Managing Space Requirements of New Buildings Using Linked Building Data Technologies

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September 13th 2018
# About me

<table>
<thead>
<tr>
<th>Year</th>
<th>Degree &amp; Details</th>
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<tr>
<td>2011</td>
<td>B.Sc. Architectural engineering, DTU</td>
</tr>
<tr>
<td>2013</td>
<td>M.Sc. Architectural Engineering, DTU</td>
</tr>
<tr>
<td>2013</td>
<td>HVAC-engineer, NIRAS (former ALECTIA)</td>
</tr>
<tr>
<td>2016</td>
<td>2,100 employees - offices in 27 countries</td>
</tr>
<tr>
<td>2016</td>
<td>Industrial PhD</td>
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<td></td>
<td>&quot;Digital Infrastructure and Building Information Modeling in the design and planning of building services&quot;</td>
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Disposition

- 01 Problem in scope
- 02 Linked Building Data
- 03 Requirement modeling
- 04 Implementation
- 05 Final Words
Problem in Scope
Building design

Planning

Design

Construction
Building design in reality

Planning → Design → Construction
“The perception of the project’s nature as ordered and linear is a fundamental mistake, as the dynamics of the surrounding world is not taken into account. Project management must perceive the project as a complex, dynamic phenomenon in a complex and non-linear setting.”

- Sven Bertelsen, 2003
Client’s requirements

Solution

Original goal

End result

Table 7.2.1. DINEN28014-1 (2008): "Installation of metal doors and window frames in buildings." The table lists various designations and requirements for metal doors and window frames.

<table>
<thead>
<tr>
<th>Door Type</th>
<th>Door Width</th>
<th>Door Height</th>
<th>Door Material</th>
<th>Door Weight</th>
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<tr>
<td>Entrance</td>
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<td>2100 mm</td>
<td>Steel</td>
<td>150 kg</td>
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<tr>
<td>Interior</td>
<td>800 mm</td>
<td>2000 mm</td>
<td>Aluminum</td>
<td>120 kg</td>
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<tr>
<td>WC</td>
<td>700 mm</td>
<td>2000 mm</td>
<td>Glass</td>
<td>80 kg</td>
</tr>
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</table>


tbl 7.2.1. DINEN28014-1 (2008): "Installation of metal doors and window frames in buildings." The table lists various designations and requirements for metal doors and window frames.

Client’s requirements

7.2.1.1. Calle- og størmakrofor

Golfkortomræde med tilknytning, der kan beslukkes samtidigt.

Change management

<table>
<thead>
<tr>
<th>No.</th>
<th>TOP</th>
<th>Date</th>
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<td>1.13</td>
<td>Design</td>
<td>29.09.2018</td>
<td>Needs to be clarified and documented.</td>
</tr>
</tbody>
</table>

Due to the client's request for more detailed documentation, the project team has agreed to provide a more comprehensive set of deliverables. This includes detailed specifications, as well as a schedule for the completion of each task. The project will be managed using a project management software tool, which will allow for real-time updates and progress tracking. In addition, the team will hold regular meetings to discuss project progress and any emerging issues. The project is expected to be completed by 31.12.2018.
Photo credit: knowledge by Nirbhay from the Noun Project
Photo credit: knowledge by Nirbhay from the Noun Project
LINKED BUILDING DATA COMMUNITY GROUP

This group brings together experts in the area of building information modelling (BIM) and Web of Data technologies to define existing and future use cases and requirements for linked data based applications across the life cycle of buildings. A list of recommended use cases will be produced by this community group. The envisioned target beneficiaries of this group are both industrial and governmental organisations who use data from building information modelling applications and other data related to the building life cycle (sensor data, GIS data, material data, geographical data, and so forth) to achieve their business processes and whom will benefit from greater integration of data and interoperability between their data sets and the wider linked data communities. For example, benefit may be obtained by publishing and combining localised data on new cheaper building materials, energy efficient building devices and systems, along with real time data on weather patterns, energy prices and geodata. By making this data available to applications, they will be better able to support decision makers during the whole of the building life cycle, which includes design, construction, commissioning, operation, retrofitting/refurbishment/reconfiguration, demolition, and recycling of buildings. The group will engage with these beneficiaries through surveys and events organised in collaboration with the affiliated workshop series on Linked Data for Architecture and Construction (LDAC).
**BOT**  The Building Topology Ontology

https://w3id.org/bot#

For describing any zone or element in its context of the building in which it belongs

**OPM**  Ontology for Property Management

https://w3id.org/opm#

For describing temporal design properties that are likely subject to changes

**PRODUCT**  Products’ ontology

https://w3id.org/product#

For describing products with relation to buildings

**PROPS**  Properties’ ontology

https://w3id.org/props#

For describing properties with relation to buildings
BOT
Main Classes

A spatial 3D division.
An instance of bot:Zone can contain other bot:Zone instances, making it possible to group or subdivide zones.

constituent of a construction entity with a characteristic technical function, form or position

Zone Subclasses
Selected relationships

- bot:Zone
- bot:Element
- arch:spaceA
- arch:spaceB
- arch:WC1

Relationships:
- bot:adjacentZone
- bot:containsElement

Ontology:
- TBox
- ABox
- rdf:type
Requirement modeling
Competency questions

- How to model a space type?
- How to assign a quantitative requirement to a space type?
- How to state that a designed space instance matches a space type of the client’s requirements specification?
- How to check if a property that also exists as a requirement is fulfilled by the architectural design?
- How to check an adjacency or quantity requirement?
- How to update a space type and its assigned requirements?
All instances of bot:Zone have a props:area of 25 m²
client:spaceTypeBathroom is a specific kind of bot:Space that has a props:area of 25 m²
client:spaceTypeBathroom is a specific kind of bot:Space that has a props:area which was most recently specified as an opm:Requirement instance having an area of 22-28 m²
The props:area of arch:spaceB was most recently specified as 23 m². This is an instance of client:spaceType-Bathroom.
Another space instance: `arch:spaceG` has a `props:area 26 m²`. Also a `client:spaceTypeBathroom`. 
Checking that the requirements are met

SELECT *
WHERE {
# Must be a space
?space rdf:type bot:Space .
# Sub-query to get requirement
{
WHERE {
?reqURI opm:hasPropertyState ?reqState .
?reqState rdf:type opm:Required .
OPTIONAL {?reqState schema:value ?reqVal}
OPTIONAL {?reqState schema:minValue ?reqMin}
OPTIONAL {?reqState schema:maxValue ?reqMax}
}
}
# Get property
FILTER(?propURI != ?reqURI) # Disjoint from req
?propURI opm:hasPropertyState ?propState .
?propState schema:value ?val
# Compare requirements to actual value
BIND( ?value < ?reqMin AS ?minViolated )
BIND( ?value > ?reqMax AS ?maxViolated )
# Show only results where a requirement is violated
FILTER( ?matchViolated || ?minViolated || ?maxViolated )
}
Checking that the requirements are met

```sparql
SELECT *
WHERE {
    # Must be a space
    ?space rdf:type bot:Space .
    # Sub-query to get requirement
    {
    WHERE {
      ?reqURI opm:hasPropertyState ?reqState .
      ?reqState rdf:type opm:Required .
      OPTIONAL {?reqState schema:value ?reqVal}
      OPTIONAL {?reqState schema:minValue ?reqMin}
      OPTIONAL {?reqState schema:maxValue ?reqMax}
    }
    # Get property
    FILTER(?propURI != ?reqURI) # Disjoint from req
    ?propURI opm:hasPropertyState ?propState .
    ?propState schema:value ?val
    # Compare requirements to actual value
    BIND( ?value < ?reqMin AS ?minViolated )
    BIND( ?value > ?reqMax AS ?maxViolated )
    # Show only results where a requirement is violated
    FILTER( ?matchViolated || ?minViolated || ?maxViolated )
  }
}
```

Checking that the requirements are met
No requirements are violated

Query will return no results
Requirement change
Requirement violated
Design change

Requirement violated
Other requirements

- Same approach can be used for any other quantitative property requirement

- Slightly different queries for:
  - Topological requirements (kitchen must be adjacent to living room)
  - Element containment requirement (bed room must contain two single beds)
  - Element adjacency requirement (must be adjacent to a fire escape door)
Revit plug-in

<table>
<thead>
<tr>
<th>User input</th>
</tr>
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<tbody>
<tr>
<td>{{host}}/{{projectNo}}/{{IFC-GUID}}</td>
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</table>
Final words
Conclusions

• Requirements modeled using existing ontologies
  
  • LBD: BOT OPM PROPS

• Same approach possible for bot:Building/bot:Site/bot:Storey/bot:Element

• Methods to identify and act on changes in requirements + design

• Knowledge base capable of answering all competency questions
Future work

- Derived properties
  - Indoor Climate Class + clothing + activity level yields max/min temperature
  - Fire sectioning yields requirements for fire- and smoke dampers
- Documentation + legal aspects
- Implementations