot e^{-\beta d_{ij}}}{\sum_j W_j \cdot e^{-\beta d_{ij}}}$$

commuting rate from *i* zone to *j* zone

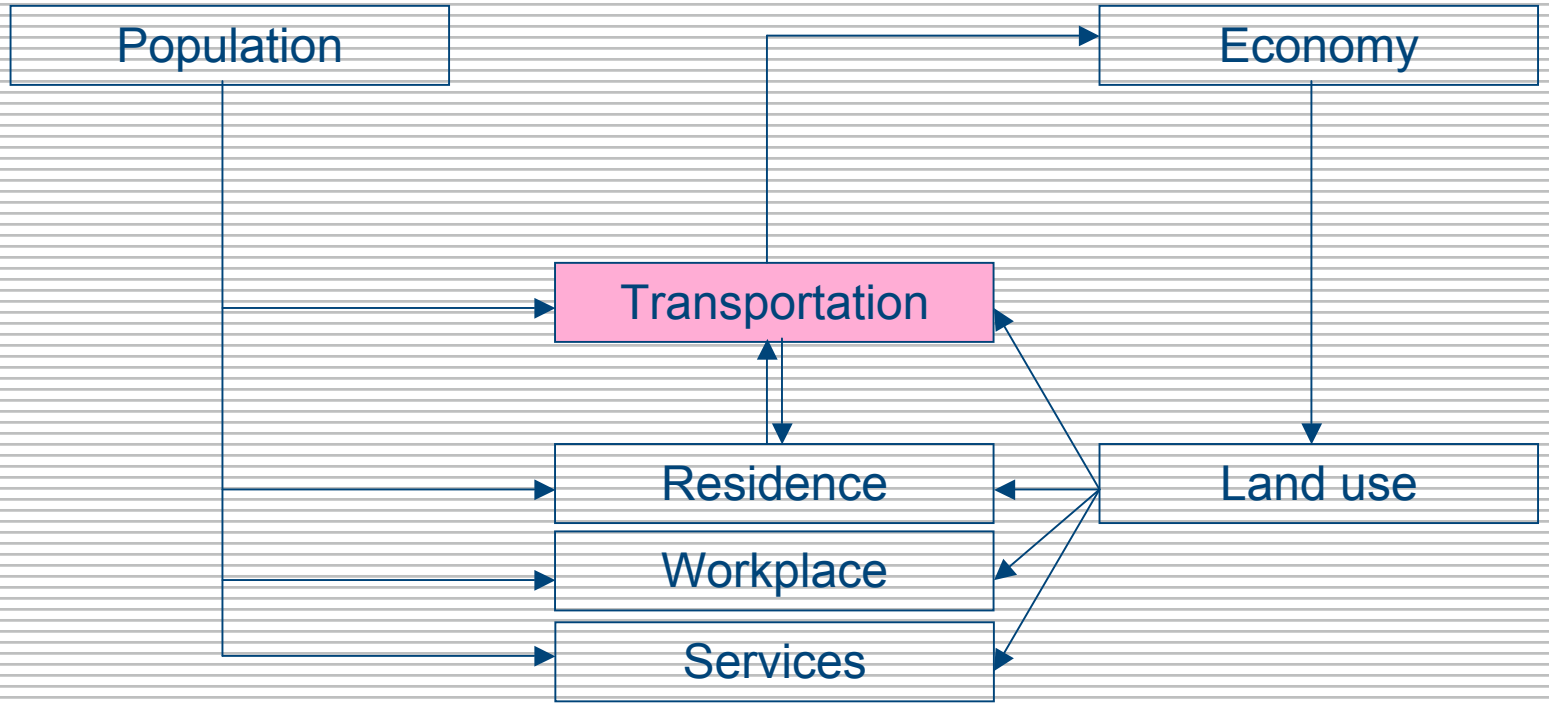
$$d^2x_1(t+\Delta t)/dt^2 = k_1(dx_2(t)/dt - dx_1(t)/dt)$$

Differential equations for vehicle movement

The Lowry Model



The Lowry Model



Conclusions

- It's possible to extract knowledge through *logical inference* (reasoning).
- Ontology as method *to build* a database and *to share* information.
- Ontology as *model building* process for urban systems.