New Modeling Frameworks for Indicators and Planning Actions

98th OGC Technical Committee
Washington, DC USA
Thomas H. Kolbe, Mostafa ElFouly, Maximilian Sindram
8th of March 2016
General Indicator Model (GIM)
Measuring City Performance

- Energy Indicators
- Ecological Indicators
- Social Indicators
- Financial Indicators
- Mobility Indicators

Evaluation is typically based on indicators, the most relevant are called Key Performance Indicators (KPIs).
Indicators

- Energy Indicators
- Mobility Indicators
- Ecological Indicators
- Social Indicators
- Financial Indicators

Geobase data

- CityGML Data
- Data from National Topography Models
- LADM Data
- INSPIRE Data
- BIM Data
Observations

1. Geobase data are available for entire countries and can be used for computing indicator values
   • (however, typically additional domain specific data are required)

2. All these geospatial information are based on standardised semantic data models / ontologies
   • e.g. 3D City Models: CityGML; European SDI: INSPIRE; BIM: IFC

3. So far, indicators are typically not formally modelled using a standardised framework

4. Furthermore, no systematic model exists yet for linking indicators and geobase data
Model Driven Engineering (MDE)

- … is a software engineering paradigm which began to evolve in the 1980s

- MDE puts the “model” in the form of formal specifications in the center of software analysis and design
  - Application relevant structures are represented by formal data models (e.g. using **Unified Modeling Language, UML**)
  - Program code is automatically derived from models

- MDE also addresses the linking of different models
  - This is called **Model Weaving**
  - Different models are linked by a **weaving model** which takes care of data transformation across the models
Geospatial Information Modelling

This is the general schema which all geospatial data models follow (e.g. CityGML, INSPIRE, LADM, national cadastre & topogr. models)

This is the data model of the 3D city model (here: CityGML) It defines the structures of all possible 3D city models

3D city model data, e.g. the objects of the 3D city model of Berlin
Indicator Modelling

Domain specific indicators follow a General Ind. Model

These are the indicator models from different application domains

Concrete indicators for concrete city / landscape objects
Requirements for Indicator Models

- Different types of indicators need to be distinguished (i.e. numerical, textual, categorical indicators)

- Complex indicators can be composed & computed from
  - attribute values from associated city / landscape model objects
  - constants
  - mathematical expressions (unary / binary arithmetic operations) on other indicators

- Indicator value aggregation (e.g. summation, average, maximum, etc.) of other indicators

- Augment indicator values with meta information like accuracy, lineage / source etc.
  - allowing for automatic sensitivity analysis
Domain Specific Indicator Modelling (I)

HeatDemand

Domain Indicators → General Indicator Model

Numeric Indicator + value

Domain of the stakeholder/application specialist

Energy Planner
Domain Specific Indicator Modelling (II)

Many of the reference objects in the context of urban indicators are spatial objects.

Energy Planner

Domain of the stakeholder/application specialist

Many of the reference objects in the context of urban indicators are spatial objects.
Linking Geospatial and Indicator Models

Geospatial Application Model (e.g. CityGML)

Weaving Model

Reference Objects

Object Related Domain Indicators

Domain Indicators

General Indicator Model

City Modeler

Energy Planner

Domal of the geodata provider

Domain of the stakeholder/application specialist

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General Indicator Modeling Framework

► Each **Indicator Application Model** is defined purely from the viewpoint and requirements of the domain specialist

- data is modeled and structured according to application domain needs only – and not according to a given geospatial data model

► The **data model** is separated into 5 consecutive sections

1. Abstract Indicator classes (e.g. numeric indicator)
2. Domain specific indicators (e.g. heat demand)
3. Object-related domain specific indicators (e.g. building heat demand)
4. Reference Objects for the indicators (e.g. building)

► The 5th section addresses linking of the indicator model with a geospatial application schema (like CityGML)

- Weaving Classes relate Reference Objects with Feature Types from the geospatial application schema
Linking Geospatial and Indicator Models

Geospatial Application Model (e.g. CityGML)

Weaving Model

Reference Objects

Object Related Domain Indicators

Domain Indicators

General Indicator Model

City Modeler

Energy Planner

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Linking of an Indicator Model to different Geospatial Application Models and BIM

- CityGML
- Weaving Classes 1
- Reference Object Classes
- Object Related Indicators Domain A
- General Indicator Model

Domains of the geodata / BIM providers

Model Weavings

Domain of the stakeholder/application specialist
Linking of an Indicator Model to different Geospatial Application Models and BIM

- CityGML
- INSPIRE
- BIM / IFC

Weaving Classes 1
Weaving Classes 2
Weaving Classes 3

Reference Object Classes

Object Related Indicators Domain A

General Indicator Model

Domains of the geodata / BIM providers

Model Weavings

Domain of the stakeholder/application specialist

Where do I get the data from?
Where can we use our data?
Linking of an Indicator Model to different Geospatial Application Models and BIM

We can analyse & compare how good / easy an indicator model fits to a specific geospatial application model!
General Planning Actions Model (GPAM)
KPIs \( t_{-1} \)

City Model \( t_{-1} \)

Reality \( t_{-1} \)

\[\text{calculation}\]

\[\text{registration}\]

\[\text{change}\]

KPIs \( t_0 \)

City Model \( t_0 \)

Reality \( t_0 \)

\[\text{calculation}\]

\[\text{registration/ update}\]

\[\text{modeled action}\]

\[\text{potential changes}\]

\[\text{planned actions}\]

City Model \( t_1\)

KPIs \( t_1\)

Reality \( t_1? \)

\[\text{NO data collection possible}\]

Reality \( t_1' ? \)

past \( t_{-1} \)

present \( t_0 \)

future \( t_1 \)
Formalization of Action Plans

→ Aim: making action plans virtually executable on 3D city models!
Properties of Planning Actions (I)

- Actions cause a change of the geometry or the attributes of the city objects
  - they are planned modifications / operations on the entities of a city

- Actions always pursue a specific goal
  - that is of different nature / motivation (e.g. monetary, cultural, personal) and is politically intended
  - can be measured by the impact on some key performance indicators (KPIs)

- Types of actions
  - extend existing objects (by new parts, properties, relations)
  - change existing objects (update attributes, relations)
  - remove existing objects (delete whole & parts, properties, relations)
Properties of Planning Actions (II)

► **Relations and dependencies** between actions – they can be composed of others, competing, conflicting, coherent

► Actions can be **applied to different reference units** from the city model
  - administrative boundaries → buildings → building parts
  - correspond to **concrete decision levels**

► Actions consist of an **ordered sequence of operations**
  - insert / delete / update of geometries, attributes, and relations

► Actions require **resources**
  - time, cost and goods
Data Model

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General Planning Actions Model (Draft)

- **Actions** _Action
  + function : String
  + description : String
  + levelOfDetail : int

- **Actions** _AbstractAction
  + before 0..*
  + after 0..*

- **Actions** _Resource

- **Actions** _Time
  + implementationDuration : int
  + int

- **Actions** _Goods
  + amount : float
  + currencyType

- **Actions** _Costs

- **Actions** _KeyPerformanceIndicator
  + description : String
  + targetValue : double
  + unit : String
  + impact : ImpactType

- **Actions** _Operation
  + operationTarget : XPath
  + type : String

- **Actions** _CityObject

- **Actions** _DeleteOperation

- **Actions** _InsertOperation

- **Actions** _UpdateOperation

- **Feature** _CityModel

- **Feature** _ObjectMember

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Semantics 3D City Model
- **refurbishment (energy)** (A): policy measure (1bn Euro)
- **sub action** (SA): renovation of a building
- **facade renovation** (S₁): insulation of a wall causes a change of U-value (of the wall)
- **window renovation** (S₂): exchanging windows causes a change of Uₗ-values (of the window)

German regulation

- (A): political funding (1m Euro in Munich)
- (SA): renovation of all buildings in main street
- (S₁) and (S₂): insulation of all buildings with: bricks (24cm) U-value > 0,8 W/m²K and double-glazed windows Uₗ-Wert > 1,1 W/m²K

11 and 12 main street

- **11 main street**: U-value = 0,7 and Uₗ-value = 2,0
- **12 main street**: listed building (age: 200)
- **13 main street**: U-value = 1,8 and Uₗ-value = 3,9

→ 11 partial renovation / 12 no renovation / 13 renovation

Buildings (11, 12 and 13 main street)
Bringing it all together
General Feature Model
ISO 19109

General Indicator Model

General Planning Actions Model

Energy Related KPIs Application Schema

Energy Planning Application Schema

Climate Related KPIs Application Schema

Traffic Planning Application Schema

KPI building X

KPI building Y

Facade retrofitting building X

CityGML Application Schema
References


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