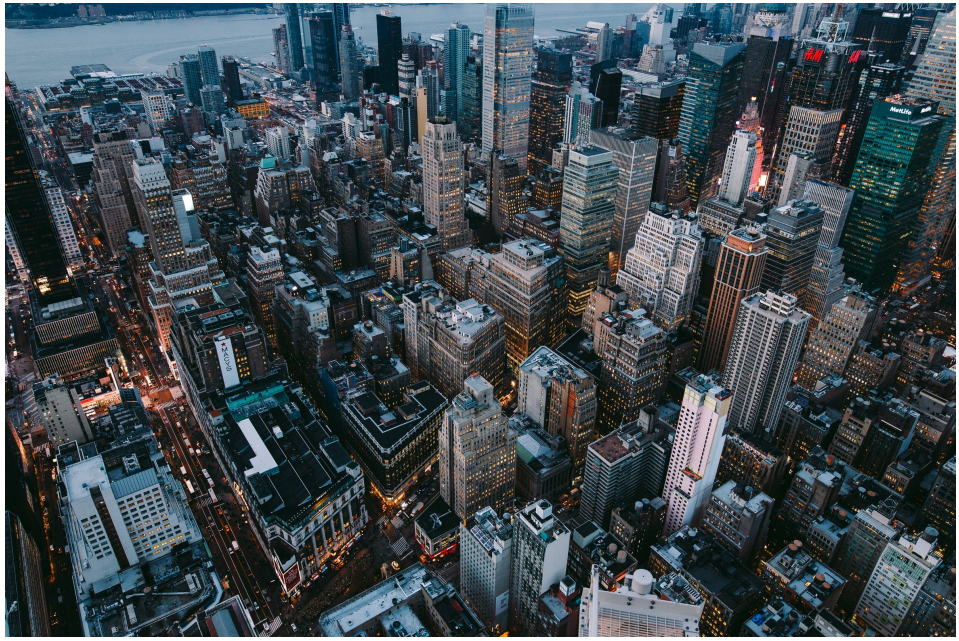


Darrel Ronald
darrel@spatiomatics.com

SPATIOMATICS
CITIES = INFORMATION = DATAFLOW

Urban Tech Stack Alliance (UTSA)

A concept for the collective development of foundational data and software technologies

Why an alliance?

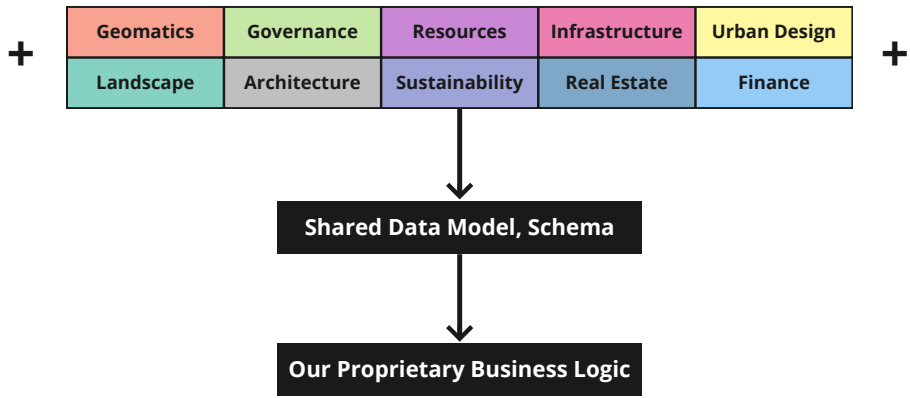
Urban Development Challenge

The planet is rapidly urbanizing, but the tools we need for urban development sit in a technology gap.

Geomatics = GIS	Urban Development = ?	Buildings = BIM
Working Group • Open Geospatial Consortium (OGC)	**Working Group** • None • Initiative "Integrated Digital Built Environment" (IDBE) by OGC + bSI • Various Urban Digital Twin initiatives	**Working Group** • Building Smart International (bSI)
Software • QGIS • ArcGIS	**Software** • No Industry Standard • CityCAD • Various Web Interfaces	**Software** • Autocad / Bricscad • Revit • Vectorworks • Rhino • ArchiCAD • ++
Data Models • CityGML + Extension • CityJSON + Extension • LandInfra • ++	**Data Models** • None? • Potentially extend CityJSON	**Data Models** • Industry Foundation Classes (IFC) only exchange of data + bSDD + MVD • BIM Collaboration Format (BCF)

Integrated Domain Knowledge - Missing Data Models

Integration (alone) in Urban Development
is (already) a big innovation.



How can we connect the different knowledge domains into a standard schema for data (& API) interoperability?

Sample Challenges for Urban Tech (Urban Dev. Perspective)

Users

- Dozens of user types and needs, often conflicting interests
- Collaboration and integration is innovation but very difficult to achieve

Business Models

- Complete mix-up of Users/Payers/Owners with those who benefit from a product
- Products are massive investments of time, energy and money and not easy to fund
- Consulting firms cannot easily fund long-term product investments
- Duplicate work on smaller pieces of the AEC tech stack

Geodata

- Complexity of processing data sets (ex. open data, geodata)
- Accuracy of geodata

Urban Development Data

- Non-standard and non-machine readable Urban Development Guidelines
- Data Silos within Municipal organizations
- Inherent need for conflicting Municipal building guidelines

Data Models

- Lack of 3D support in many OGC standards
- Complexity and Limitations of OGC standards
- Incompleteness and conflicts between OGC, bSI, ISO and other standards

Software

- Web: Limitations of modelling capabilities
- Software: Limitations of data exchange
- Code: Limitations on legacy code bases (ex. dotNET, Python 2)

Six Challenges for 3D City Modelling (GIS Perspective)

Jantien Stoter, 2020.04.09 - GIM International
The article is a collaboration of 7 TU Delft 3D Geomatics team members

1. **Consistency Between Models**
2. **Standardization**
3. **Data Quality**
4. **Data Interoperability**
5. **Data Maintenance / Governance**
6. **From Utopian Pilots to Real-World Use Cases**

Goals and Structure?

Mission

Create a **community to help each other** build products that solve the complex and integrated urban development challenges. Innovate through **integration** and **standardization**. Create a **new market** and grow together with **interoperable services**.

Goals

1. Define: the Missing Technologies
2. Combine: Expertise and Solutions
3. Connect: existing Standards, Technologies and Partners
4. Build: New Partnerships
5. Assemble: a community Urban Data Model
6. Build: Foundation Technologies
7. Build: Interoperable Products

Alliance Models - Join One or Create One?

Legal and Business Models

1. Consortium * ex. Open Design Alliance (ODA)
2. Collaboration ** ex. Innochain
3. Joint Venture
4. Cooperative
5. Foundation
    a. Linux Foundation ex. Academy Software Foundation (ASWF)
    b. Apache Foundation
6. None

External Partners and Funding

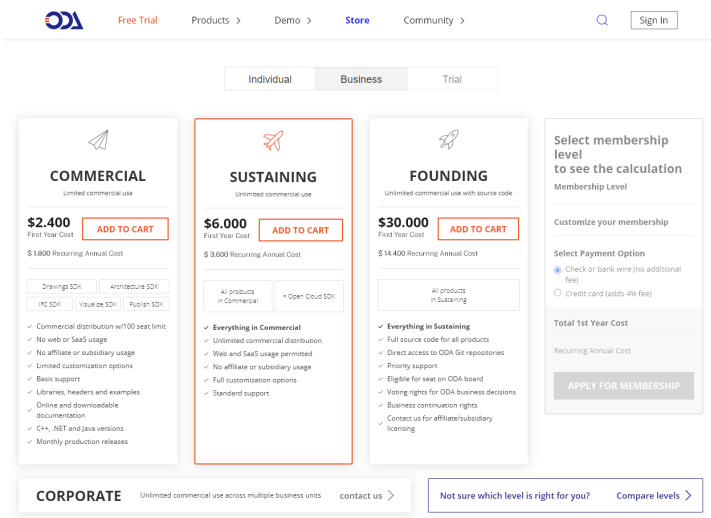
- International Standards Organization (ISO)
- Open Geospatial Consortium (OGC)
- Building Smart International (bSI)
- Governments
- Institutes
- Non-profits
- Academia
- Businesses

* synonym: Alliance, Partnership
** synonym: Collective, Coopetition, Network

Example - Open Design Alliance

About ODA

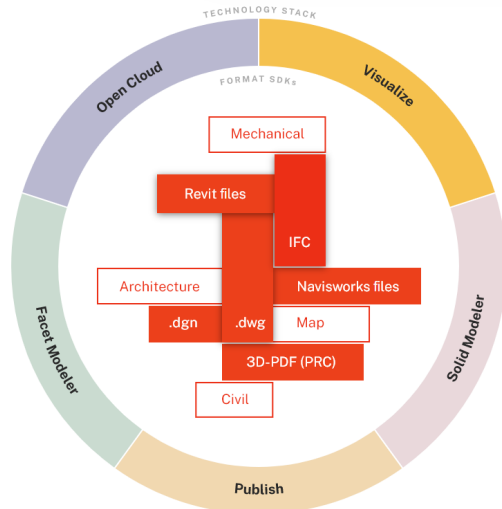
- Non-profit consortium
- 90 full-time engineers
- 1200 Member companies
- 85% revenue for R&D
- goal: provide common solutions for complex problems within industry
- 100 year commitment for some file types
- Success lead to many new initiatives and products



THE ODA PLATFORM

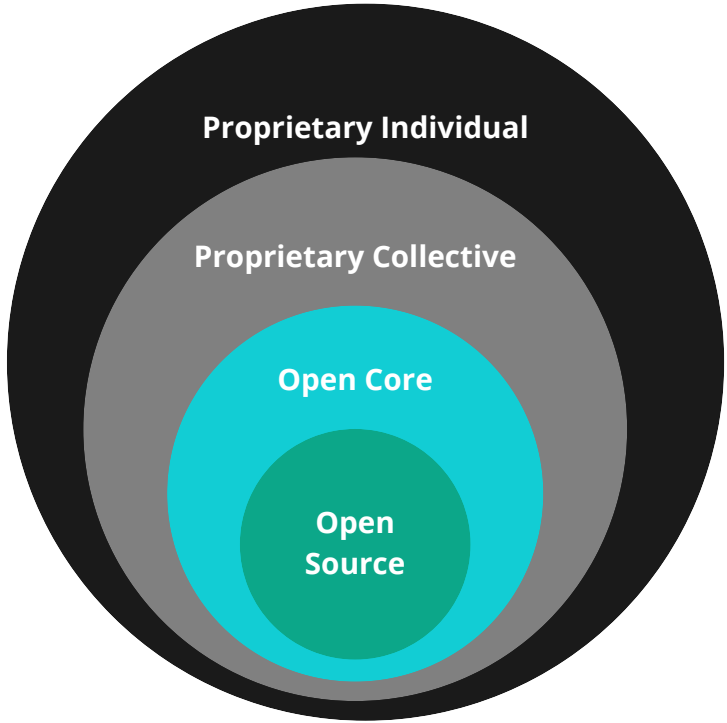
The ODA Platform is a comprehensive solution for developing engineering applications, consisting of:

- SDKs for popular CAD and BIM formats
- The ODA Technology Stack, a set of building blocks for application development



www.opendesign.com
https://www.youtube.com/c/OpenDesignAlliance

Licensing Models



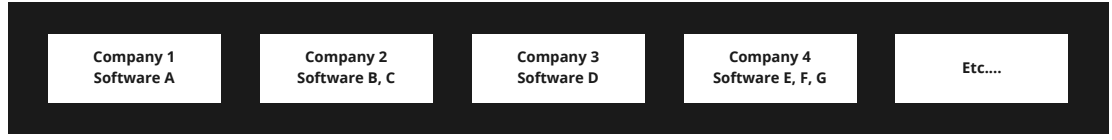
Business Models

1 - Sold Separate

2 - Sold Separate but in product 'family'

Collectively build interoperable technologies, data models, APIs, databases, web apps, etc.

3 - Sold Together as 'family'



Most competitive offering. Use Accounts + Analytics to track usage and distributed revenue by use.

Tech Stack?

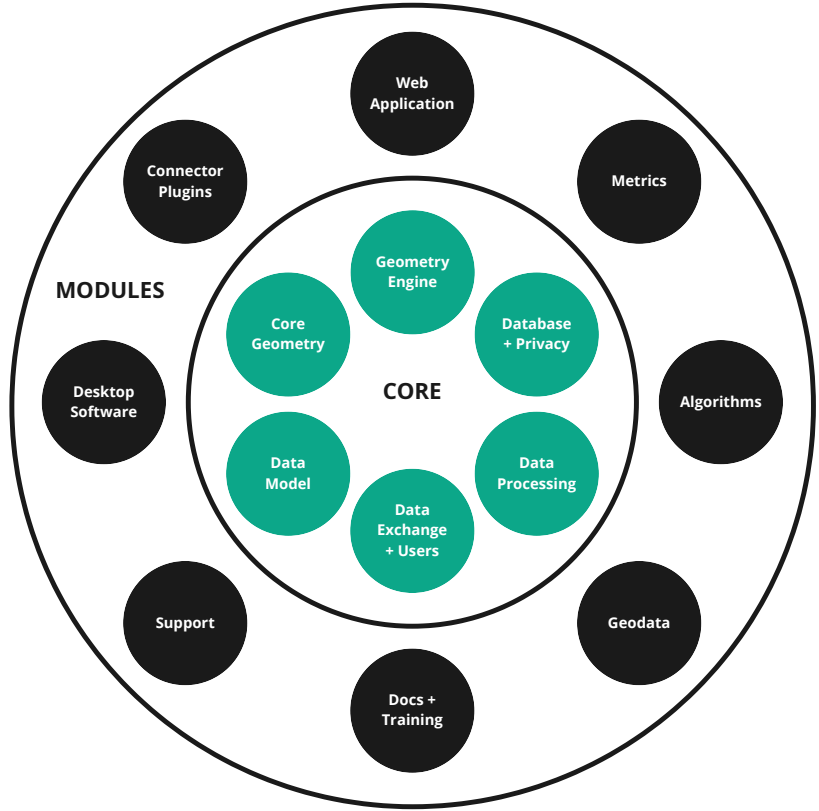
Urban Tech Stack Model

Core

- Foundation tech stack
- Open Source (no limitations)
- Shared responsibility

Modules

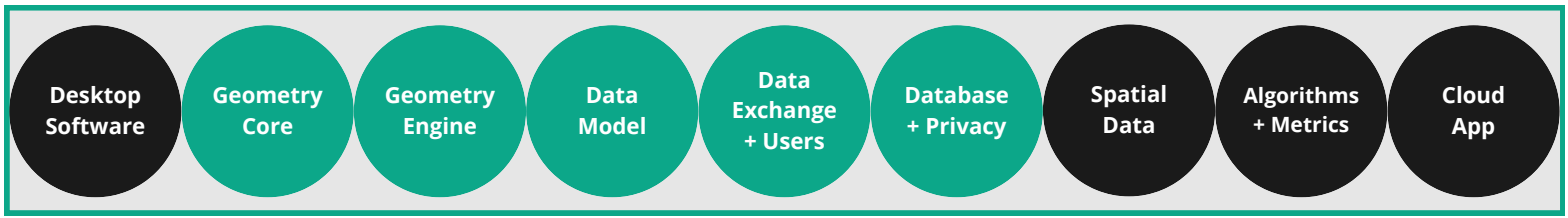
- Optional layers on Core
- Optional Partnerships
- Mixed Licensing
- Based on business needs



Open Licensing | Mixed Licensing

Full Stack Technologies

APIs



Tech Options
1. QT (C++, Py, JS)
2. Electron (JS)
3. .NET (C#)
4. UNO (C#)

Tech Options
1. Compas (Py)
2. Ladybug (Py)
3. Speckle 1.0 (C#)
4. Speckle 2.0 (C#,Py)
5. BHoM (C#)
6. Rhino3DM (JS, Py, C#)
7. glTF (JS)
8. openNURBS (C#)
9. ...

Tech Options
1. Compas (Py)
2. BHoM (C#) [limited] **?**
3. CGAL **?**
4. GDAL **?**
5. Rhino3DM (Py, C#, JS) [limited] **?**
6. ...

Schema Options
1. GML
2. JSON
3. CityGML
4. IFC
5. LandInfra
6. Speckle flexible
7. W3 Spatial Thing?
8. I3S
9. Custom UIM

Tech Options
1. API (REST)
2. API (GraphQL)
3. API (Websockets)
4. RPC
5. Speckle
6. database file
7. file type
8. LUCI

Generic Structures
1. Dictionary
2. Array
3. NDArray
4. Graph

Filetype Options
1. JSON
2. GML
3. uimJSON
4. CityJSON (3D)
5. CityGML (3D)
6. GeoJSON (2D)
7. i3S
8. gLTF

Tech Option
1. Graph
2. NoSQL
3. PostgreSQL
4. PostGIS
5. SQL
6. in software

Local /or/ Cloud
1. Neo4J
2. MongoDB
3. PostgreSQL
4. PostGIS
5. SQLite
6. SQL
7. GeoDjango
8. GeoServer
9. Apollo Data Graph

Data Integration
1. Airbyte
2. GeoKettle
3. Mapped (IoT)
4. Apache Spark
5. Apache Superset

Tech Option
1. Open Data
2. Government
3. Proprietary
4. Real Estate
5. Wikipedia
6. News
7. ...

Local / Cloud
1. many options...
2. OSM
3. Esri
4. Mapbox
5. GeoNode

Examples
- GIS
- IFC
- FIBREE UOI
- DiS Geo

Domain Algorithms
- Open Licensing
- Proprietary
- ...

Domain Metrics
- TOD
- LEED
- BREEAM
- WELL
- SDG
- ...

Tech Option
1. Vue
2. React
3. ...

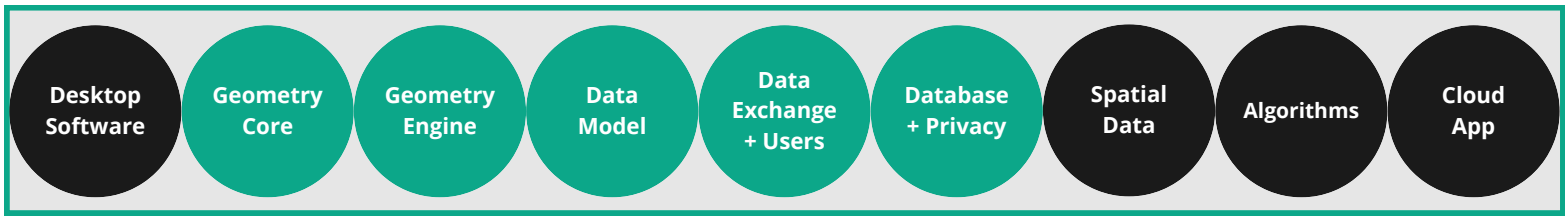
Other Components
- Cloud Provider
- API
- Admin
- Authentication
- Mapping
- Data Storage
- Data Visualization
- Data Editing
- ML

Industry Software Plugins

Tech Options
1. QGIS
2. Esri
3. Autodesk
4. McNeel
5. Bricsys
6. Trimble
7. Adobe
8. Microsoft
9. other...

Open Licensing | Mixed Licensing

Sample Urban Tech Stack (Python)



QT (C++, Py, JS)

Compas (Py)

Compas (Py)
+ CGAL
+ GDAL

uimJSON
Based on W3C Spatial Thing principles

uimAPI
- GraphQL
- REST

Web GIS
- WFS
- WMS
- WMTS
- TMS
- WCS
- SPARQL

Collaboration
- Speckle 2.0

Generic
- Graph
- NoSQL
- SQL / SQLite
- Postgres
- PostGIS
- Or save within Industry Software OOP entities

Search
- GraphQL
- GeoSPARQL
- PySpark
- Redash
- Elasticsearch
- +

Options
- Database
- WFS
- WMS
- GML+
- JSON+

Domain Algorithms
- GIS (Py)
- Data Science (Py)
- Data Vis (Py)

Options
- Javascript
- Python

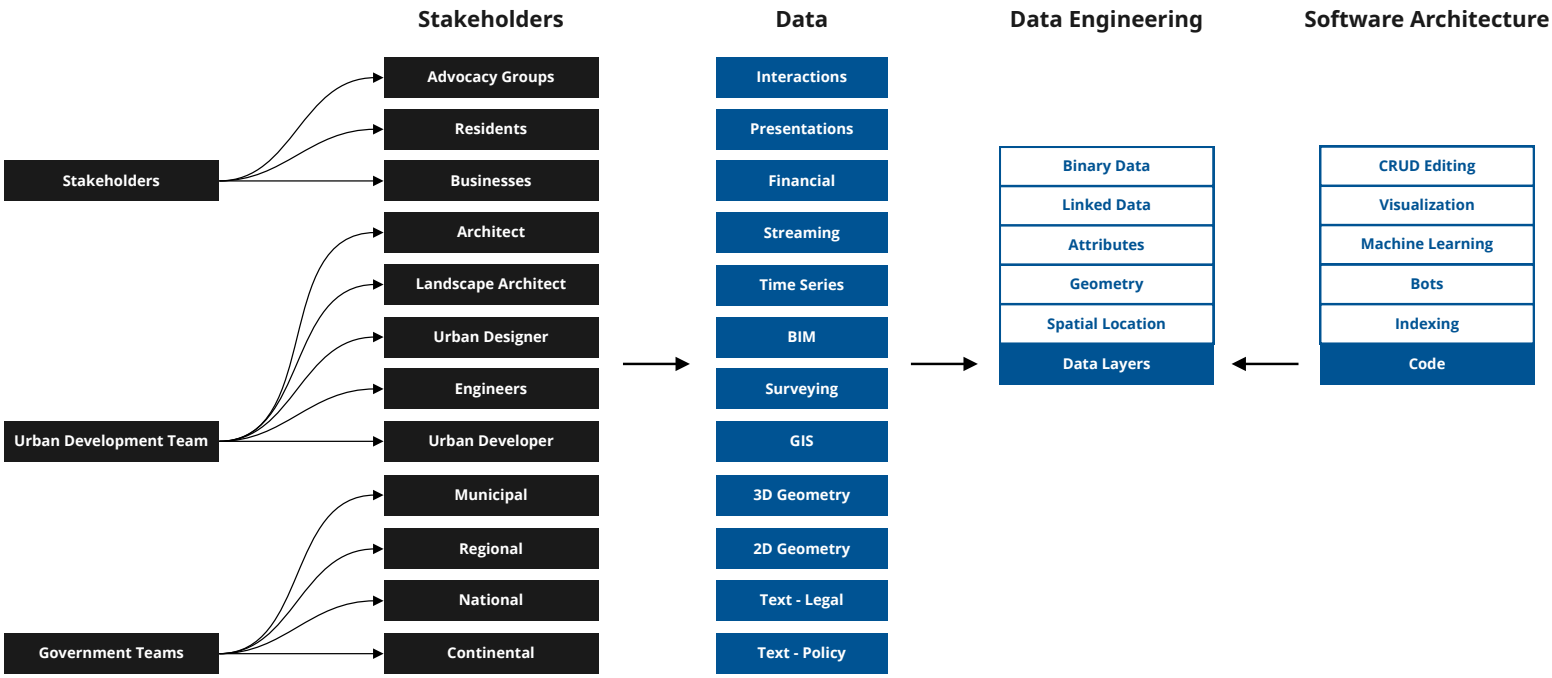
Industry Software Plugins

Mixed
- custom plugins
- Speckle connectors
- COMPAS connectors
- other

OSS or Proprietary | Open Licensing | Mixed Licensing

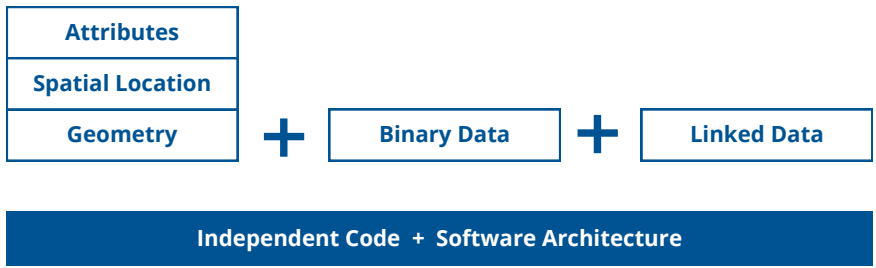
Data Infrastructure?

Urban Data Complexity

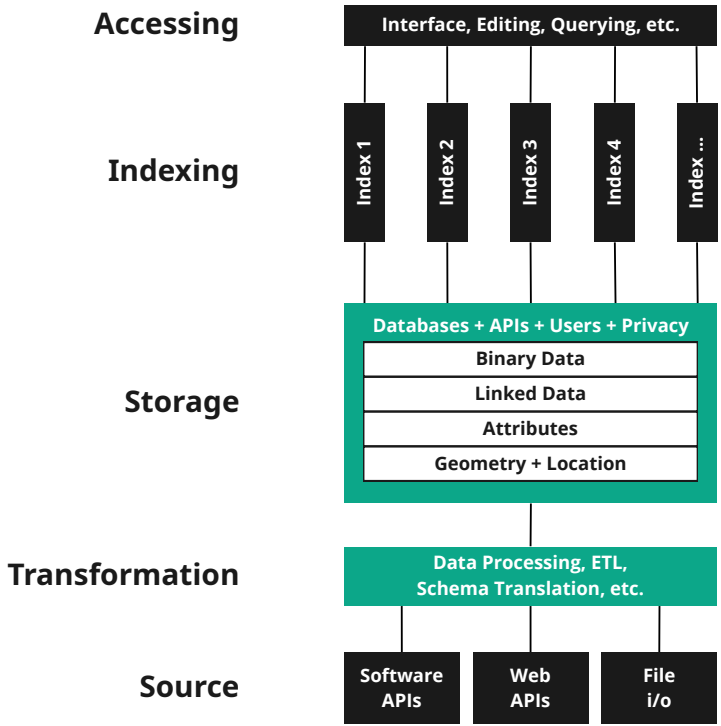


Unlimited Stakeholders and Many Data Types

Data Strategy - Seek Simplicity



Data Infrastructure



Data Model?

Current International Standards

Many Applicable and Interlinked Standards

~ 21580 ISO, International Standards Organization
~ 275 ECMA, European Computer Manufacturers Association
~ 275 W3C, Worldwide Web Consortium (*recommendations*)
~ ? IETF, Internet Engineering Task Force
~ 30 OGC, Open Geospatial Consortium
~ 8 bSI, Building Smart International

Challenge

- many standards criss-cross and don't interoperate
- complexity of urban development creates problems
- full stack nature of urban tools creates problems
- integrating the wide spectrum of urban domains creates problems

We must find a simple and elegant solution.

Example - Data Model Conflicts

Built environment data standards and their integration: an analysis of IFC, CityGML and LandInfra

Image credit: Bioregional

Version 1.0 • 02 March 2020
OGC Document 19-091r1
bSI TR1012

OGC Making location count. buildingSMART International

IDBE v1.0, March 2020 Page 1 of 16
Open Geospatial Consortium & buildingSMART International

Figure 1 - Thematic coverage of the three data standards. Dark shading indicates strong coverage, light shading weaker coverage (or under development) and no shading implies no known coverage. The object icons are ordered approximately; the intention is to cluster by theme and represent finer spatial scales nearer the top.

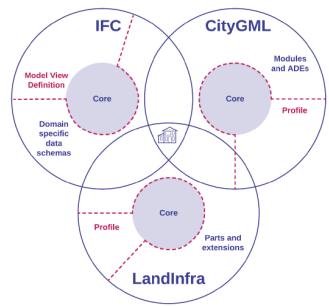


Figure 2 – The three standards differ but overlap in their thematic coverage; as an example, the concept of a building is common to all three. IFC is always subset into Model View Definitions (MVDs) for implementation, whereas the GML-based standards of CityGML and (the InfraGML implementation of) LandInfra can be subset optionally into profiles; for all three, the core of the schema must be implemented. Application Domain Extensions (ADEs) enable anyone to extend the CityGML standard to accommodate more specialist themes;

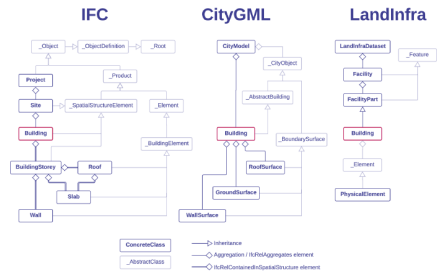


Figure 3 - The concept of a building is represented by all three standards but the detailed structure of the conceptualisation is dissimilar (geometries are not represented in this figure). The UML-like diagrams show possible representations of a very simple building; they are derived from example building instance models that are valid in each of the three standards. The IFC representation is valid for IFC4; in IFC5, a building is a predefined type of facility and a building storey is a specialisation of a facility part.

Context

- Slow to develop (ex. CityGML 3.0 is 9+ years in the making
- Huge areas of domain knowledge not included
- Difficult to extend
- Complicated to create export files

Therefore

- Why do we even need the existing schemas and file types?
- Why can't we just use an extensible JSON data object?
- Decouple Code from the Data Model - Data Oriented Design
- Radically simplify the Data Model
- Complete Data Model pulling from existing standards
- Fast development (like web) with "Worse is better" approach

Article source Link
OGC Discussion Papers Link

Example - CityGML / LandInfra / IFC

Table 1 - A Comparison of CityGML, IFC and LandInfra

#	Criterion	CityGML	LandInfra	IFC
1	Body	OGC	OGC	buildingSmart
2	Version	2.0.0	1.0.0	IFC 4 Addendum 2
3	Users	3D City Modellers	Survey Engineers & BIM	BIM & AEC
4	Encoding	GML	GML	STEP (mainly)
5	Focus	City Objects	Land and Infrastructure	BIM Models
6	Geometry	Subset of ISO 19107 / GML 3.1.1	ISO 19107 & More	ISO 10303
7	Topology	Shared surfaces only	Between facility parts	Openings, coverings & other
8	Semantics	Detailed	Not so detailed	Detailed
9	Metadata	Basic	ISO 19115 compliant	Extensively but inconsistently used
10	LODs	5 different LODs	Not supported	Not supported
11	Extensions	Generics or ADEs	Not supported	Supported
12	Appearance	Supported	Not supported	Supported
13	Software Support	Low	Almost nonexistent	Medium
14	Codelists	Supported with ISO 19103	Supported with ISO 19103	Enumerations only
15	Land Use	Simple types	Complex LADM types	Not relevant
16	File Size	Large	Large	Very Large

Reworked Table source: LandInfra to Solve GIS/BIM Quagmire Link
LandInfra Conceptual Model

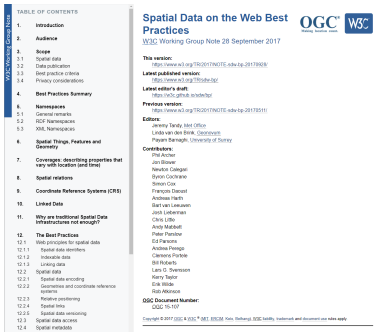
Current Data Models and Encodings - Incomplete

None fit the job. Do we create our own, open source data model

Data Models + Encoding	Owner	Detailed 3D	Data Oriented Design	Domain Complete	Extendable	Simple, Flexible	Materials	CRS Limits	Inherits	Web First	Version, Year	Good for UIM?
XML	W3C	-	-	-	yes	no	-	-	-	no	1.0, 2008	no
GML	OGC	no	no	no	yes, hard	no			XML	no	3.3, 2010	no
CityGML	OGC	yes	no	no	yes, hard	no	X3D	no	GML	no	2.0, 2012	no
JSON	ECMA	-	-	-	yes	yes		-	**-**	yes	2013	no
GeoJSON	IETF					yes		Only WGS84	JSON	yes	2016	no
GeoJSON 3D	OGC					yes		no	JSON	yes	**tbd**	possibly
CityJSON	CC	yes	no	no	yes, hard	no	X3D	no	CityGML	yes	2.0, 2012	
JSON-LD	W3C								JSON			
JSON Graph Format	CC											
LBD: Linked Building Data	W3C											
i3S	OGC	yes	no	no	?	?			JSON	yes	1.1, 2019	
Land/InfraGML	OGC	yes	no	no	no	no			GML	no	1.0, 2016	
LADM	ISO	yes		no	?	?			-	-	2012	no
IFC	bSI	yes	no	no	yes	no			-	no	4.0.2.1, 2017	no
Spatial Things	W3C	-	yes	-	-	-		-	-	-	-	-
uimJSON	**?**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes, how?**	**no**	**JSON**	**yes**	**0.1, 2021**	**?**

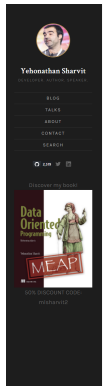
Urban Data Model Inspiration

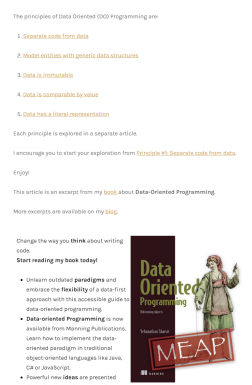
1. Web First 'Spatial Things'



- Web of Data / Linked Data
- No Platform
- No Architecture
- Tiny Files
- Serialize easily
- REST/GraphQL

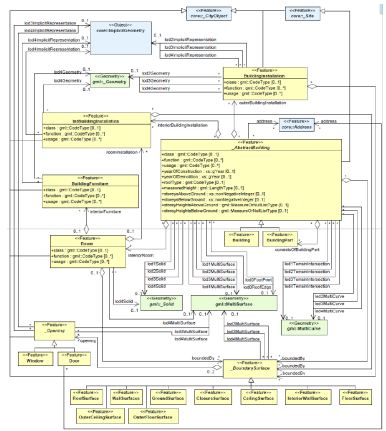
2. Data-Oriented Design





1. Separate code from data
2. Model entities with generic data structures
3. Data is immutable
4. Data is comparable by value
5. Data has a literal representation

3. No UML Hell

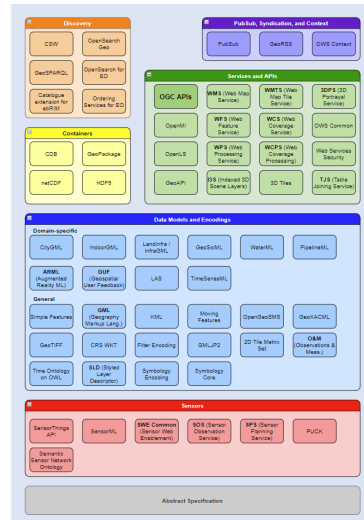


The data model should have extreme simplicity for software architecture flexibility.

There should be 3 independent elements in the encoding:

1. Geometry
2. Encoding Meta Data
3. Domain Knowledge sub-schemas

4. Copy What's Good



Use existing Nomenclature to support data mapping:

- OGC
- ISO
- bSI
- W3C
- ECMA
- OSM
- ,,,

Urban Data Model - Critical Needs and Goals

1. **Complete** urban development needs
2. **Many Schemas** that can index a single dataset
3. Consistent use of existing standards **Nomenclature** (ex. CityGML)
4. **Multi-dimensional**: **3D** (X, Y, Z) + **4D** (Time) + **5D** (NData Arrays)
5. Works with **all Geometry** Primitives, Shapes and Data Structures
6. Supports both **Cartesian Space + Geodetic Space**
7. **Loose coupling** of Geometry + Attributes
8. **Pick-and-choose freely** from Domain Knowledge Schemas
9. **Decoupled** Code and Data (Data Oriented Design)
10. **Useful Ontology:** Preserve Technical, Semantic and Descriptive details
11. Schemas don't determine **Software Architecture**
12. **Scaleless - No LOD** (Level of Detail)
13. Simple, **Maintainable, Machine Readable** (W3C Spatial Things)
14. **Web First** technologies and data exchange
15. **Generic Encoding** (JSON) and smallest file size
16. **Open Source, Community Driven**
17. **Human readable** and typeable
18. Fast, iterative development for **Business Needs** (Worse is Better)

Urban Data Model Concept

Schemas can copy: OGC, bSI, ISO, OSM, INSPIRE, while removing overlaps. Schema Mapping can create bridges to other file type exports

Meta

Schema
- Schemas & Versions

Project
- Name
- ID
- Version
- Option
- Date
- Owner
- Creator
- Organization
- Contact
- Copyright

Geo Coordinate Reference System (CRS)
- CRS

Geo Coodinates
- lat
- long
- altitude

Data Public
- Topology + Geometry + Attributes
- Coordinate Overrides

Data Private
- Topology + Geometry + Attributes
- Coordinate Overrides

+

Geometry

Primitives
- Circle
- Ellipse
- Frame
- Line
- Plane
- Point
- Polygon
- Polyline
- Quaternion
- Vector

Shapes
- Box
- Capsule
- Cone
- Cylinder
- Polyhedron
- Sphere
- Torus

Data Structures
- Array_flat
- Array_numpy
- Aggregate Data
- Graph Network
- Tree
- Mesh

+

Domain Knowledge / Ontologies

Sub-Schemas
1. Linked Data (JSON-LD)
2. Address
3. Graphics
4. Geography
5. Land Administration
6. Surveying
7. Regulations
8. Legal
9. Urban Design (LandInfra, LADM, Spacematrix)
10. Landscape
11. Building (CityGML, LandInfra)
12. Building_IFC (ifcJSON)
13. Building_indoor (indoorGML)
14. Mobility (LandInfra)
15. Utilities (CityGML ADE Utilities)
16. Water
17. Waste
18. Metabolism
19. Status (Construction)
20. Maintenance
21. Lifecycle
22. Time Planning
23. Moving / Time-Based Data
24. Constraint
25. Real Estate
26. Feature / POI (Safegraph, SLIPO)
27. Sensors
28. Disaster
29. Economy
30. Demographics
31. Politics
32. Weather
33. Climate Change
34. Nature Conservation
35. History / Event

External Stakeholder Sub-schemas
- TOD
- Leed
- Breeam
- UN SDG

[Google Sheets with Extended Information]

Urban Data Model JSON

[Github Source]

Simple Example: Inspired by multiple sources

```
// SIMPLE EXAMPLE OF A uimJSON file

{
    "schema": {"name":"UIM", "version": 1.0, "uri": "https://github.com/Spatiomatics/UTS/blob/main/data_model/UrbanDataModel.json"},
    "project": {"name": "Spatiomatics", "id": "UTS", "copyright": "CC BY 4.0", "creator": "Darrel Ronald"},
    "defaults":
        {
            "geo_crs": "WGS 84",
            "geo_coordinates": { "lat": 49.8951, "lng": 97.1384, "alt": 10},
        },
    "data_public":
        [
            {
                "uuid" : "123e4567-e89b-12d3-a456-426614174000",
                "guid" : "rhino3D-27592535heefgiesexxxx",
                "geometry": {"type":"point", "xyz": [0, 0, 100]},
                "graphics": {"color": "red", "material": "prairie grass"},
                "geography": {"state": "Canada", "province": "MB", "city": "winnipeg"},
                "urban_design": {"development": 10, "district": 5, "block": 7, "plot": "WPG-10599"},
                "regulations": {"max_height": 100, "min_setback": 5, "max_GFA": 10000},
                "time_planning": {"planning_application_deadline": "timedate", "construction_start": "timedate"},
                "construction": {"contractor": "name", "construction_start": 2020, "construction_finish": 2021},
                "real_estate": {"year_last_sale": 2001, "price_last_sale": 500000, "price_current_asking": 600000},
                "property": {"occupied": false}
            },
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                "topology": "network",
                "nodes":
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                        "guid": "rhino3D-27592535heefgieseyyyy",
                        "geometry": {"type":"point_collection", "xyz": [ [0,0,0], [1,1,1], [2,2,2], [3,3,3], [4,4,4], [5,5,5]]},
                        "graphics": {"color": "orange", "material": "polder grass"},
                        "urban_design": {"development": 10, "district": 5, "block": 7, "plot": "WPG-10599"},
                        "regulations": {"max_height": 100, "min_setback": 5, "max_GFA": 10000},
                        "real_estate": {"year_last_sale": 2010, "price_last_sale": 250000, "price_current_asking": 300000}
                    },
                "edges": null
            }
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    "data_private":
        [
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                "uuid" : "123e4567-e89b-12d3-a456-426614174000",
                "address_CA": {"country": "canada", "province":"manitoba", "city":"winnipeg", "street": "street", "postal_code":"code"}
            },
            {
                "uuid" : "123e4567-e89b-12d3-a456-426614174111",
                "address_NL": {"country": "nederland", "province":"zuid holland", "city":"rotterdam", "street": "BM", "postal_code":"code"}
            }
        ]
}
```

ex. you can override coordinate defaults with localized coordinate 'frames' (ex. COMPAS) use case: large geometries that need accuracy

Simple Example without topology

Simple Example with topology

Private data linked with UUID

Geometry Model?

Geometry Core Objects + Geometry Engine

	Open Source	Geometry Core	Geometry Engine	Software Plugins	Code	Active Dev.	Contributors (Github)	License	Link
 **Ladybug**	yes	yes	limited	no	Python	yes	19	AGPL-3.0	web
 **Speckle 2.0**	yes	yes	no	AEC	Python, C#	yes	14	Apache-2.0	web
 **BHoM**	yes	yes	limited	AEC	C#	yes	34	LGPL-3.0	web
 **COMPAS**	**yes**	**yes**	**yes**	AEC	**Python**	**yes**	**32**	**MIT**	web
 **Rhino3DM**	yes	yes	limited	no	C#, JS Python	yes	19	MIT	web
 **GDAL**	yes	-	-	GIS	C, C++ Python	yes	276	MIT/X	web

Geometry Description Source - Incomplete

Geometry Encodings

Geometry Standards

	Ladybug	Speckle	COMPAS	GeoJSON	CityGML	LandInfra	LBD *	gLTF	I3S	IFC
WKT *				x (analogous)						
GML 3 *					x					
ISO 19107					x (subset)	x (& more)				
ISO 10303										x
OpenGIS SF SQL*				x						
Mathematical		x	x							
Euclid	x									
Open Studio	x									

* WKT : Well Known Text
* GML: Geographic Markup Lanaguage
* LBD: Linked Building Data
* Simple Features Implementation Specification for SQL

Geometry Coverage - Incomplete

	Speckle	COMPAS	Ladybug	WKT	GML	GeoJSON	GeoJSON 2021	TopoJSON	CityGML 2.0	CityGML 3.0	LandInfra	LBD *	gLTF	I3S	IFC
Primitives															
Arc	x	x	x												
Circle	x	x	x												
Ellipse	x	x	x												
Frame		x													
Line	x	x	x	x		x									
Plane	x	x	x												
Point	x	x	x	x		x									
Polygon	x	x	x	x		x									
Polyline	x	x	x												
NURBS Curve	?		?												
Quaternion		x	x												
Vector	x	x	x												
Shapes / Surfaces															
Box	x	x	x												
Capsule		x	x												
Cone	x	x	x												
Cylinder	x	x	x												
Polyhedron	x	x	x												
Sphere	x	x	x												
Torus		x	?												
BREP	x	x	x												
Data Structures															
Array	x	x	x												
Array Numpy		x													
Aggregate (Network)		x													
Network		x													
Tree		x													
Mesh	x	x	x												
Volmesh		x													
Matrices		x	x												

User Needs?

Map Urban Development Users, Payers, Stakeholders

Cross Disciplinary Brainstorming Sessions

1. Stages of the Urban Development Process
2. Users, Payers, Stakeholders at each stage
3. Needs and Requirements at each stage for users
4. Tools needed versus tools available
5. Data Model overlap with other stages
6. Data Integration opportunities and challenges
7. Minimum Viable Product opportunities