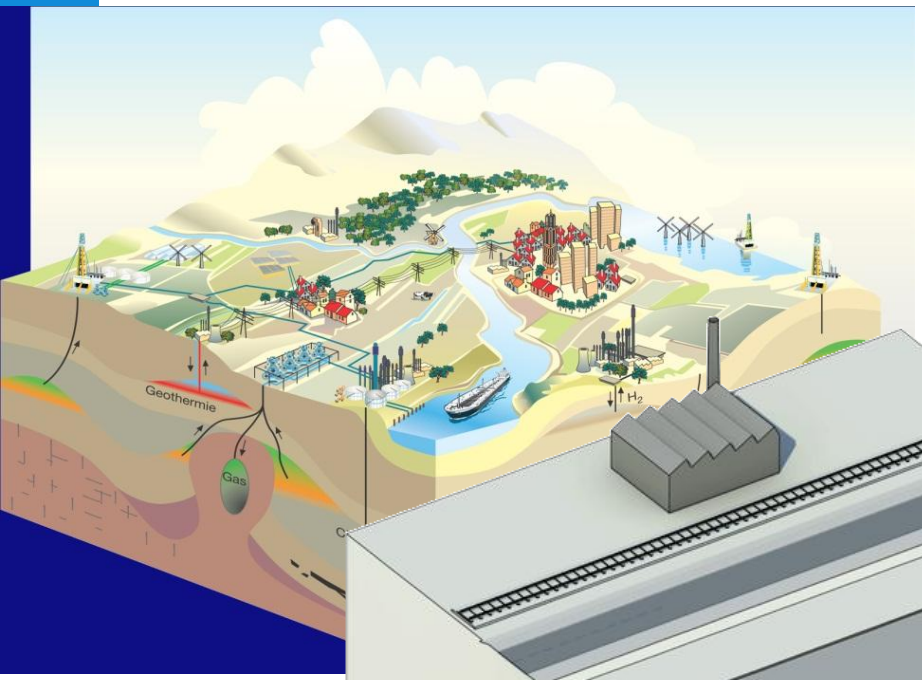
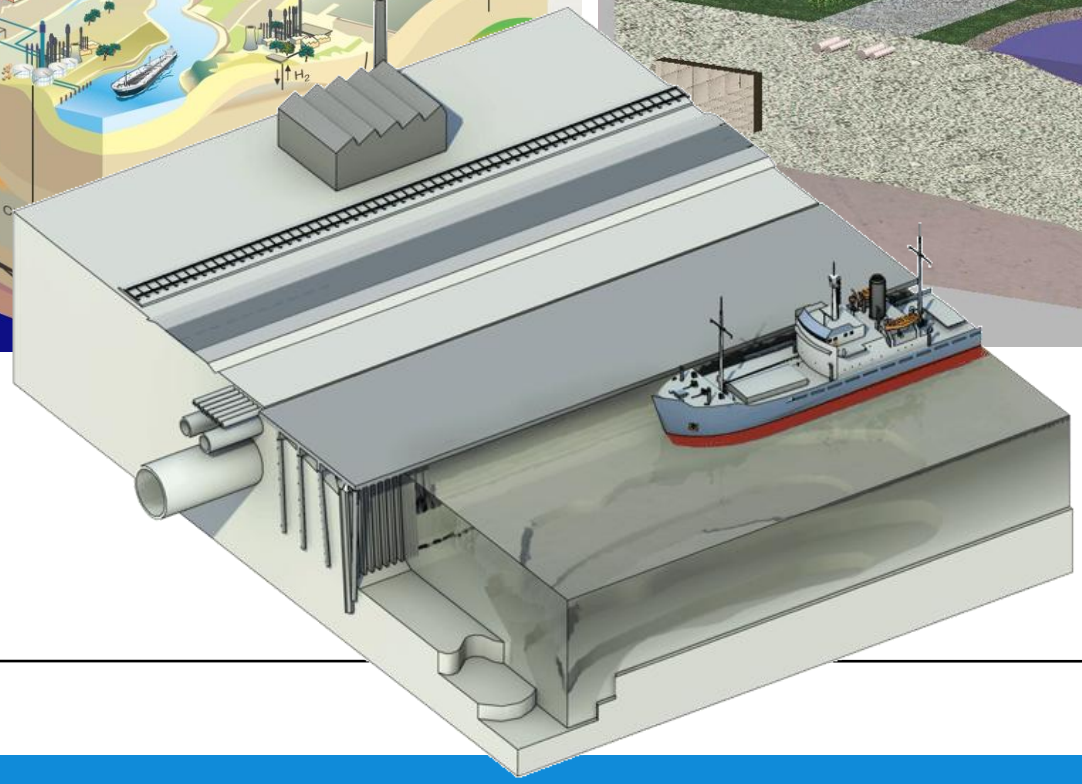
3D TOPOLOGY FOR MODELLING OF URBAN STRUCTURES

Tarun Ghawana & Sisi Zlatanova

Increased awareness of underground information

Ludvig Emgard

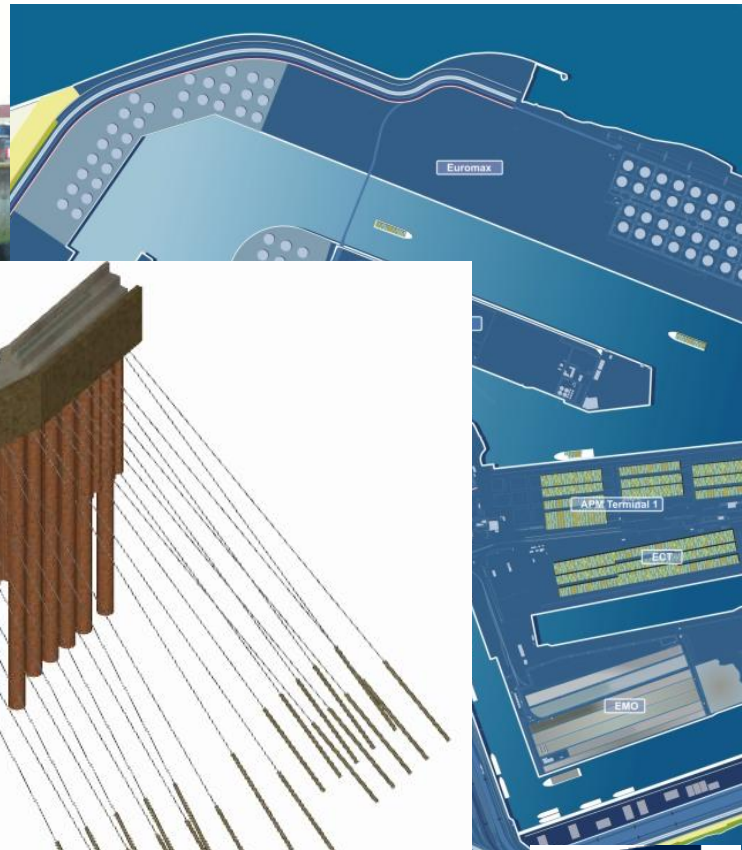




Jakob Beetz

Infrastructure Projects
Maasvlakte 2, Port Rotterdam

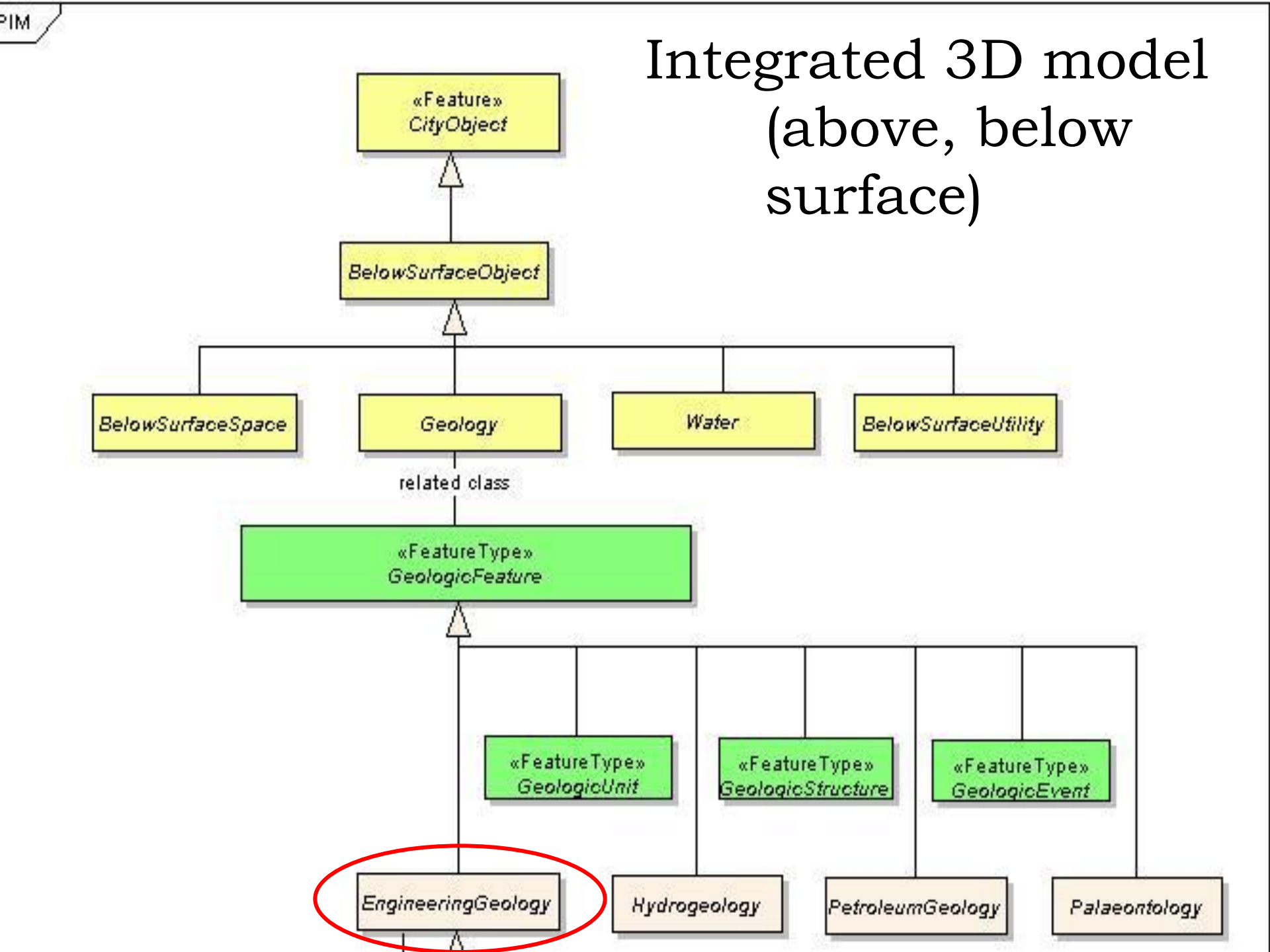
http://maasvlakte2-3dsdi.ddss.nl/

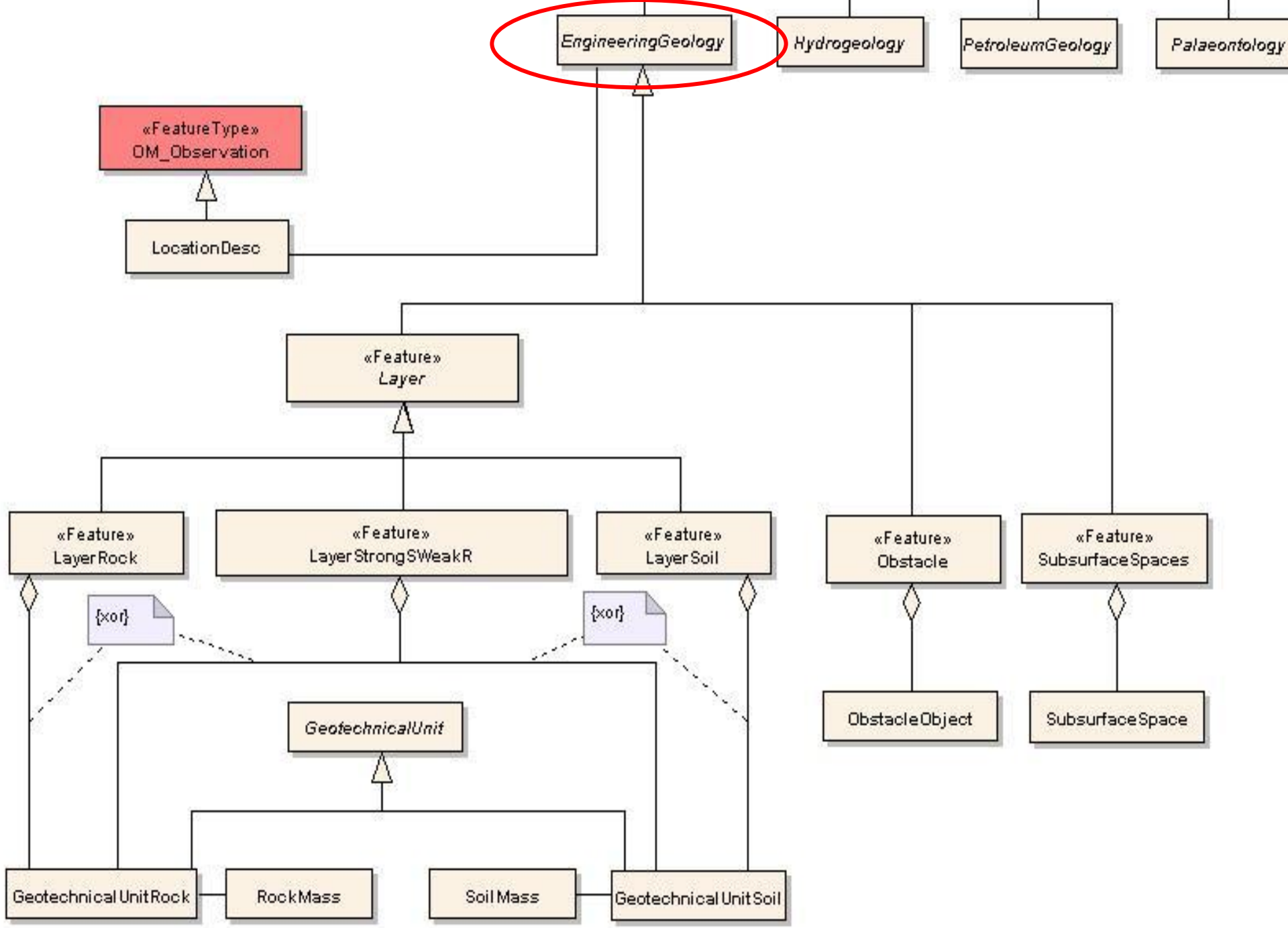


Port of Rotterdam
PROJECTORGANISATIE MAASVLAKTE 2


Physical models!
NAR
-22.30

Integrated 3D model (above, below surface)




EngineeringGeology
Hydrogeology
PetroleumGeology
Palaeontology
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SubsurfaceSpaces
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GeotechnicalUnit
ObstacleObject
SubsurfaceSpace
GeotechnicalUnitRock
RockMass
SoilMass
GeotechnicalUnitSoil

Spoorzone Delft

Renovation of the area of the railway station

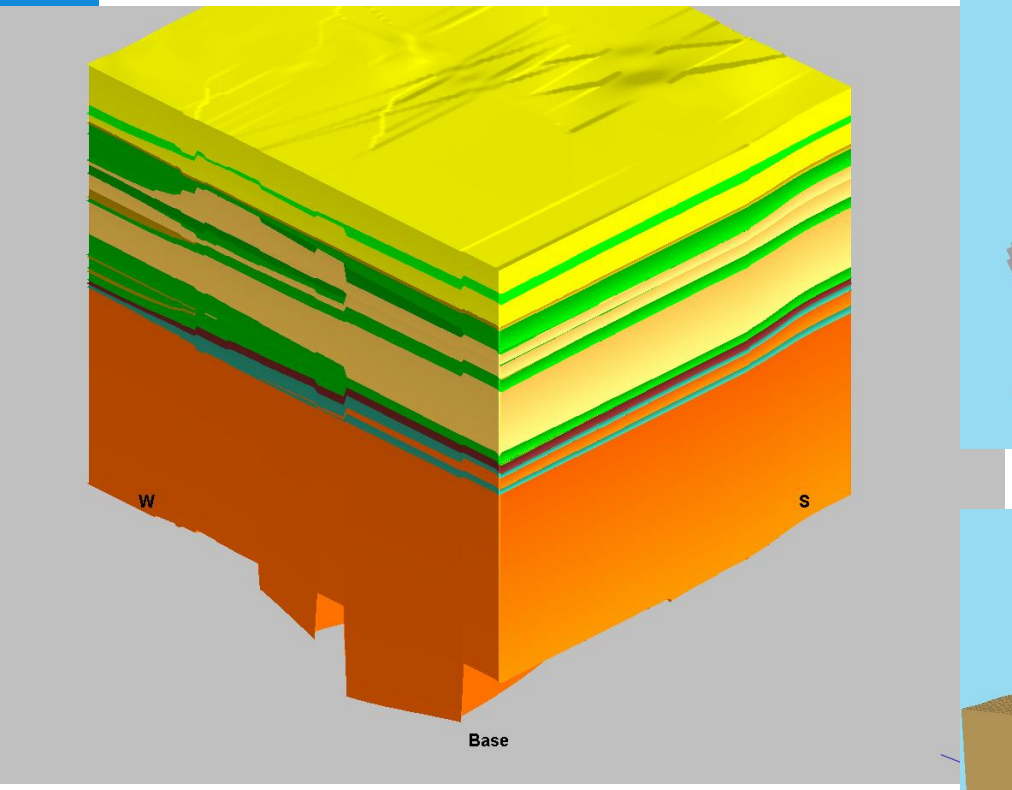
- Drawings, images
- 2D plans and sections
- Vertical sections
- 3D physical models
- Lots of documents

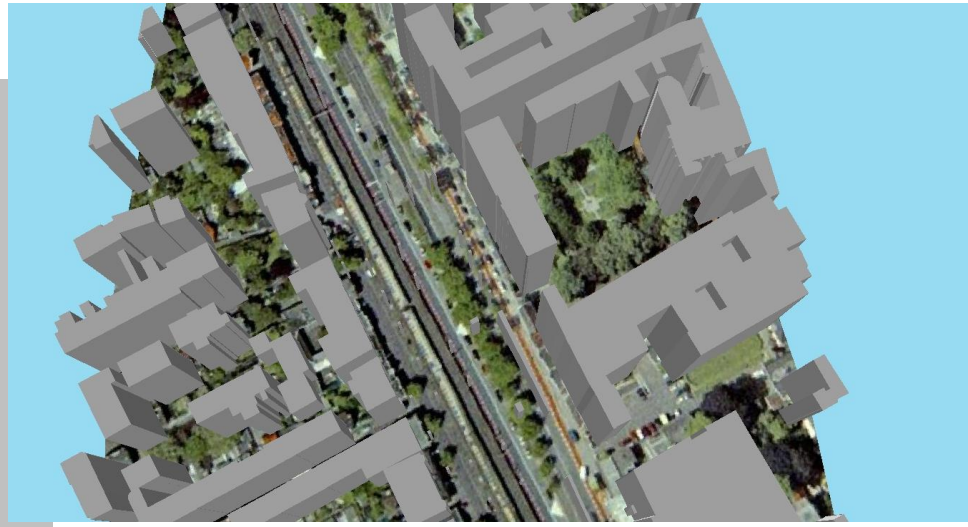
Creating the 3D model

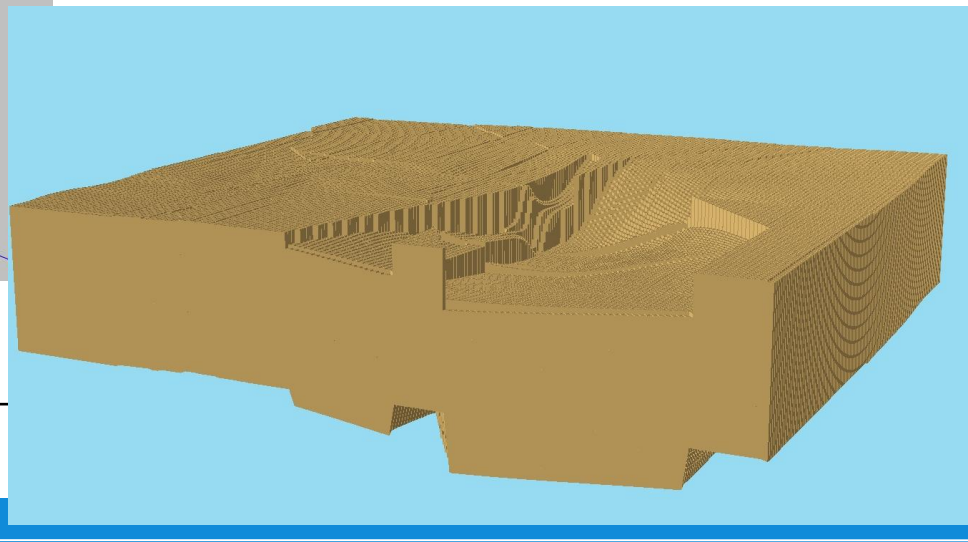
- Above surface
  - Buildings (extrusion)
  - Terrain (with integrated surfaces objects as streets, bicycle paths, pavements
  - Boreholes, soundings (given as points on the surfaces)

- Below surface
  - Loading measurements in the tables
  - Interpretation of boreholes and soundings
  - Modelling of the surfaces in RockWorks and export of shape files to get the geometry

Integration of all data in ArcGIS

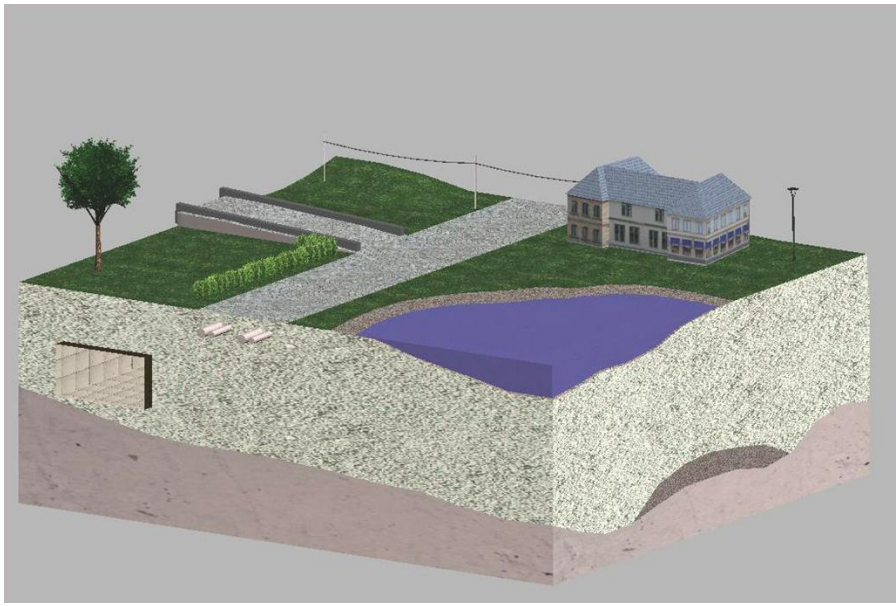




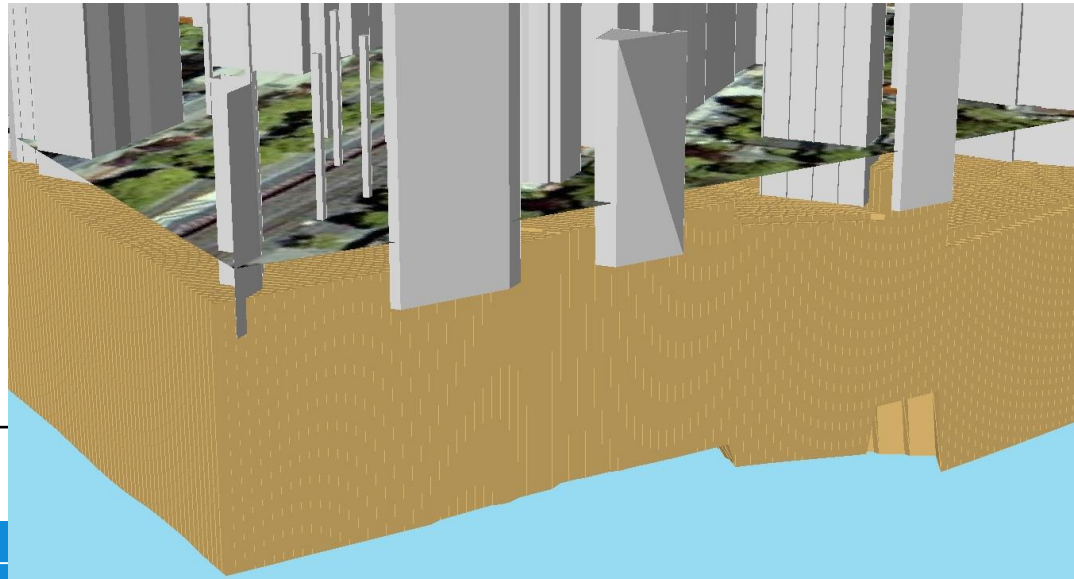


Wiebke Tegtmeier

The result …



- We had geometries:
  - Self-intersecting objects
  - Intersecting objects
  - Overlaps
  - Gaps between objects
  - …



… Many issues familiar from 2D cases…

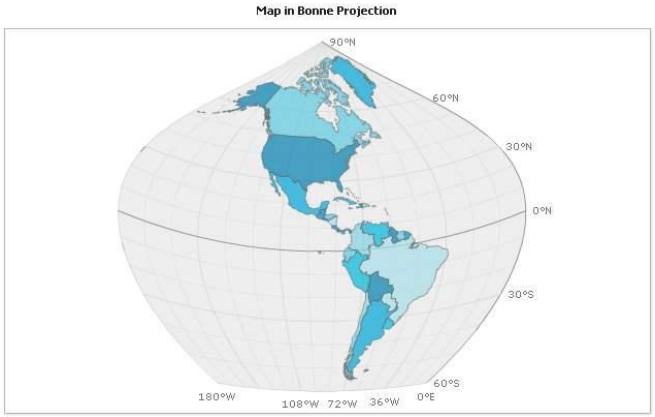
- Complex constructions
- Vertical and horizontal dimensions

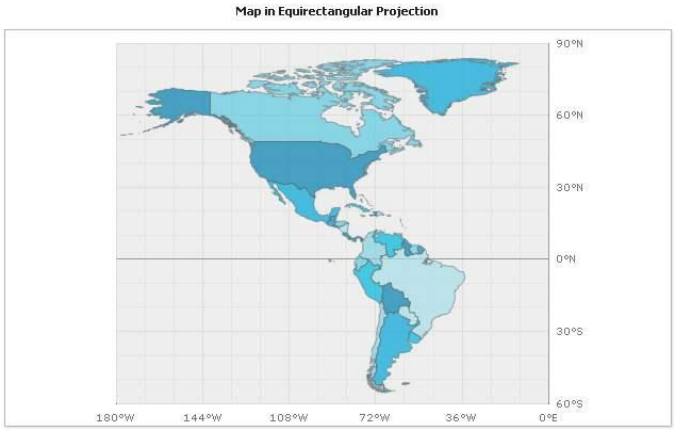
- Correct geometries (wind should not blow through the buildings)
- Geometric analysis (compute volumes)

….Can we have an integrated topological model?

Where topology can be useful?

- Data modelling (construction and validation)
- Analysis (after structuring in a topological model)

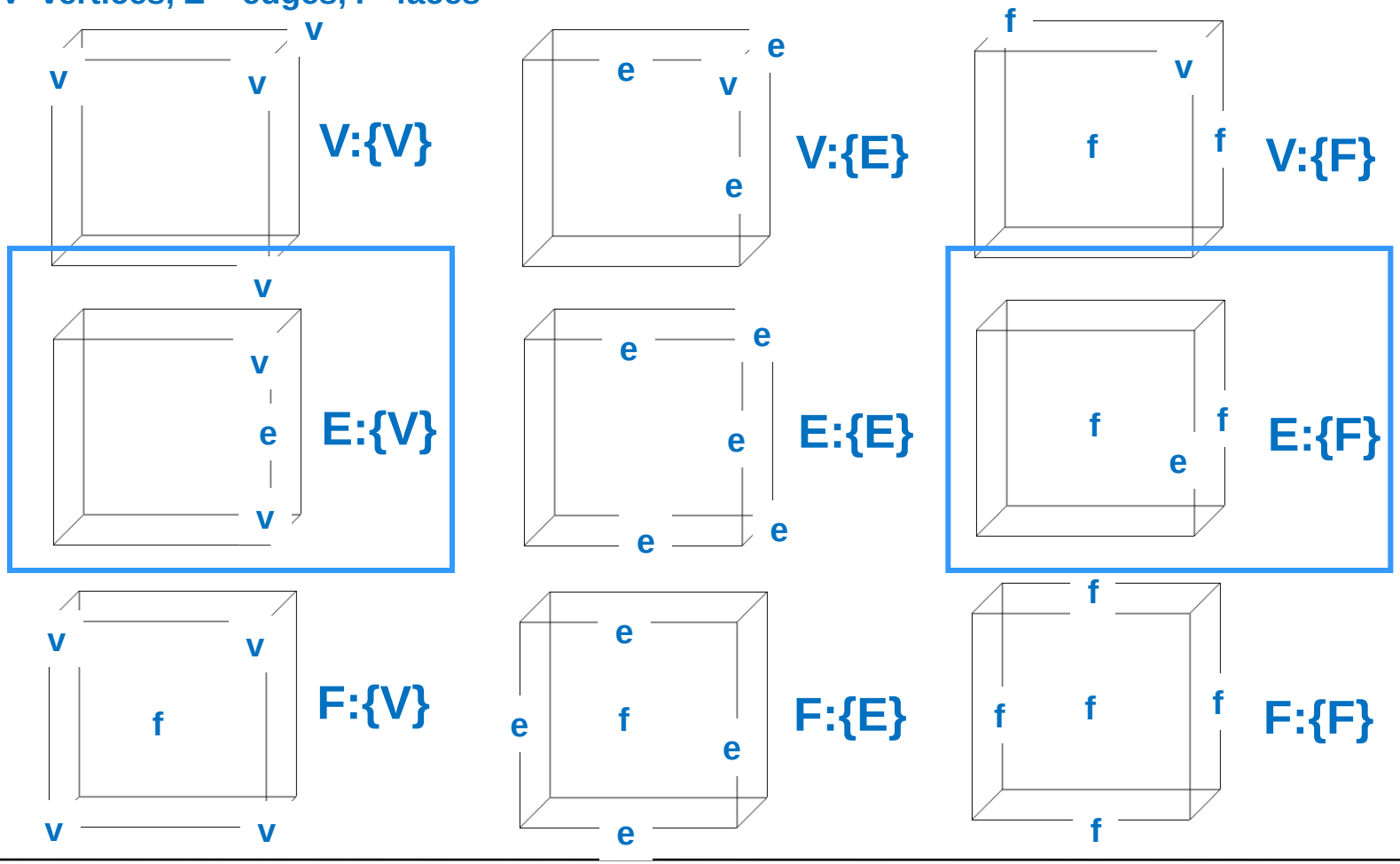




Models in CG

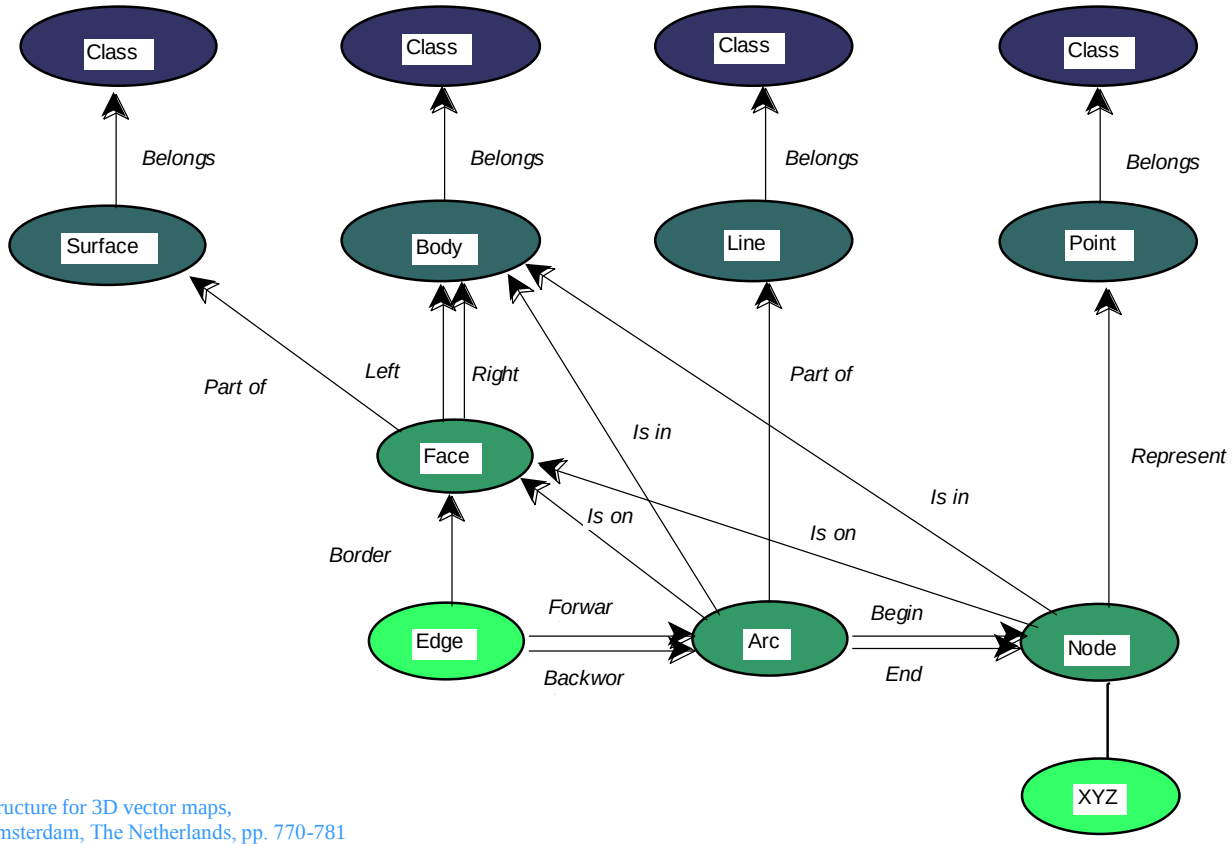
Only few relations are constant:
Edge-vertex (1edge has 2 adjacent vertices)
Edge-face (1edge has 2 adjacent faces)

V- vertices, E – edges, F- faces



Adapted from Baer, A., C.Eastman and M. Henrion, 1979, Geometric modelling: a survey, Computer Aided Design, vol. 11(5) pp. 253-272

Example GIS: 3D Formal Data Structure (3D FDS)



Molenaar, M. (1990): A formal data structure for 3D vector maps,
in: Proceedings of EGIS'90, Vol. 2, Amsterdam, The Netherlands, pp. 770-781

3D (spatial) models

- Semantic (thematic)
- Geometry (coordinates, derive relationships)
- Appearance
- Topology (relationships, derive coordinates)
  - explicit primitives
  - explicit relationships

Models in GIS

• Topology	• Very rare
• Topology/Geometry	• Very rare
• Geometry/Topology	• Possible
• Geometry	• Most often
• Geometry/Semantics, Semantics/Geometry	• Very often
• Semantics/Geometry/Topology	• Possible

Above surface

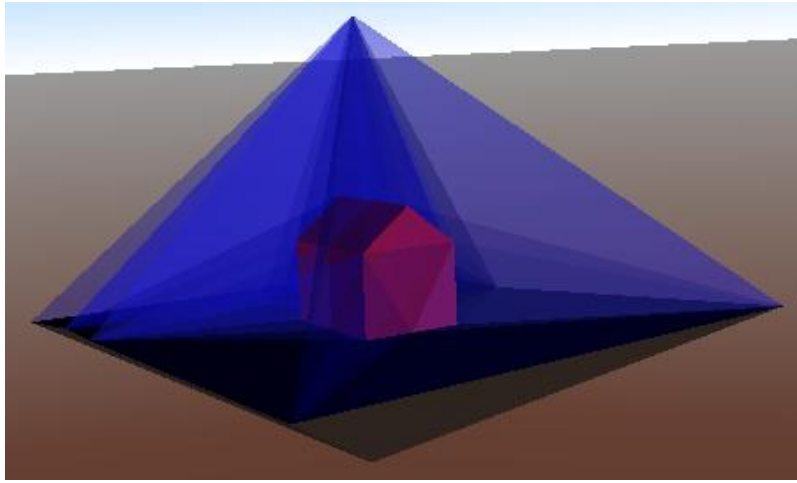
3D Model	Supported Primitives	Constraints on primitives	Relations between primitives	Representation of objects	Subdivision of space	Thematic Semantics (yes, no)
3D FDS	Node, Arc, Edge, Face	node has unique coordinates Arc is straight lines Face is planar	arc has two nodes arc has left and right face ace has left and right body. Singularities: node-on-face, arc-on-face, node-in-body and arc-in-body.	Point: node Line: arcs Surface: faces. Body: faces (closed volume). .	Full	Theme Classes
TEN	Node. Arc, Triangle, Tetrahedron,	Node has unique coordinates Arc is straight lines	Arc has two nodes Triangle has three arcs Triangle has left and right tetrahedron Singularities are not permitted.	Point: nodes Line: arcs Surface: triangles Body: tetrahedrons	Full	Theme classes
SSS	Nodes, Faces,	Node has unique coordinates Arc is straight lines Face is planar and convex	Faces are described by nodes Singularities: node-in-face and face-in-body	Point: nodes Line: nodes Surface: faces Body: faces (closed volume)	Embedding (single-valued)	Not Discussed
CityGML	Point, Curve, Surface, Solid	Primitive is described by set of coordinates (GML3 compliant geometry).	Xlinks for topology implementation between solids. Xlinks performs aggregates to components directional topology.	Point: point Line: curve Surface: surface. Body: surface/volume	Embedding (single valued)	Yes

Below surface

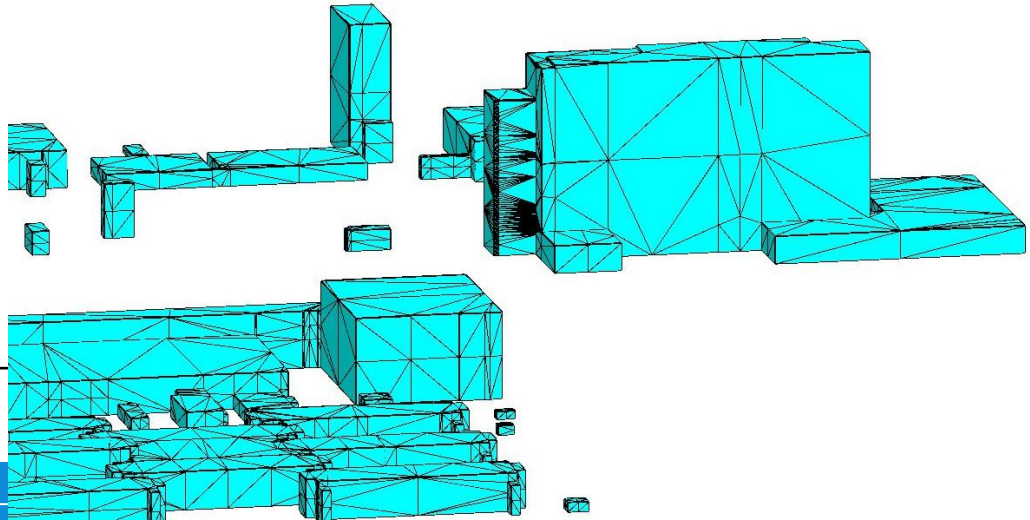
Integral Real -3D Spatial Model *G-GTP*	Generalised tri-prism (GTP)	Side-face is planar (subdivision to prism or tetrahedron with diagonals)	GTP has: 6 nodes, 6 TIN-edges, 3 Side-edges, 2 TIN-faces, 3 Side-faces, 3 diagonals	Body: GTP	Full	Not discussed
3D Vector Topological Geological Model	Point, Line, Face, Polyhedron	Polyhedron must be valid.	Face in a multi-hierarchic network. Node connects more than two edges or arris Face has arris.	Body: polyhedron	Full	Yes
3D OO-Solid Model	Node, Arc, Polygon, Region, Solid	Node has coordinates (6 types of nodes) Polygon must have orientation	Arc has 2 nodes Polygon is composed of arcs Region has polygons	Line: arc Surface: regions Simple volume: regions (closed) Composed volume: simple volume.	Full	Yes

Comparison

F. Penninga and P.J.M. van Oosterom, 2008,
A simplicial complex-based DBMS approach to 3D topographic data modelling
In: International Journal of Geographical Information Science, Volume 22, 7, 2008, pp. 751-779



- Above surface:
  - Polyhedron (when 3D primitive)
  - Faces (for texturing), arcs, nodes
  - Full subdivision of space
- Below surface:
  - Polyhedron/Prism/Tertahedron
  - Full subdivision of space



Adding topological model

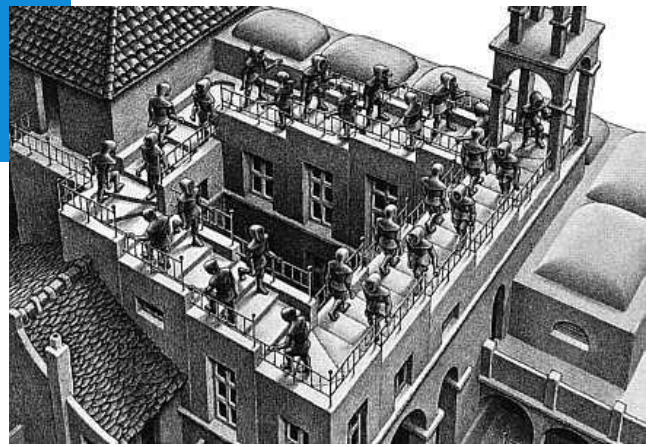
- What kind of primitive for the 3D
  - Tetrahedron based-model
    - (-) Subdivide objects, which might become very complex as the LOD increases
    - (+) simple and robust model; can be maintained easily
  - Polyhedron-based
    - (-) Require check of many rules (closed, orientable, non-intersecting)
    - (+) Closer to the real outlook of objects.

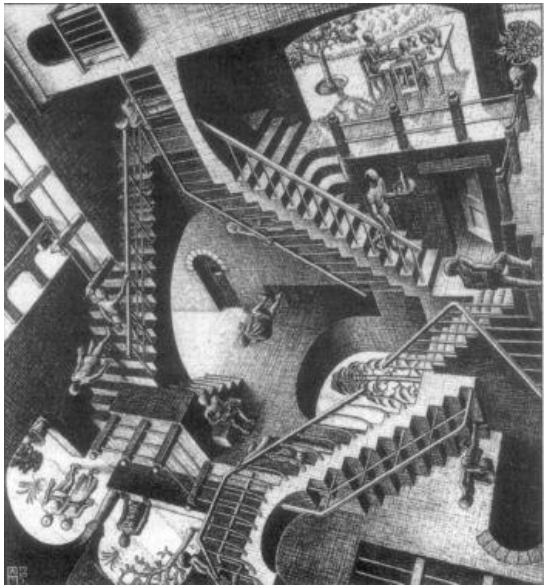
- What kind of relationships (data structure)
  - Still not uniformity
  - Study CG solutions

Conclusion

- Current software
  - hardly provides valid 3D objects (polyhedrons)
  - does not offer 3D topological structures
- The work on 3D topological model should consider above and below objects.
- Investigate other volumetric data structures

3D Topology?





Maurits Cornelis Escher (1898-1972)