# Meta-Modeling and Modeling Languages

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# Models and Modelling

**Model**

A reproduction of the part of reality which contains the essential aspects to be investigated.

**Modelling**

Describing and Representing all relevant aspects of a domain in a defined language.

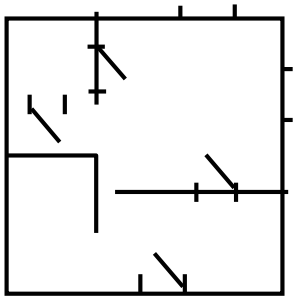
Result of modelling is a model.

# Model in Architecture

**real object**

house

**model**



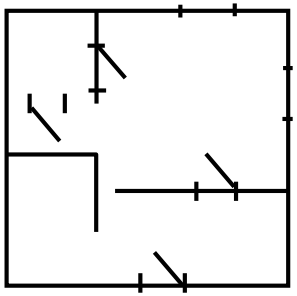
architect's drawing
(plan)

# Model and Modeling Language in Architecture

**real object**

house

**model**



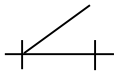
architect's drawing
(plan)

**modeling language**
(concrete syntax)

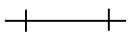
object types:



wall

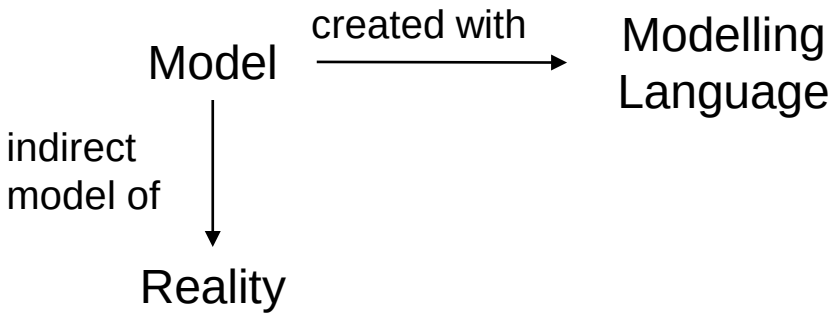


door



window

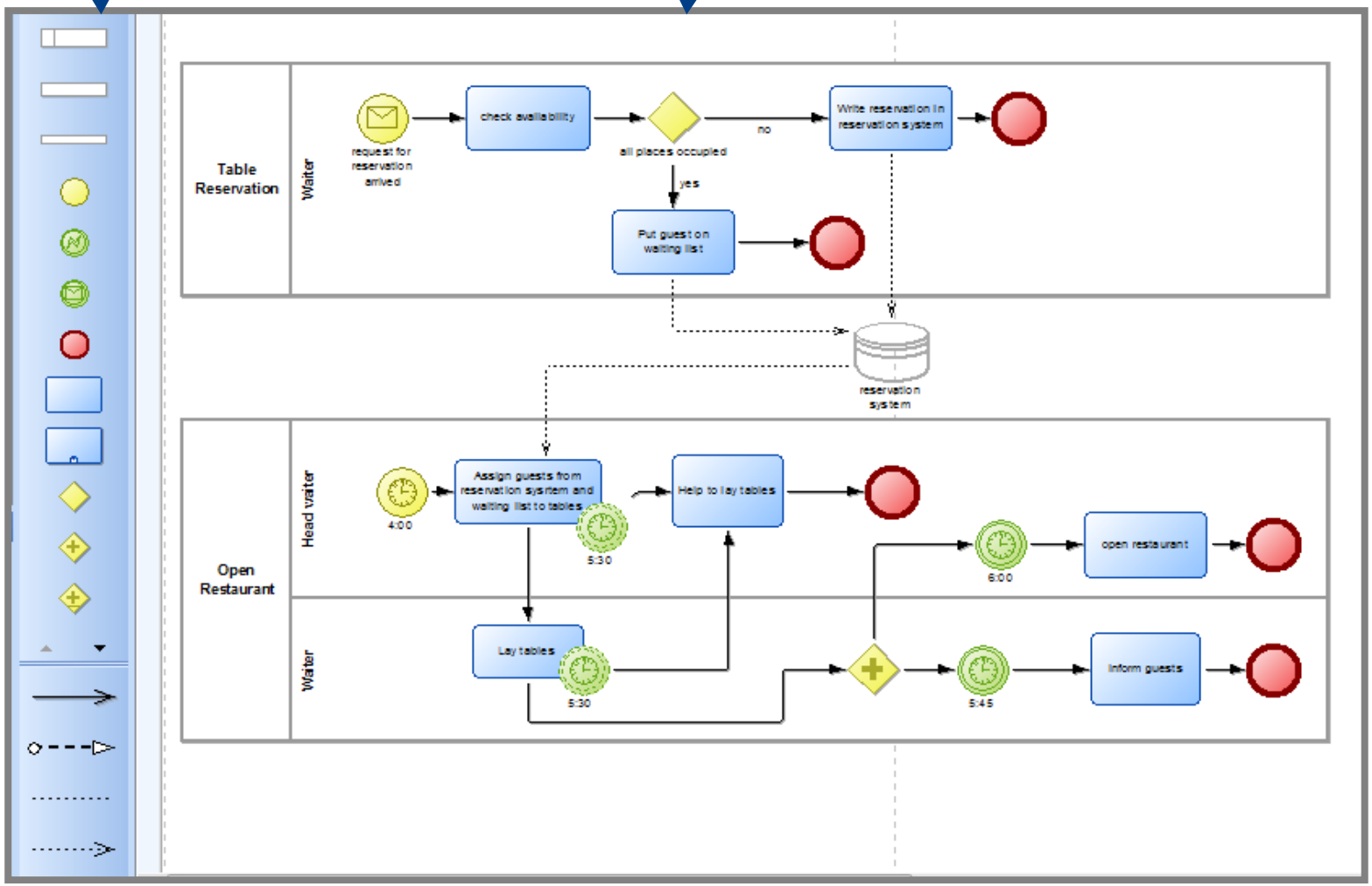
# Modelling Language




- A modelling "language" specifies the building blocks (elements) from which a model can be made.
- There can be different types of modelling languages, depending on the kind of model
  - ♦ graphical model
  - ♦ textual description
  - ♦ mathematical model
  - ♦ conceptual model
  - ♦ physical model

Modeling Language

Model

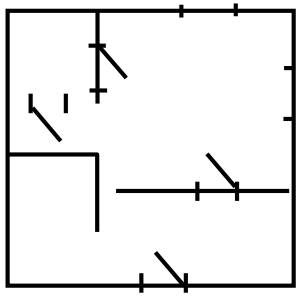


# Model and Meta-Model in Architecture

**real object**

house

**model**



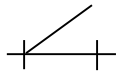
architect's drawing (plan)

**modeling language**
(concrete syntax)

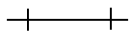
object types:



wall



door



window

**meta-model**
(abstract syntax)

object types:
- wall
- door
- window

rules:
- a door is adjacent to a wall on both sides
- Windows are on outer walls.

# Metamodel and Modeling Language

## Metamodel

- The *metamodel* is a model of a model. It defines the modeling elements (concepts, relations, constraints) without specifying the layout and notation

## Modeling language

- The *modeling language* defines the notation/appearance of the modeling elements

# Illustration: Meta-model and Model for Processes

## Metamodel:

Abstract syntax:
Concepts which can be used to create models.

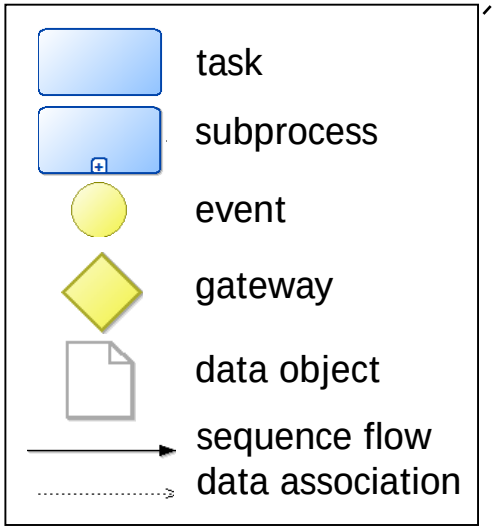
Example: A process model consists of concepts for

- «task», «subprocess», «event», «gateway», «data object»
- «sequence flow», «data association».

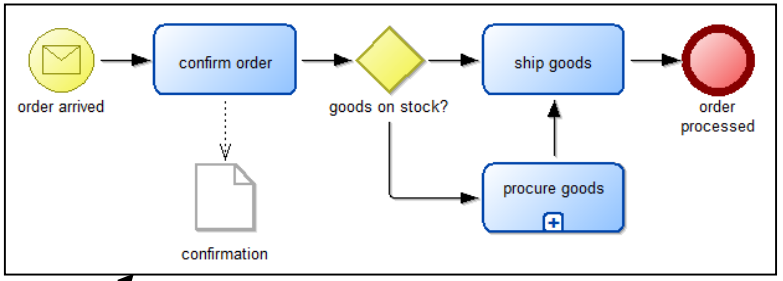
The elements have attributes and there are rules how the elements can be combined.

## Modeling Language:

Concrete syntax:
Notation/appearance of meta-model elements

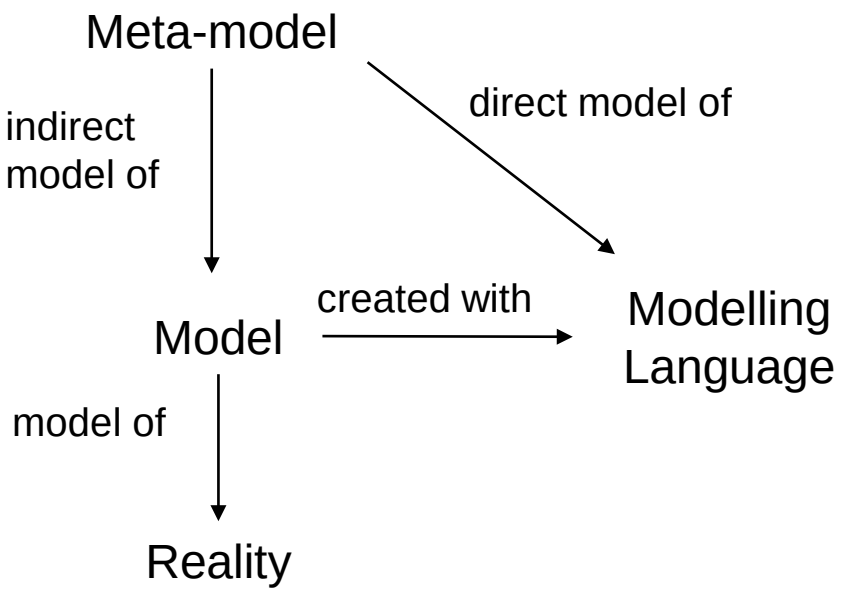



## Model:




*A model contains instances of the object types defined in the meta-model, according to the concrete syntax of the modeling language. The object „confirm order" represents a real entity; it is an instance of the object type «task"*

# Meta-model

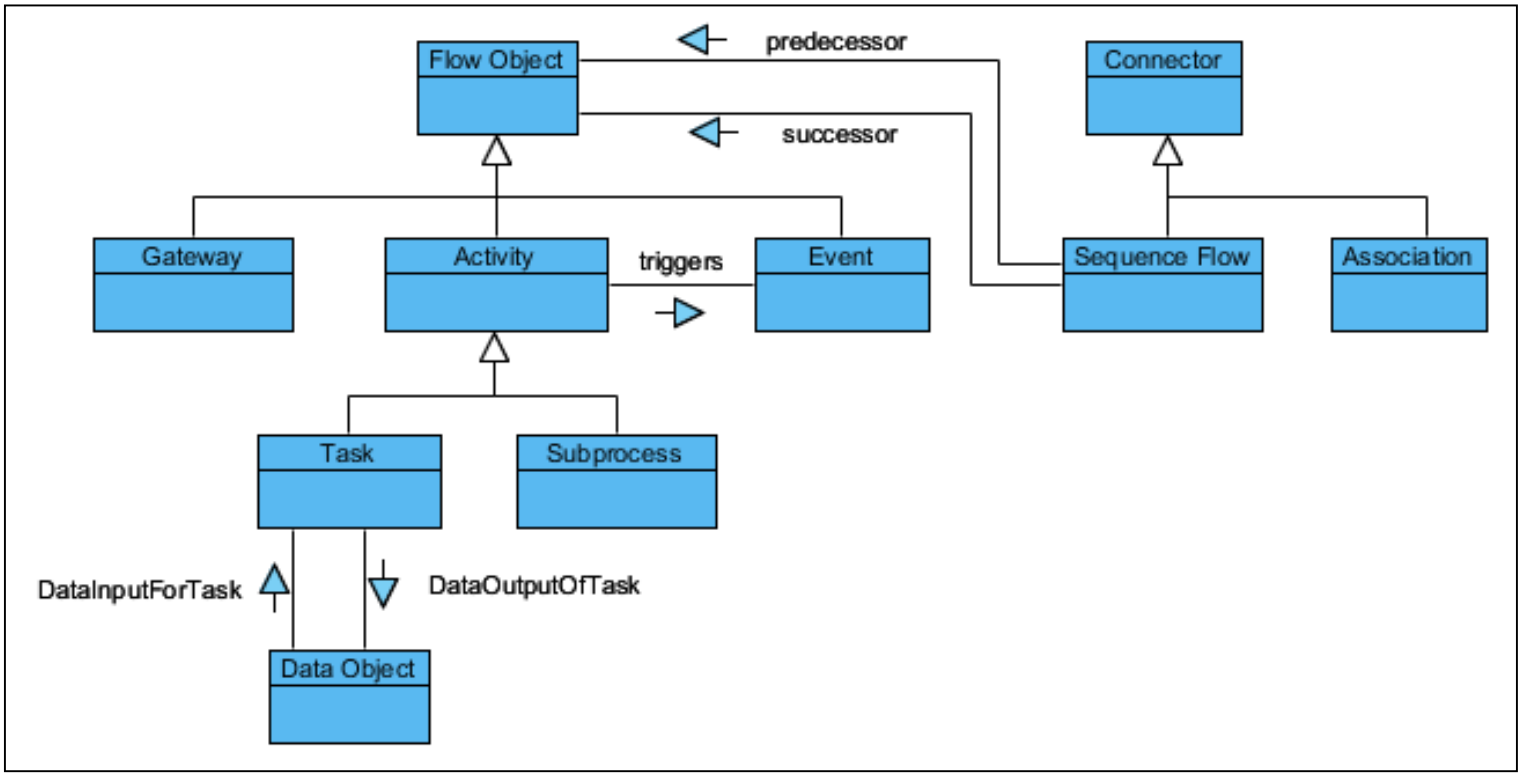



A meta-model defines the semantics of the modelling language, i.e. the building blocks that can be used to make a model. It defines the

- object types that can be used to represent a model
- relations between object types
- attributes of the object types
- rules to combine object types and relations

# Metamodels can be defined as Class Diagrams

To model a metamodel one can use (a subset of) UML class diagrams

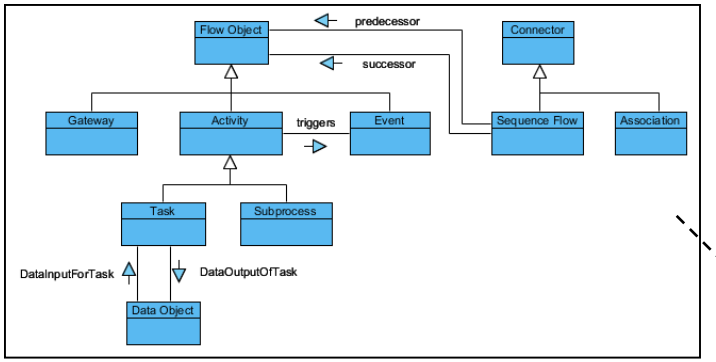



(UML Class diagrams where originally designed for modeling in object-oriented programming. This is why they contain operations and other features, which are not relevant for most modeling languages)

# A Domain-specific Metamodel for Processes

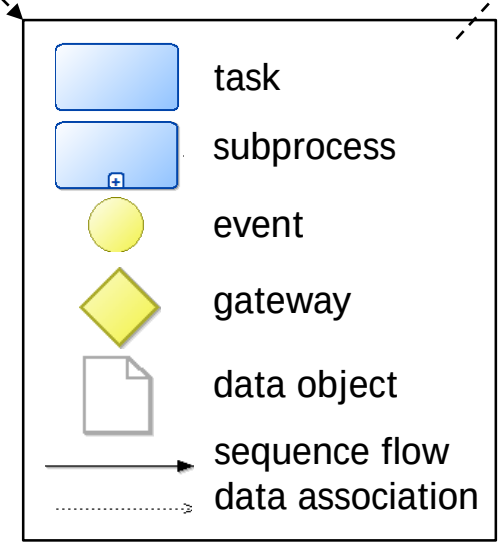
## Meta-model:

- Classes and relations that can be used for modeling

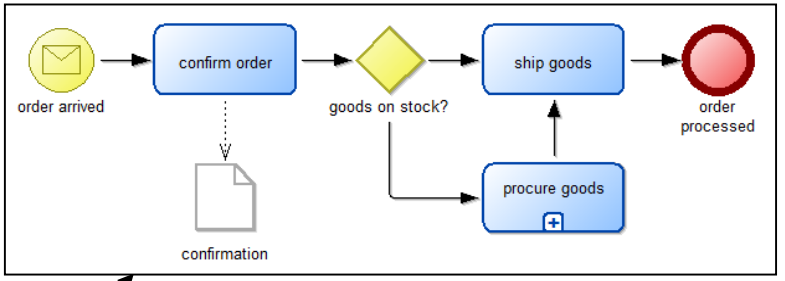



## Modeling Language:

Concrete Syntax (notation, appearance) of meta-model elements

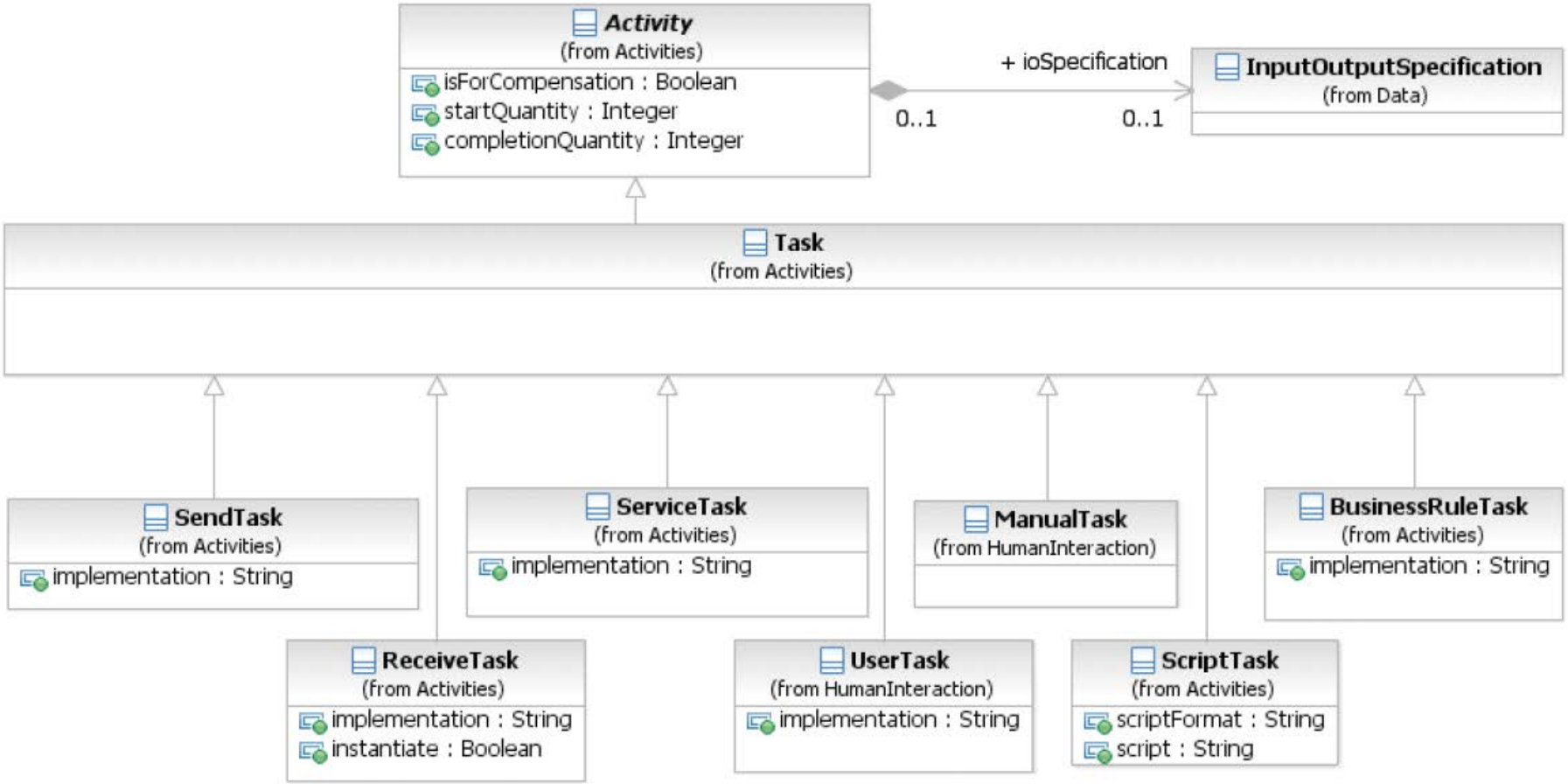



## Model:




*A model contains instances of the object types defined in the meta-model, according to the concrete syntax of the modeling language. The object „confirm order“ represents a real entity; it is an instance of the object type «task"*

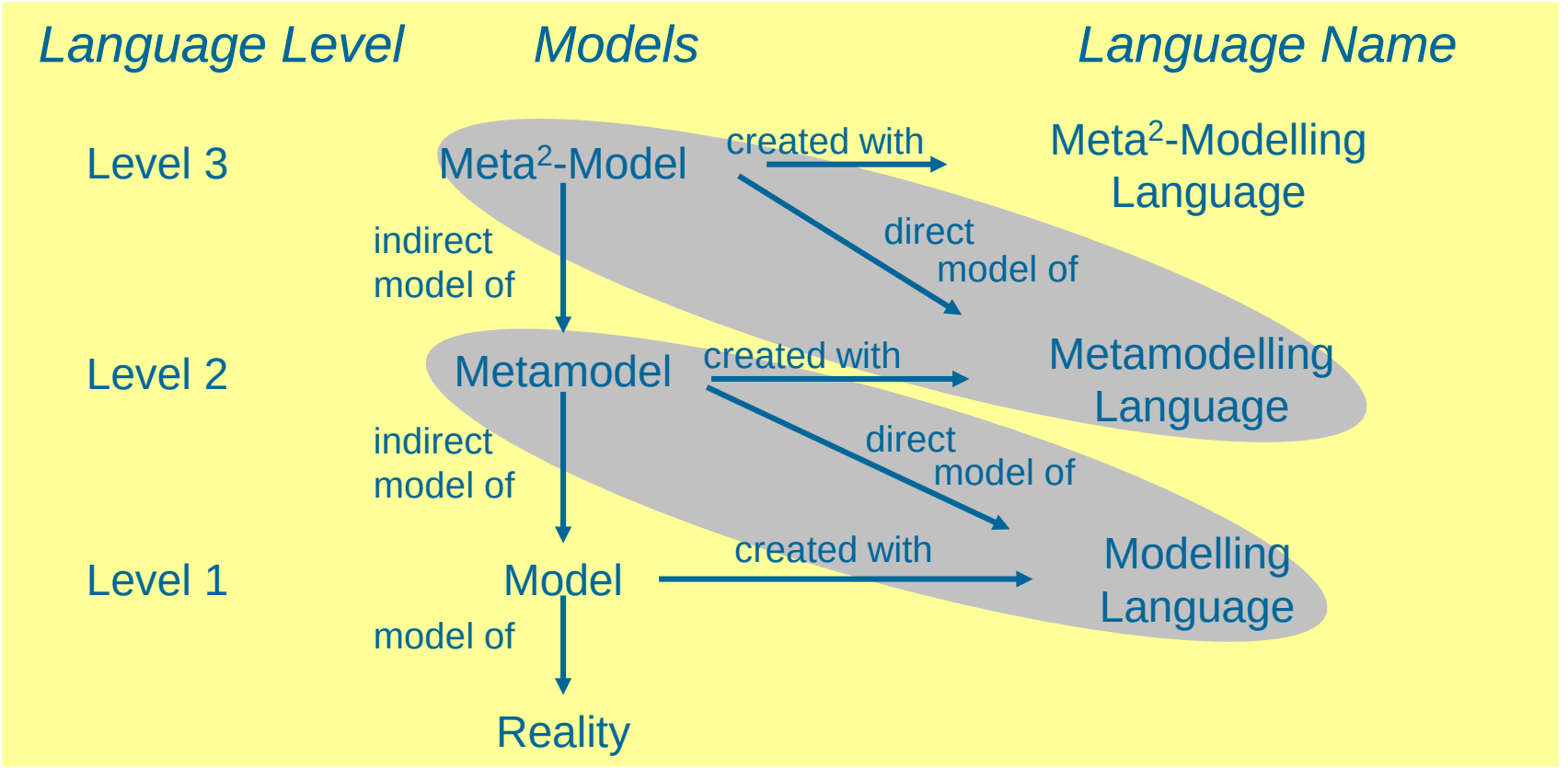
# Subset of the BPMN Metamodel in UML




Source: BPMN 2.0 specification

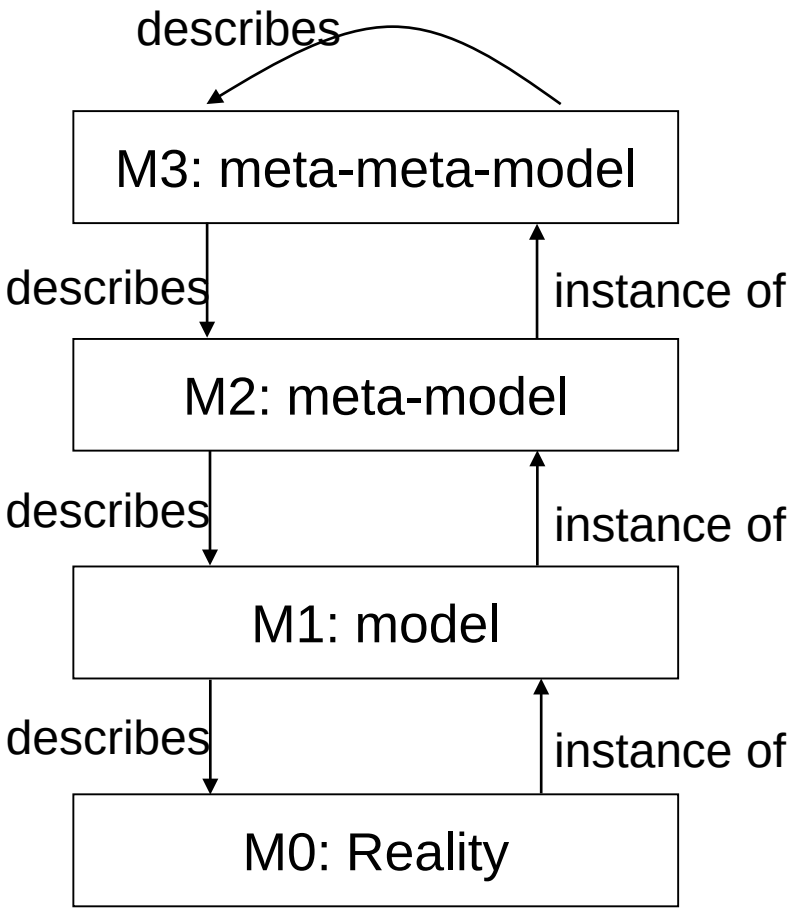
# Meta Model Hierarchy

The meta-model must again be described in some language, which has to be specified in a meta-meta-model




Karagiannis, D. & Kühn, H., 2002. Metamodelling Platforms. In K. Bauknecht, A. Min Tjoa, & G. Quirchmayer, eds. *Proceedings of the Third International Conference EC-Web at DEXA 2002*. Berlin: Springer-Verlag.

# The Model Stack simplified



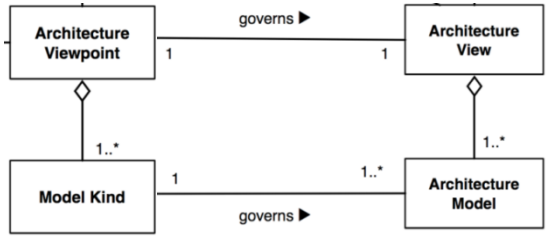

- A model is a ***simplified representation of a reality***
- A meta-model defines a **modeling language** in which a model can be expressed.
- A meta-meta model defines the **language in which a meta-model** can be expressed.

# Domain-specific vs. General-purpose Modeling Languages

- Domain-specific languages are notations which are defined to model knowledge about a specific domain

- General-purpose modeling languages can be used to represent any kind of knowledge

# Domain-specific Modeling Languages




- Domain-specific modeling languages have modeling elements for typical concepts and relations of a domain of discourse
- Domain-specific modeling languages correspond to *model kinds* which have modeling elements for concepts and relations to represent specific *views*
- Examples of domain-specific modeling languages:
  - **BPMN** is a domain-specific language for business processes
    - Modeling elements: task, event, gateway, ….
    - relations: sequence flow, message flow, data association, …
  - **ArchiMate** is a domain-specific language for enterprise architectures
    - Modeling elements: process, actor, role, business object, …
    - relations: uses, realizes, …

# Degree of Domain-Specificness

- BPMN is a domain-specific modeling language for business processes
- It would be possible to make BPMN more domain-specific for business processes in a specific application area, e.g.
  - Education: specific tasks for teaching like lecture, self-study, exam with predefined roles for lecturers and students
  - Health: specific tasks for diagnosis, therapy with roles like physician and patient

# Strengths and Weaknesses of Domain-specfic Modeling Languages

- Strengths
  - Comprehensiblity of models
    - elements and relations are adequate for stakeholders
    - domain-specific shapes
  - Reuse of models
    - domain-language can be standardized (e.g. BPMN, ArchiMate)
- Weaknesses
  - Restricted to a specific domain
    - Only what can be expressed with the modeling elements can be modeled

# What do we do if there is no Domain-specific Modelling Language

- If there is no domain-specific modelling language for a domain of interest, we have two options
  1. Define a new domain-specific modelling language
     - meta model
     - modeling language
  2. Use a general-purpose modeling language

# General-purpose Modeling Languages

- General-purpose modeling languages can be used to represent any kind of knowledge
- There are a wide range of general-purpose modeling languages
  - Natural language allows to express any knowledge
  - Formal languages: Typically a subset of Logic
  - Graphical Diagrams
- General-purpose graphical modeling languages have been developed in a many difference fields:
  - Artificial Intelligence: Semantic networks, Ontologies
  - Data Modeling: Entity Relationship Diagrams
  - Object-Oriented Programming: UML Class Diagrams

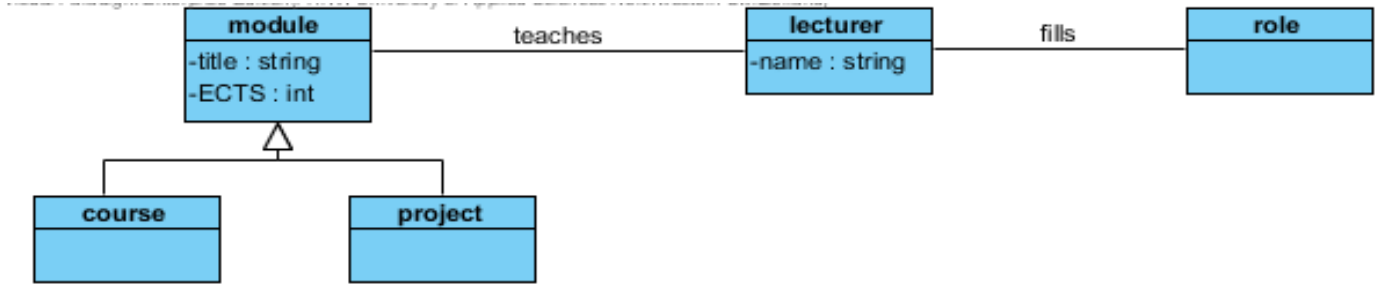
# The Metamodel for a General-purpose Modeling Language

- The metamodel for a general-purpose modeling language has only few modeling elements
  - Class
  - Attribute
  - Association
  - Object
- This can be modelled with Class Diagrams, e.g.
  - (a subset of) UML Class Diagrams
  - Ontology Languages
- Modeling means to
  - define classes
  - create instances of these classes

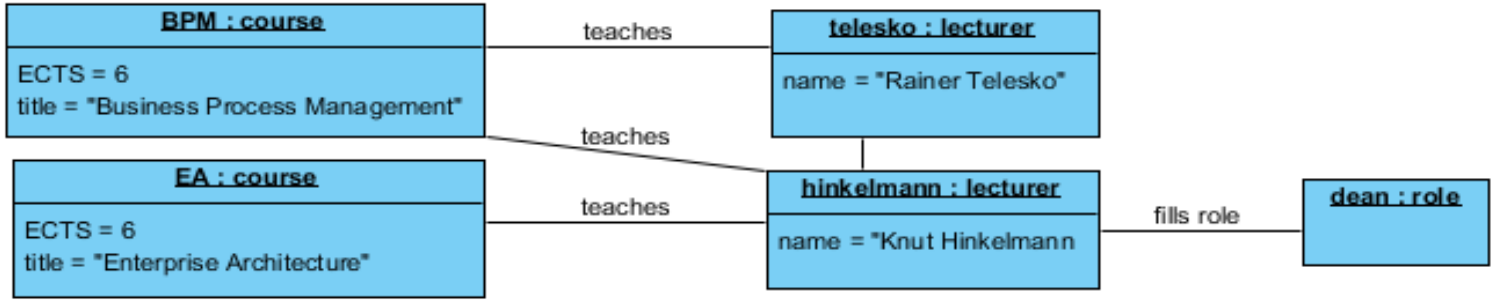
# Modeling with a General-purpose Modeling Language

The metamodel for this generic modeling language corresponds to subsets of UML Class Diagrams and UML Object Diagrams

Classes




Objects




The classes specify a (new) domain-specific metamodel – In this case for modeling modules of a study program

Disadvantage: No specific modeling shapes

# Customizing Modeling Languages in Visual Paradigm

- In the Visual Paradigm tool we can use stereotypes to specialize UML class diagrams.
- Stereotypes can be defined and added to any model element.
- We can define a new stereotype for a class and
  - change color
  - add an icon
- Example: stereotypes for modules and lecturer