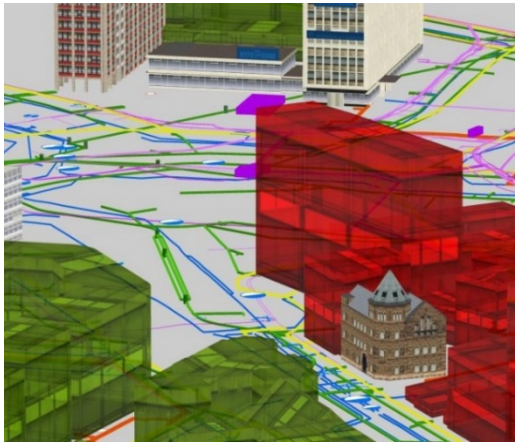
CityGML Utility Network ADE – Semantic modeling of 3D utility networks



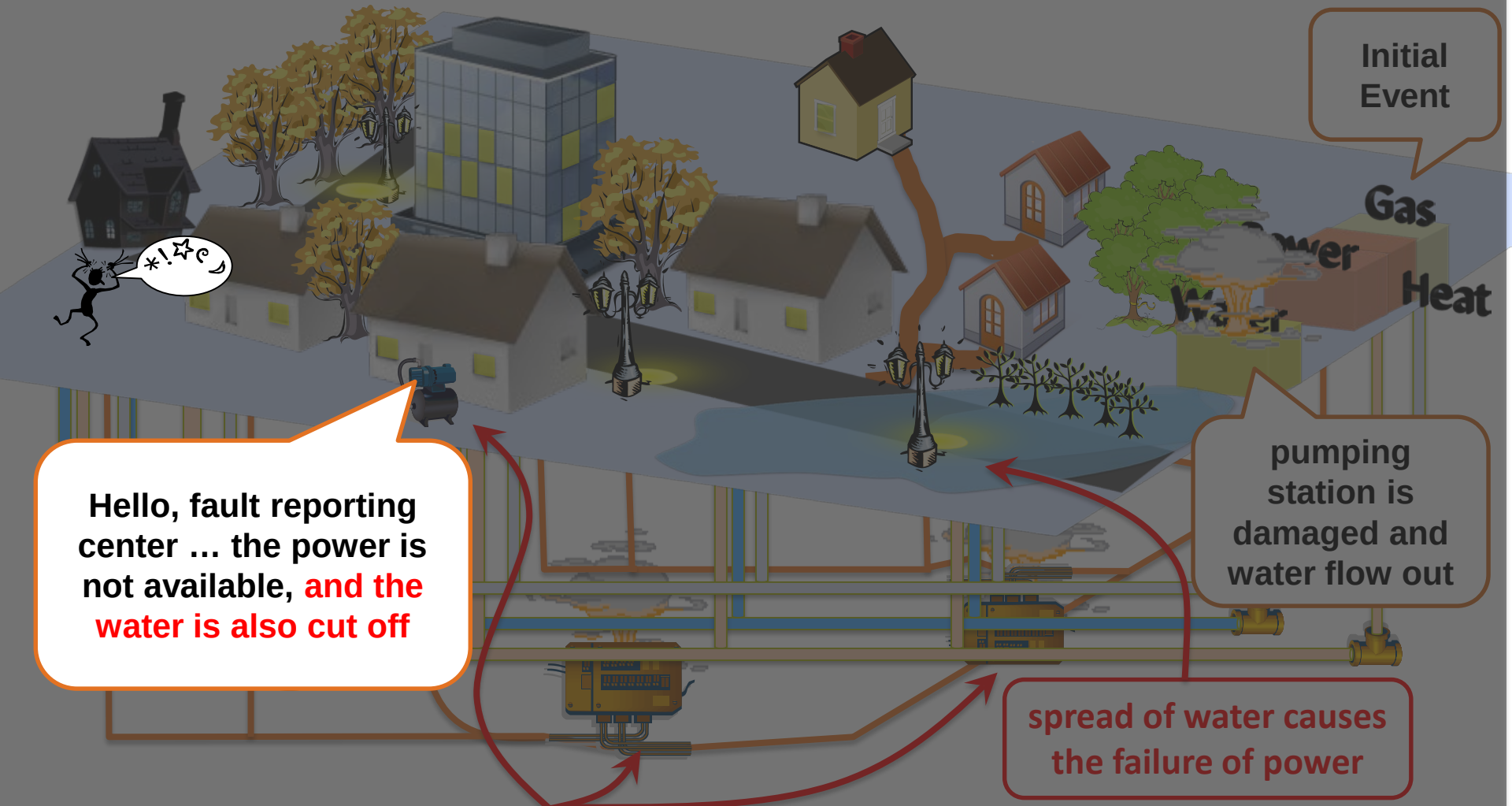
Tatjana Kutzner, Thomas H. Kolbe

Chair of Geoinformatics
Technical University of Munich

kutzner@tum.de, thomas.kolbe@tum.de

Intelligence in Subsurface Infrastructure Workshop
Enschede, November 27, 2017

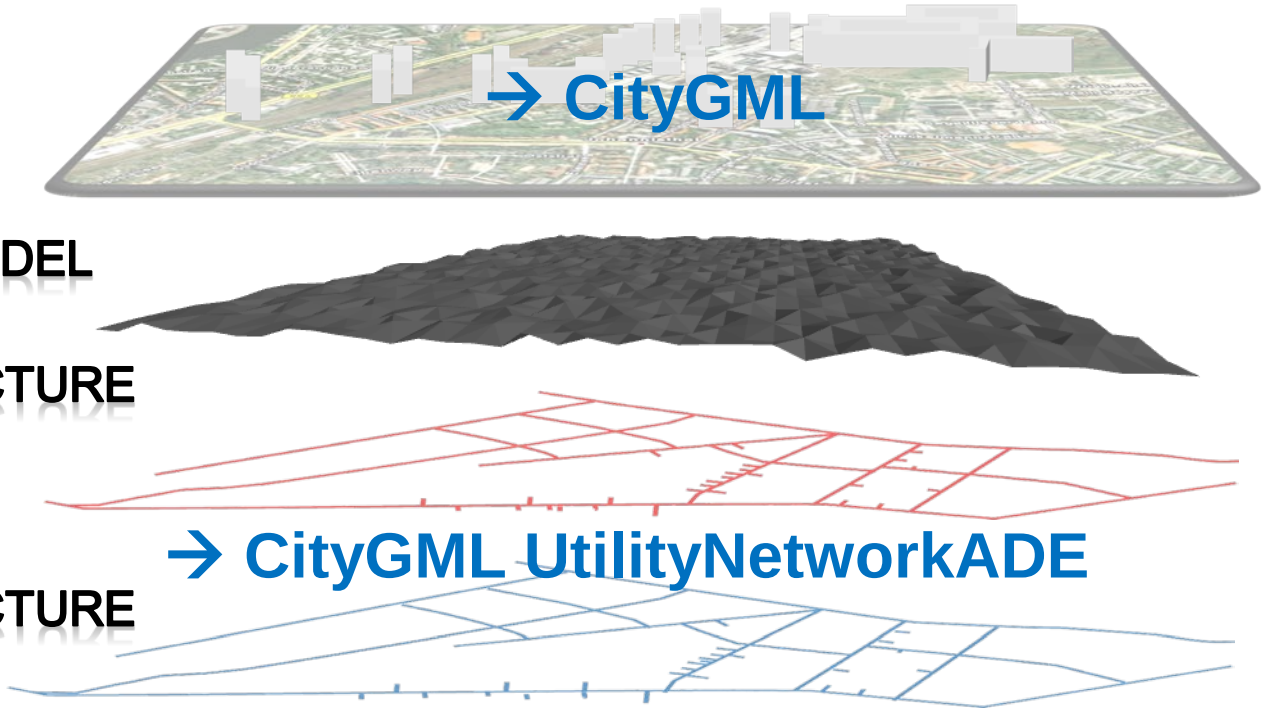
Motivation


Initial Event
Gas
Heat
Hello, fault reporting center … the power is not available, and the water is also cut off
pumping station is damaged and water flow out
spread of water causes the failure of power
due to the power failure, the pumps won‘t work

Integration of Utility Networks into the 3D City Model

- **Goal:** Development of a homogenized 3D network model for multi-utility failure simulation including the relevant thematic attributation (usage type, commodity, materials, operating parameters, no. of affected citizens etc.)

SEMANTIC
3D CITY MODEL
+
HIGH RESOLUTION
DIGITAL TERRAIN MODEL
+
UTILITY INFRASTRUCTURE
OF TYPE A
(E.G. ELECTRICITY)
+
UTILITY INFRASTRUCTURE
OF TYPE B
(E.G. WATER)



Projects using the Utility Network ADE

Disaster Management with SIMKAS 3D

- Simulation of intersectorial cascading effects caused by a failure of supply infrastructures using the 3D city model of Berlin (2009-2012)
- Focus on
  - simulating interdependent crisis situations
  - linking of situation information with the urban space
  - implementation of a common situation map which also allows for individual views and analyses by each provider
- An ArcGIS geodatabase was implemented based on the Utility Network ADE

Risk Analysis Supply Infrastructure

- Cooperation project with the company ESG (Germany) on behalf of the German Armed Forces (2015-2016)
- Study on the possibilities of utilizing supply infrastructures in training simulators
  - for crisis scenarios (e.g. evacuation)
  - for simulating the impact of a failure on the population
  - for simulating the impact on tactical operations

SIMKAS 3D

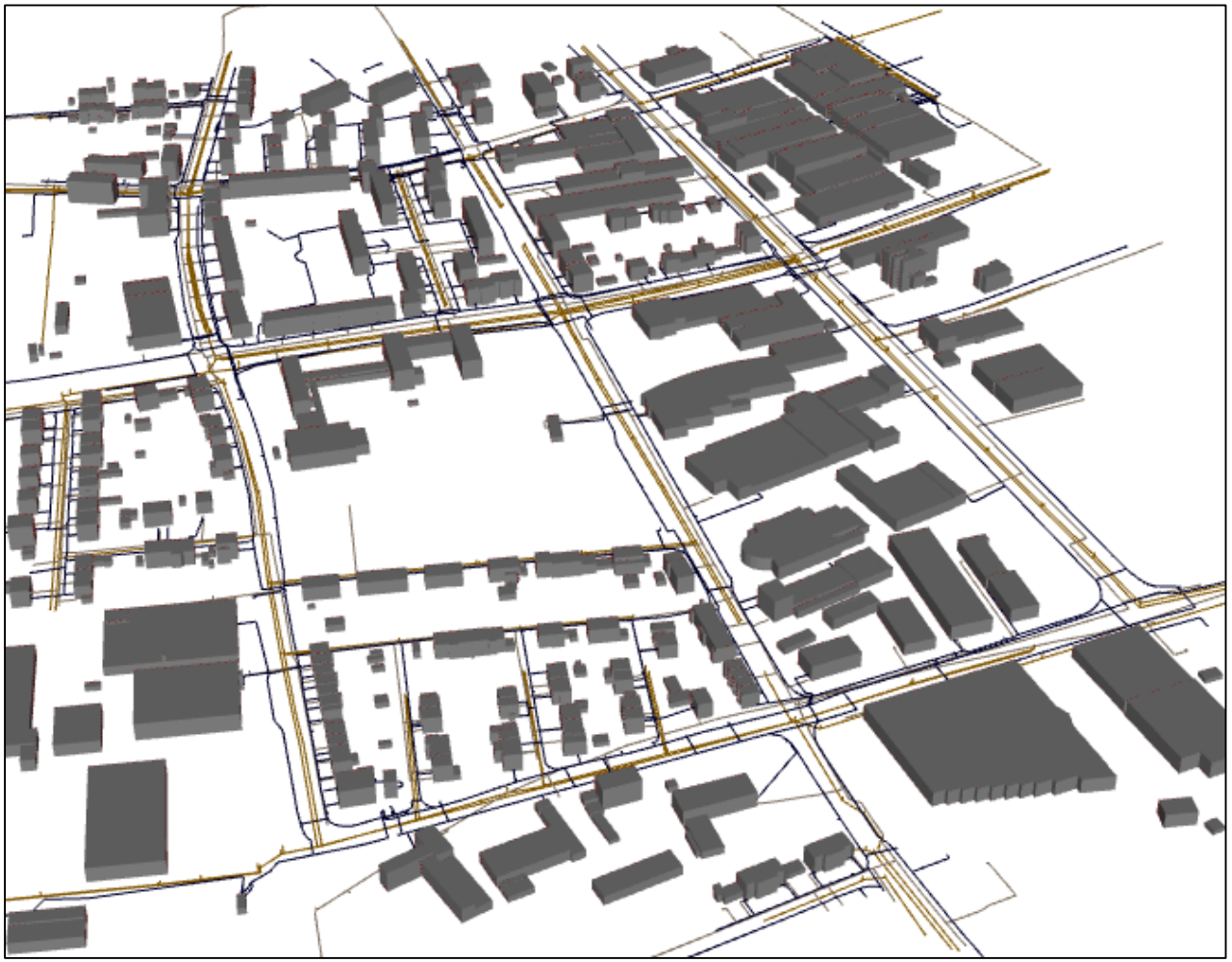
Das 3D-Stadtmodell von Berlin mit integrierten Infrastrukturen

Institut für Geodäsie und Geoinformationstechnik
Technische Universität Berlin

Hinweis: Die Präsentation spiegelt lediglich einen momentanen Bearbeitungsstand wieder, soll aber trotzdem den Kontext bzw. zukünftige Entwicklungen verdeutlichen!

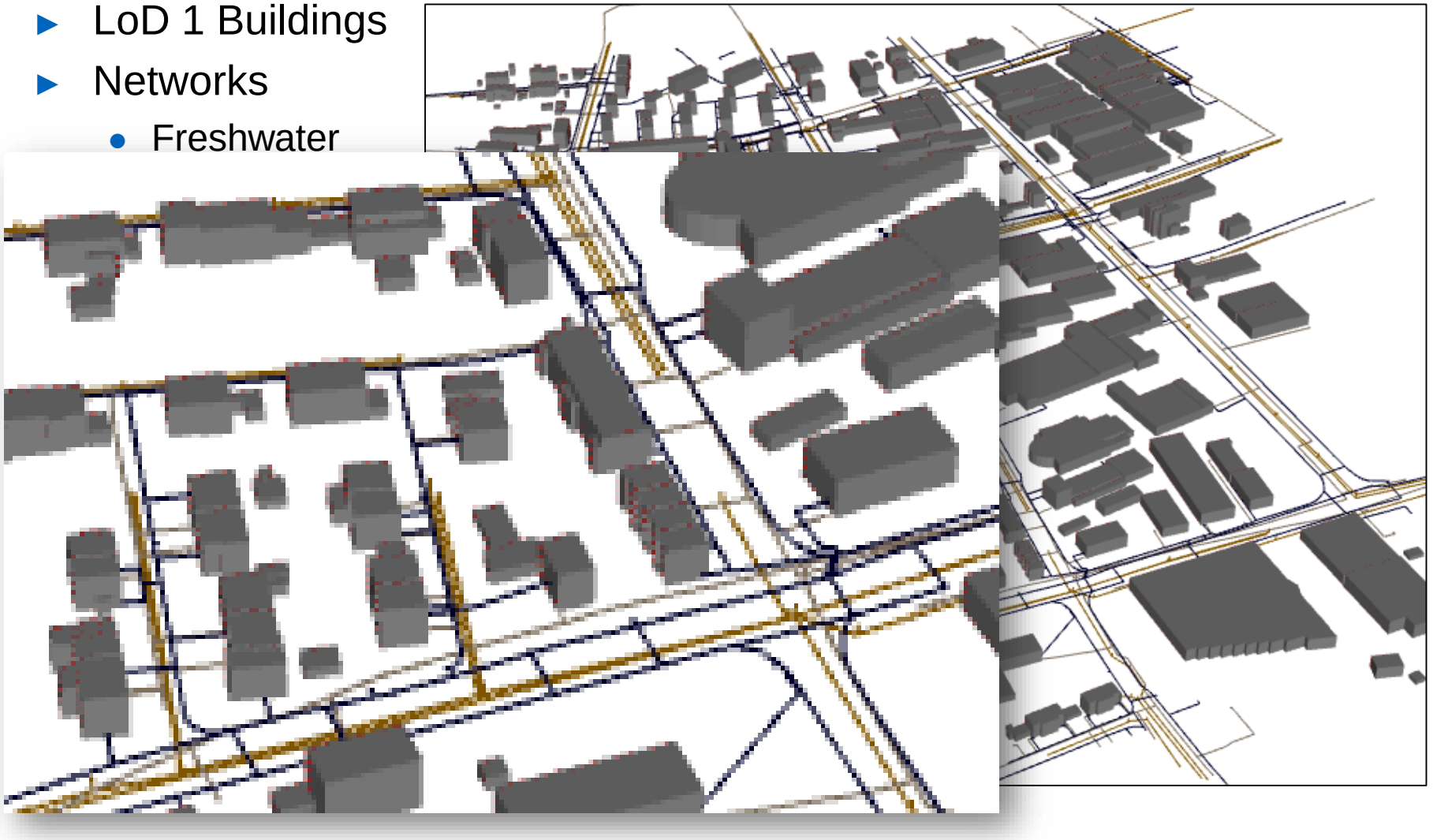
Use case – Simulation of cascading effects (I)

- LoD 1 Buildings
- Networks
  - Freshwater
  - Electricity
  - Wastewater



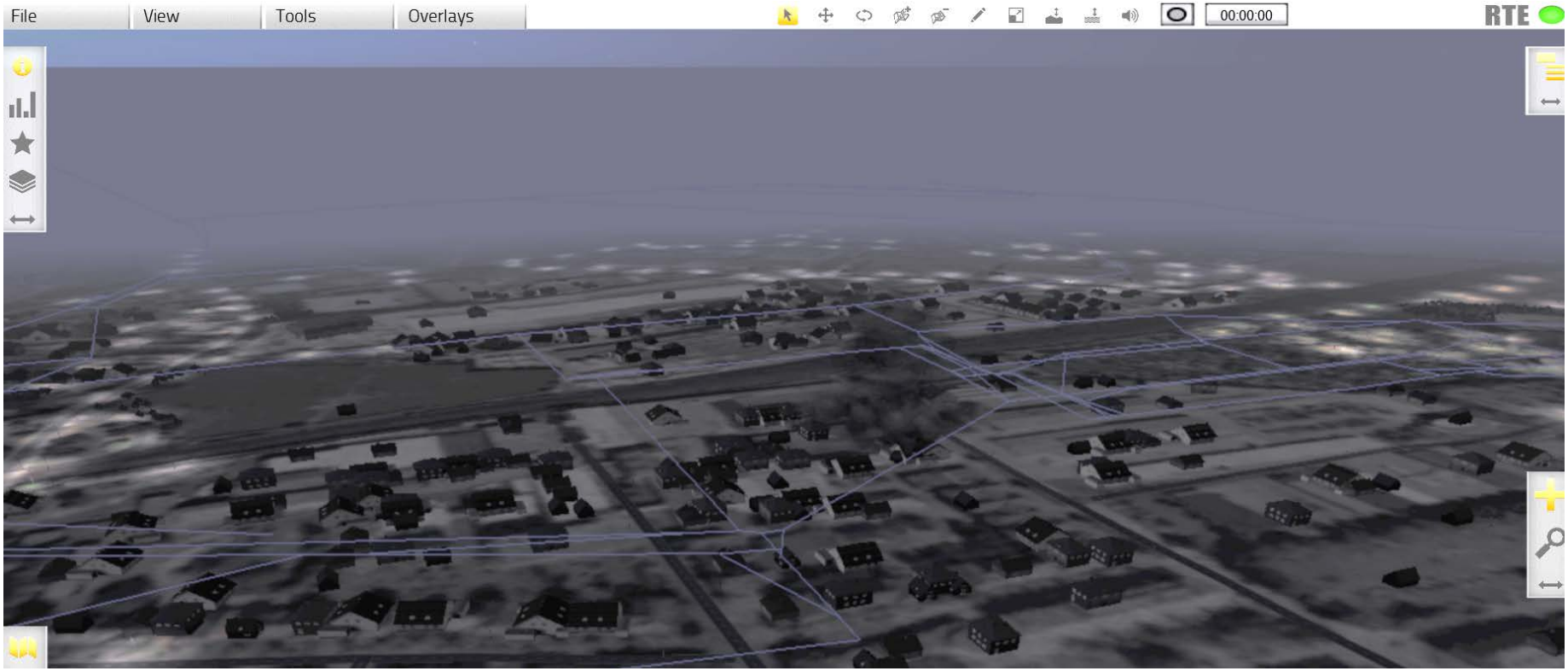
Use case – Simulation of cascading effects (I)

- LoD 1 Buildings
- Networks
  - Freshwater



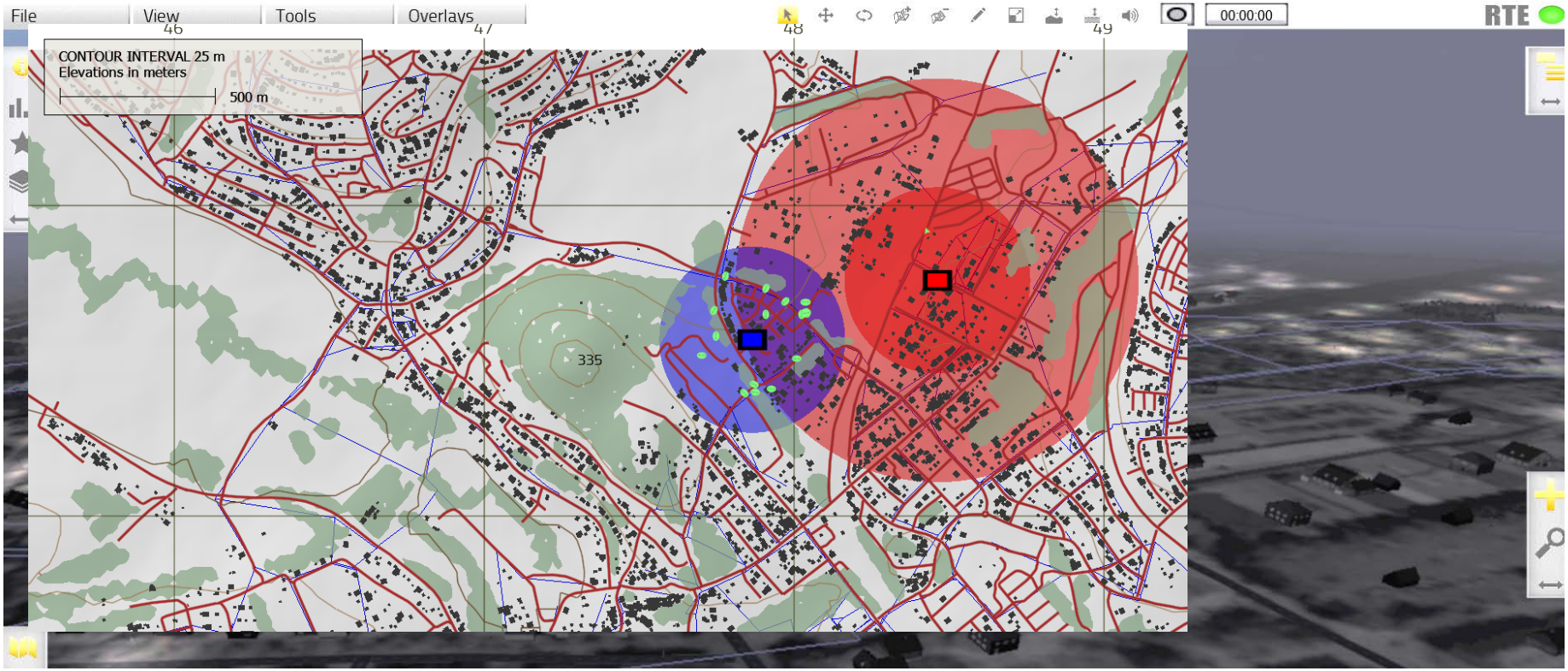
Use case – Simulation of cascading effects (II)

- Explosion in distribution station → Power failure in a district of the city
- Cascading effects caused by power failure → Failure of water works and of water supply → Water tanks provide water to population



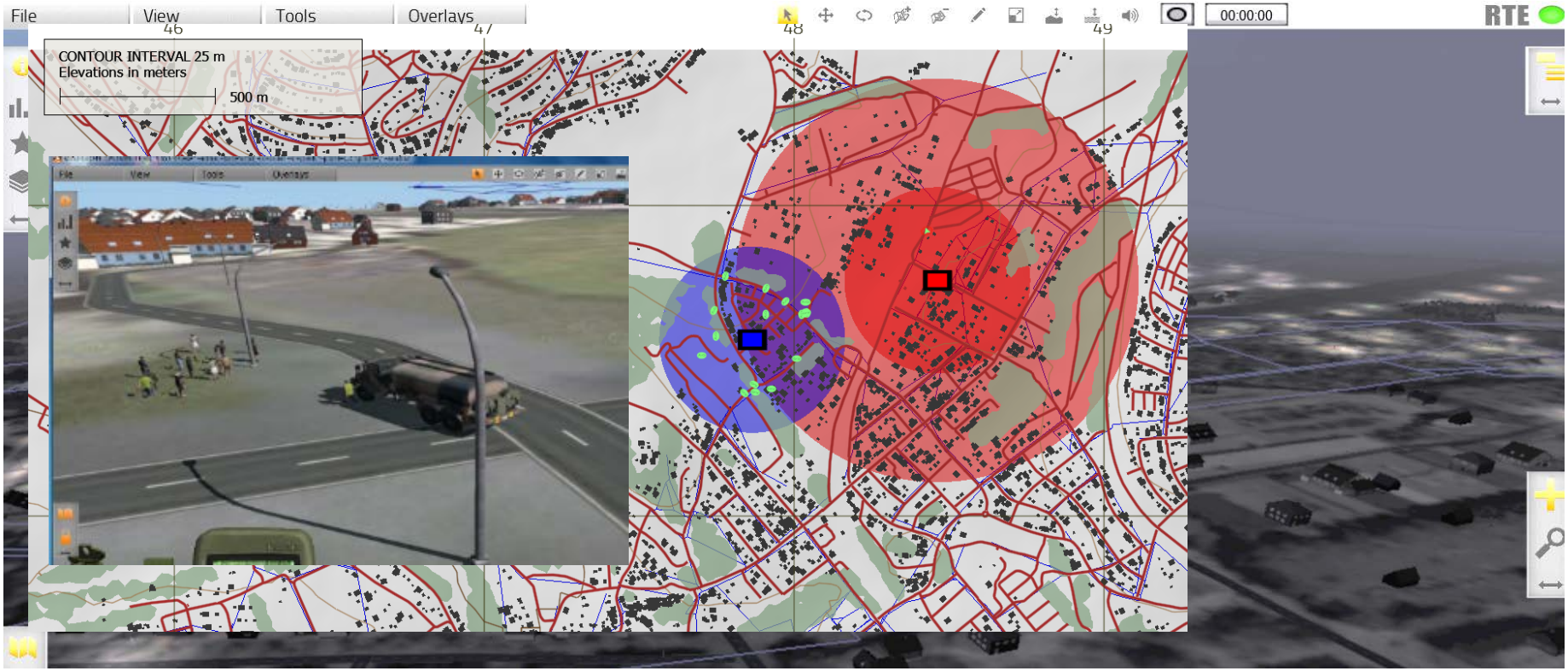
Use case – Simulation of cascading effects (II)

- Explosion in distribution station → Power failure in a district of the city
- Cascading effects caused by power failure → Failure of water works and of water supply → Water tanks provide water to population



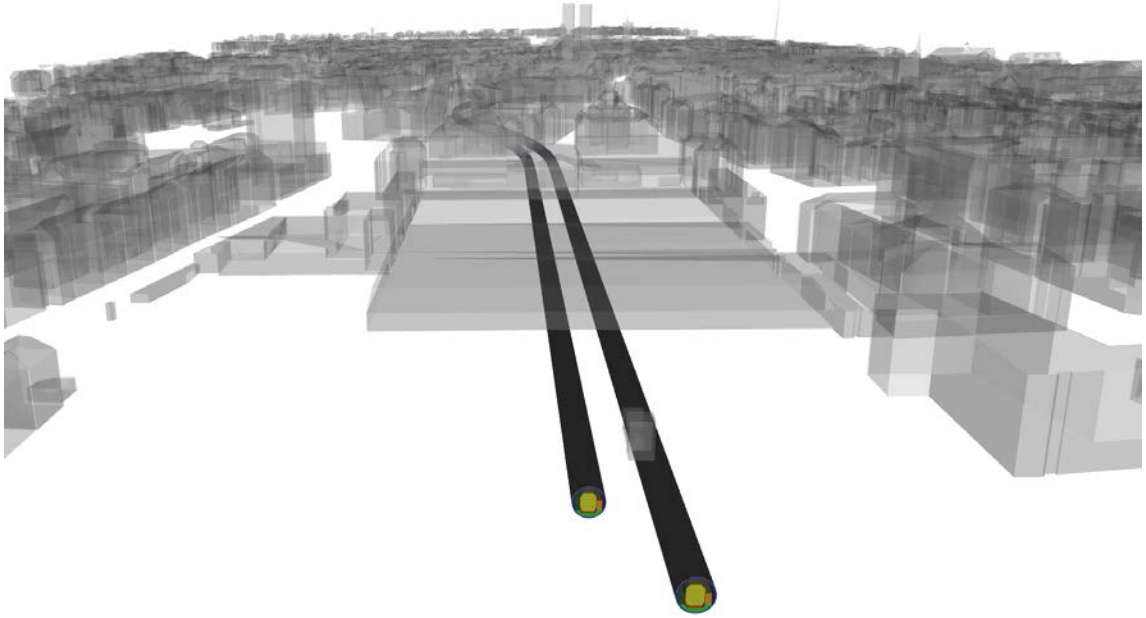
Use case – Simulation of cascading effects (II)

- Explosion in distribution station → Power failure in a district of the city
- Cascading effects caused by power failure → Failure of water works and of water supply → Water tanks provide water to population



Further underground research at TUM

- **3DTracks**: Computer-aided cooperative planning in multi-scale 3D city and building models (2011-2018)
  - Use of 3D/4D models (e.g. CityGML) for planning subway tracks
  - Integration of Geoformation Systems (GIS) / Building Information Modeling (BIM) and spatio-temporal databases
  - Collaborative planning platform including testing processes, e.g. collision detection between **buildings** and **tunnel**



City Geography Markup Language (CityGML)

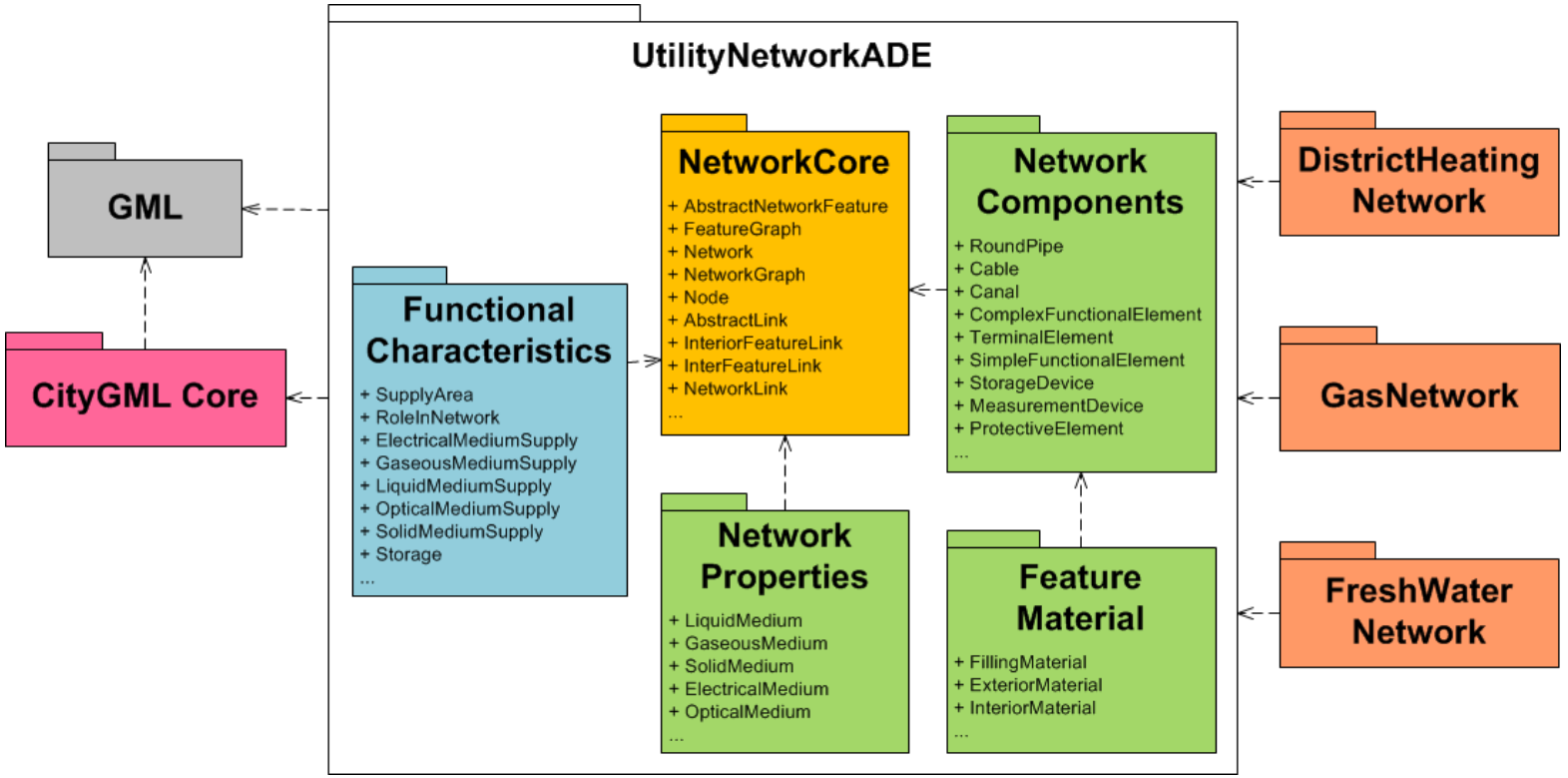
Application independent geospatial information model
for semantic 3D city and landscape models

- comprises **different thematic areas** (buildings, vegetation, water, terrain, traffic, tunnels, bridges etc.)

- International standard of the Open Geospatial Consortium
  - V1.0 adopted in 08/2008; **V2.0** adopted in 3/2012
  - V3.0 development started in 6/2014
- **Data model** (UML) + **Exchange format** (based on GML3)
- CityGML represents
  - 3D geometry, 3D topology, semantics, and appearance
  - in 5 discrete scales (Levels of Detail, LOD)

CityGML Utility Network ADE

- **ADE (Application Domain Extension)** = **CityGML's systematic extension mechanism** which allows extending every CityGML object type by additional attributes and introducing new object types
- The **CityGML Utility Network ADE** extends CityGML by the possibility to **represent supply and disposal networks in 3D city models**



Complete Network Core Model in UML

Topography

«FeatureType»
Core::AbstractCityObject

«FeatureType»
AbstractNetworkFeature

«Property»
+ function :FunctionValue [0..1]
+ usage :FunctionValue [0..*]
+ connectedCityObject :URI [0..1]
+ yearOfConstruction :Date [0..1]
+ status :StatusValue [0..1]
+ locationQuality :SpatialQualityValue [0..1]
+ elevationQuality :SpatialQualityValue [0..1]

+component 0..* 0..*

«FeatureType»
Network

«Property»
+ class :Code [0..1]
+ function :Code [0..*]
+ usage :Code [0..*]

+subNetwork 0..*
+superOrdinateNetwork 0..*
+subOrdinateNetwork 0..*

+consistsOf 0..

Graph Representation

+topoGraph 0..1
+topoGraph 0..1

«FeatureType»
FeatureGraph

+featureGraphMember 0..*

«FeatureType»
NetworkGraph

2

+nodeMember 1..*

«FeatureType»
Node

+ type :NodeValue
+ connectionSignature :AbstractSignature [0..1]
+ linkControl :AbstractLinkControl [0..1]

GM_Primitive
«type»
Geometric primitive::
GM_Point

+realization 0..1

+start 1 0..*
+end 1 0..*

GM_OrientableCurve
«type»
Geometric primitive::
GM_Curve

+realization 0..1

«FeatureType»
AbstractLink

+ direction :Sign [0..1]
+ linkControl :AbstractLinkControl [0..1]

0..* +linkMember

0..* +linkMember

«FeatureType»
InteriorFeatureLink

«FeatureType»
InterFeatureLink

+ type :InterFeatureLinkValue

«FeatureType»
NetworkLink

0..* +linkMember

«enumeration»
NodeValue
exterior
interior

«enumeration»
InterFeatureLinkValue
connects
contains

«DataType»
AbstractSignature

«DataType»
AbstractLinkControl

Existence of characteristics relevant to network modelling in various data models

	INSPIRE Utility Networks	IFC	ArcGIS Utility Networks	SEDRIS	Pipeline ML	CityGML Utility Network ADE
Representation of heterogeneous networks	+	•	•	+	•	++
Dual representation	+	++	+	++	–	++
Topographic/graphic aspects	++	++	++	++	++	++
3D geometries	–	++	–	+	–	+
Functional aspects	–	–	–	–	–	•
Hierarchical modelling						
• networks/ subnetworks	++	–	–	++	–	++
• components/ subcomponents	++	++	•	–	•	++
Interdependencies between						
• network features and city objects	–	•	–	•	–	++
• network features of different network types	–	++	–	–	–	++

– = no support, • = basic support, + = sophisticated support, ++ = comprehensive support

Source: Kutzer, T. & Kolbe, T. H., 2016: Extending Semantic 3D City Models by Supply and Disposal Networks for Analysing the Urban Supply Situation, http://www.dgpf.de/src/tagung/jt2016/proceedings/papers/36_DLT2016_Kutzner_Kolbe.pdf

Existence of characteristics relevant to network modelling in various data models

	INSPIRE Utility Networks	IFC	ArcGIS Utility Networks	SEDRIS	Pipeline ML	CityGML Utility Network ADE
Representation of heterogeneous networks	+	•	•	+	•	++
different network types						
– = no support, • = basic support, + = sophisticated support, ++ = comprehensive support						

- The CityGML Utility Network ADE meets best the requirements for modeling utility networks regarding the characteristics in question.
- The ADE was created based on an extended review of data models and software systems in use for utility networks.
- The **aim of the CityGML Utility Network ADE**, however, is not to replace the other models or systems, but to **provide a common basis for the integration of the diverse models in order to facilitate joint analyses and visualization tasks**, e.g. by mapping data which is based on the IFC or ArcGIS model to the ADE.

Source: Kutzer, T. & Kolbe, T. H., 2016: Extending Semantic 3D City Models by Supply and Disposal Networks for Analysing the Urban Supply Situation, http://www.dgpf.de/src/tagung/jt2016/proceedings/papers/36_DLT2016_Kutzner_Kolbe.pdf

Utility Network ADE working group

- A joint SIG 3D and OGC working group is further developing the ADE to make it usable for other use cases as well
  - Further information on the Utility Network ADE workshops including presentations and results is available at: http://en.wiki.utilitynetworks.sig3d.org/
  - Resources (UML model, XML schema, using the ADE with FME, test data sets) are provided on this github repository: https://github.com/TatjanaKutzner/CityGML-UtilityNetwork-ADE
  - The next workshop will take place in Karlsruhe, Germany, 6-8 December 2017 (jointly with the Energy ADE working group): https://en.wiki.utilitynetworks.sig3d.org/index.php/CityGML_Utility_Network_ADE_workshop_2017_December_-_Karlsruhe,_Germany
  - If you are interested in participating in the working group, please contact Tatjana Kutzner (kutzner@tum.de)

Next steps

- **Publicly available test data** are currently generated for the ADE, including data from the City of Rotterdam, Netherlands, and the City of Nanaimo, Canada.
  - Please let us know if you would be able to provide test data as well
- As part of the development of CityGML 3, the final CityGML Utility Network ADE is to be integrated as individual module into CityGML.
- „**Dynamizers**“ will be another new concept introduced to CityGML 3. It will allow for connecting sensors and sensor data with city objects and utilities.
- The **3DCityDB** (www.3dcitydb.org), a free geo database to store, represent, and manage virtual 3D city models, is currently being extended to support the Utility Network ADE schema as well.

Possible use cases for future research work (I)

- **Storm drainage network**
  - Planning and managing of networks is important to reduce the overflow and to collect storm drainage network fees
  - Information on the total number of buildings sites, roofs and sewer system connected to the storm drainage network is required
- **Clean water act**
  - Inspection of waste water discharged by chemical labs / factories
  - Information on the network helps in finding the location of elements not working properly
- **Vulnerability assessment and disaster management emergency response**
  - Assessing the impact of a natural or man-made disaster on networks and analysing how their failure affects buildings and inhabitants

Possible use cases for future research work (II)

- **Urban facility management**
  - Coupling of supply/disposal networks with indoor installation
  - Management of planned/unplanned maintenance operations at the level of the individual consumer
  - Failure detection based on the suppliedness of individual consumers
  - Location of easy access points for maintenance
- **Smart energy planning, simulation and operation**
  - Analysing how a change in land use can affect energy consumption and production
  - Simulating and forecasting feed-in power and consumption over small periods which allows network operators to optimise operation in small-scale distribution networks

Linking utility networks with city models is not supported by other standards!

Possible use cases for future research work (III) – Multi-utility scenarios

- **Multi-utility planning, simulation and operation**
  - Planning of combined district heating and electrical power generation and distribution
  - Analysing how a change in consumption of one commodity (e.g. gas) impacts consumptions of other commodities (e.g. district heating)
- **Smart Cities**
  - Integrated urban planning, i.e. analysing the implact of planned urban transformations on multiple aspects (energy, traffic, environment)
- **Cascading effects in the failure of infrastructures**
  - Failure propagation of an electric grid on the water and gas supply

Existing utility modeling standards do not cover multi-utility scenarios!

Summary

- **Core model for the representation of arbitrary utility networks**
  - **3D topographic** modelling
  - **3D topological** and **functional** modelling
  - Support of **hierarchies**: complex objects, network hierarchies
  - Provides homogenized and integrated view on multi-utility networks
- **The core model is independent of a specific type of utility / commodity**
- **Utility-specific, concrete feature classes**
  - including characteristics, materials and functional aspects of the features
- The ADE allows for
  - **linking utility networks with 3D city models**
  - **modeling multi-utility scenarios**

  → this is not supported by other existing utility modeling standards
- **CityGML** itself already defines **object types for subsurface structures** (**buildings**, e.g. subway stations and underground parking, and **tunnels**)