Towards Better Co-Design with Disciplinary Ontologies:
Review and Evaluation of Data Interoperability in the AEC Industry

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Outline

- **Background and motivation**

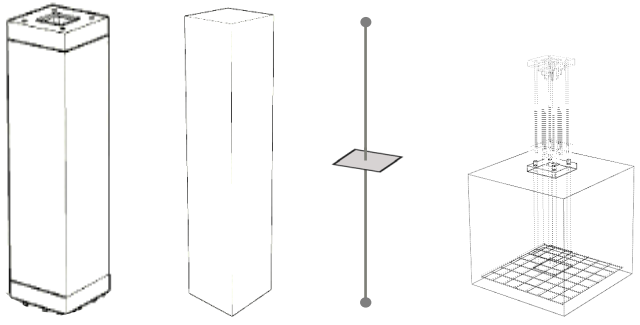
- **Review of key approaches to the interoperability problem**
  - Data schemas and frameworks for interoperability
  - Linked data and ontologies

- **Evaluation and proposal**
  - Comparison of interoperability approaches
  - How ontologies can support collaborative design tools
  - Proposal: Using disciplinary ontologies with BHoM

- **Conclusion**

What is a column?

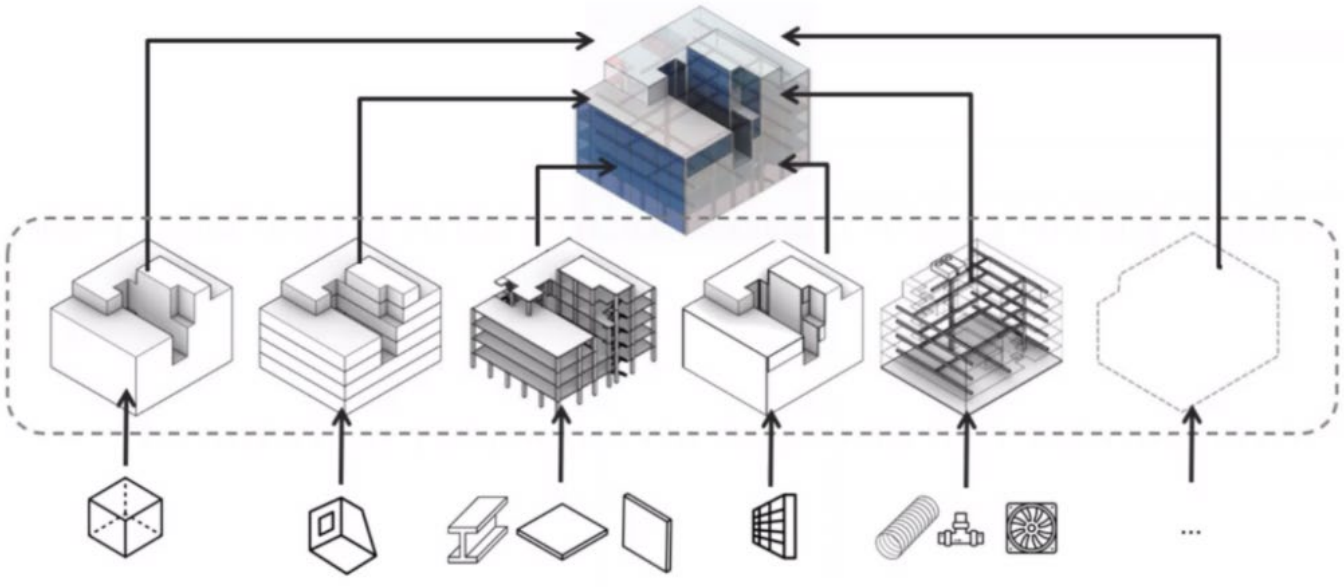
the answer depends on whom we ask



Multi-disciplinarity in co-designing buildings

"All models are wrong, but some are useful"

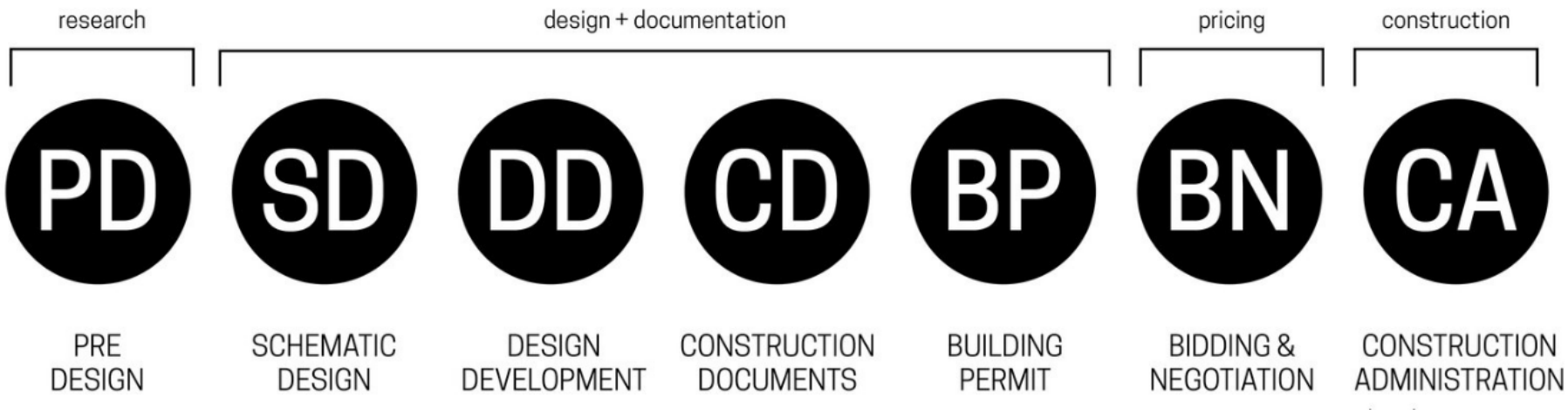
George E. P. Box



Dr. Al Fisher , 2021. Buro Happold. Building and Habitats object Model: A common language for design and multi-representational computation

Design Phases and Decisions

Design Phases



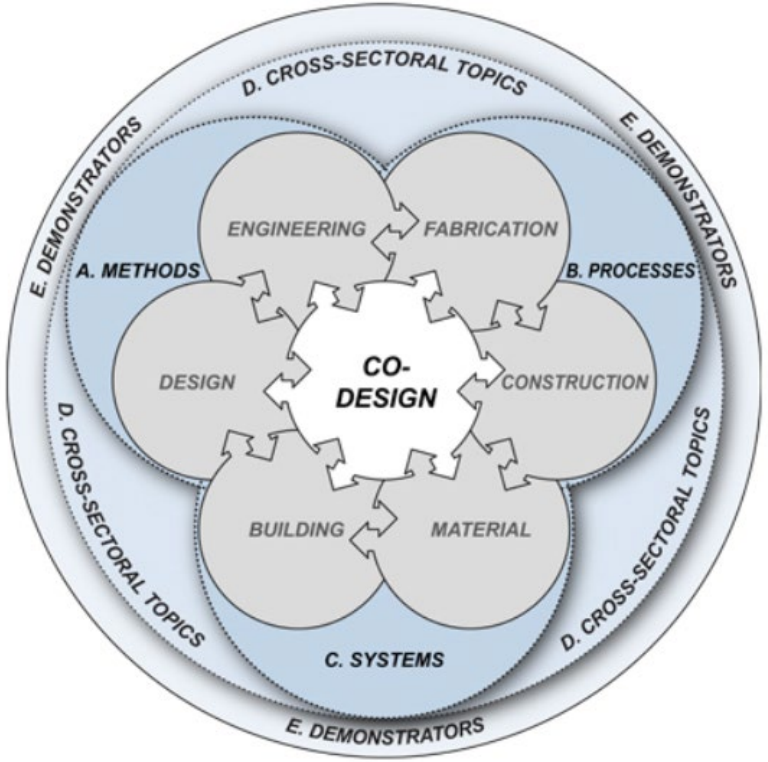
Surce: https://wc-studio.com/journal/2019/7/5/working-with-an-architect-understanding-phases-of-design-construction

the most critical design decisions happen in the early stages of design.

influence →

- **Construction costs**
- **Subsequent building energy use**

Co-Design IntCDC



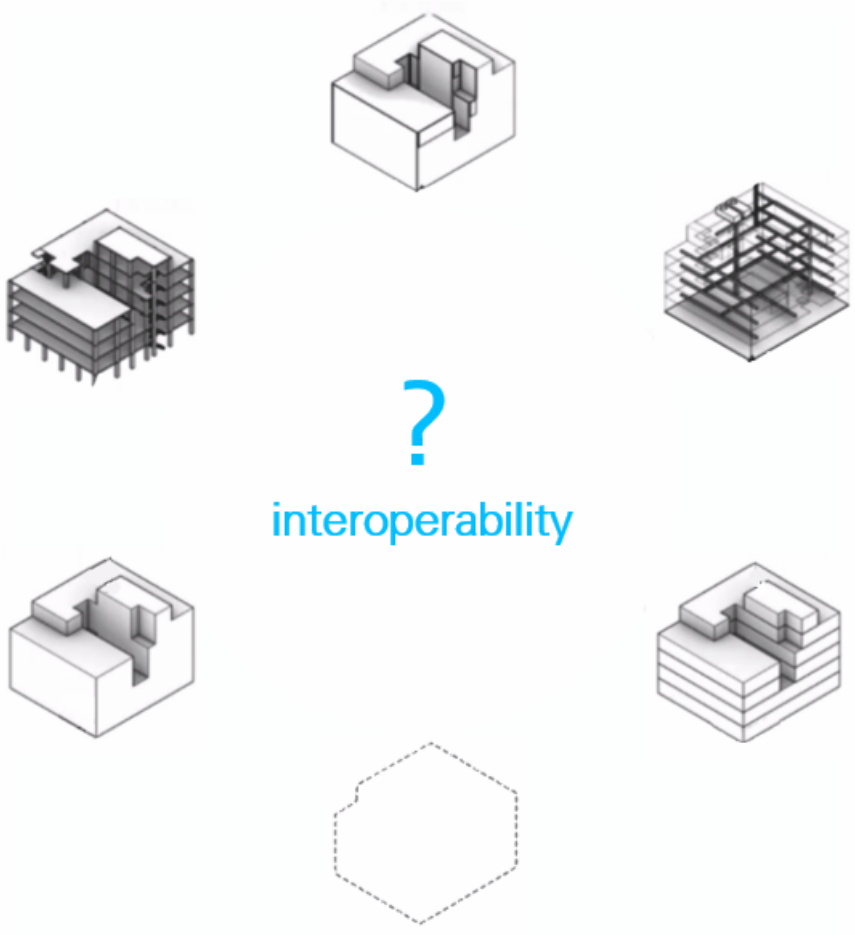
The Research Areas

Methods: Truly integrative computational design and engineering methods
Processes: Robotic cyber-physical fabrication and construction processes
Systems: Genuinely digital, next-generation material and building systems
Cross Sectoral: Inclusive and sustainable innovation with critical reflection
Demonstrators: Rapid turn from visionary research to architectural application

The Research Units

Architecture
Structural Engineering, Building Physics and Geodesy
Manufacturing and Systems Engineering
Computer Science and Robotics
Humanities and Social Sciences

Data Interoperability



Source: adapted from: Dr. Al Fisher , 2021. Buro Happold. Building and Habitats object Model: A common language for design and multi-representational computation and Toth, B., Janssen, P., Stouffs, R., Chaszar, A., & Boeykens, S. (2012). Custom digital workflows: a new framework for design analysis integration. International Journal of Architectural Computing, 481-500.

Data schemas and frameworks for interoperability

Data schemas and frameworks for interoperability

IFC

- Is a standardized data schema for the AEC industry based on the EXPRESS data model;
- Represents data in a monolithic approach;
- Powerful in representing/ documenting element classification and product properties, but it falls when representing dynamic data;

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SPECKLE

- Open source, web-based collaborative framework
- Offers a neutral schema for the specification and creation of basic geometry types
- Around 150 object models, and numerous connectors to design software

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BHoM

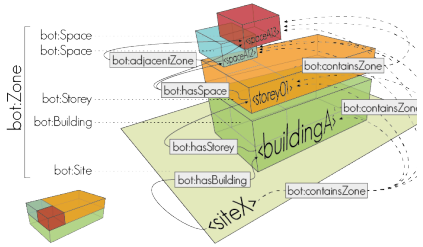
- Open source, collaborative framework
- Offers multiple, discrete disciplinary representations of building elements, therefore it has a rich object model library with over 1200 object models.
- It separates objects from functions; consists of (1) object models, (2) engines that operate on data, (3) adapters that map and translate data among different software and (4) user interfaces for software where its functionality is exposed.

Linked Data and Ontologies

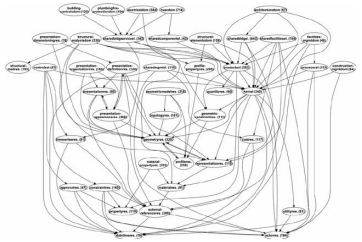
Semantic Web technologies remains one of the most promising solutions to link data from heterogenous systems.

W3C standard data model: RDF

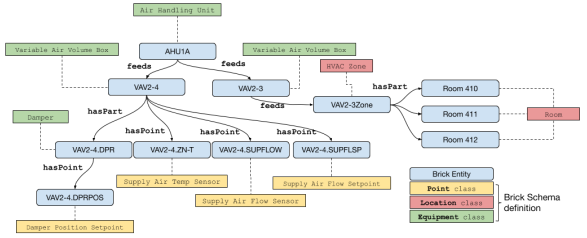
Linked Building Data (LBD) community group/ AEC ontologies



Building Topology Ontology BOT

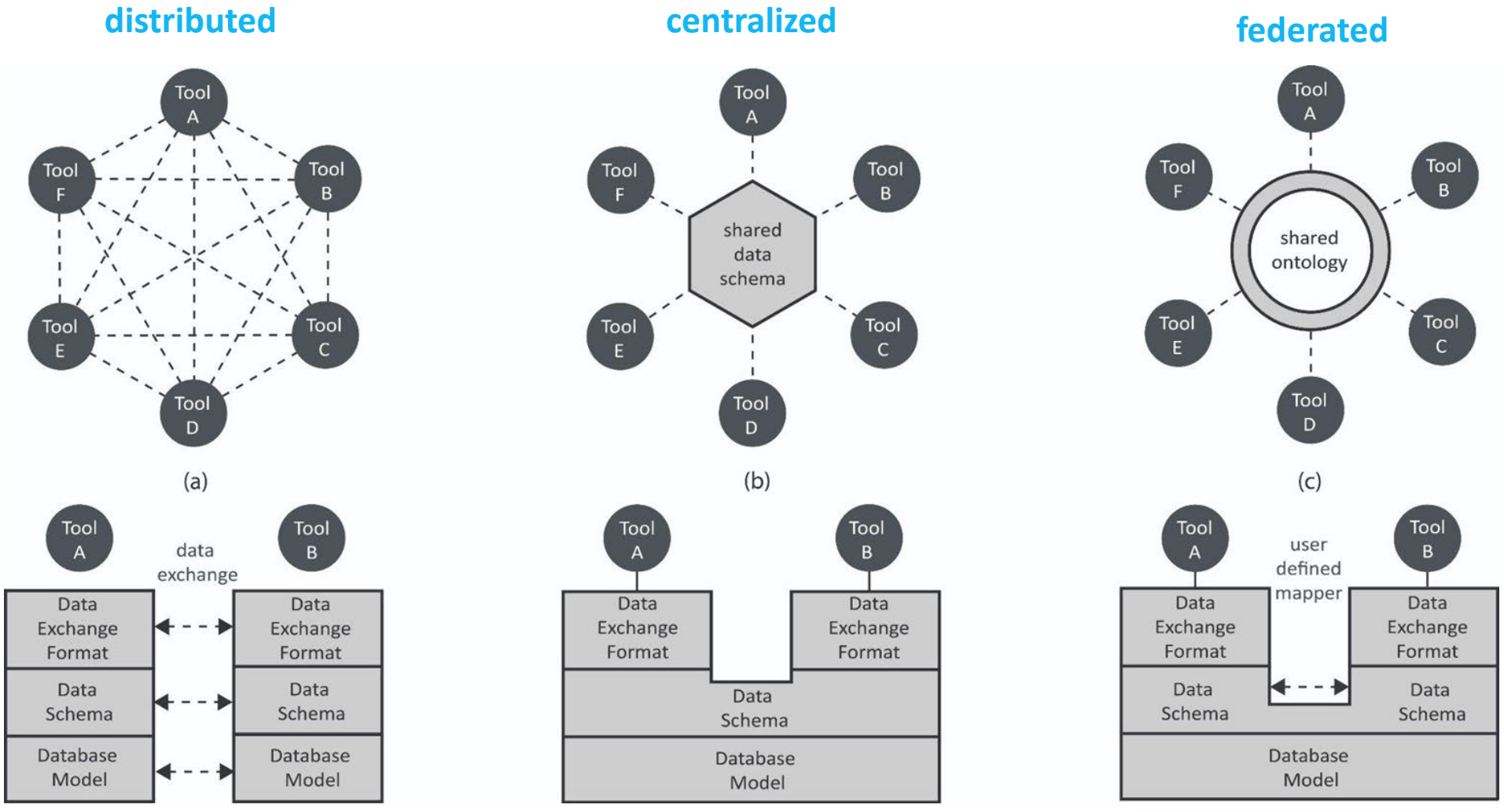


IFC represented in OWL ifcOWL



Brick Schema

Interoperability Approaches



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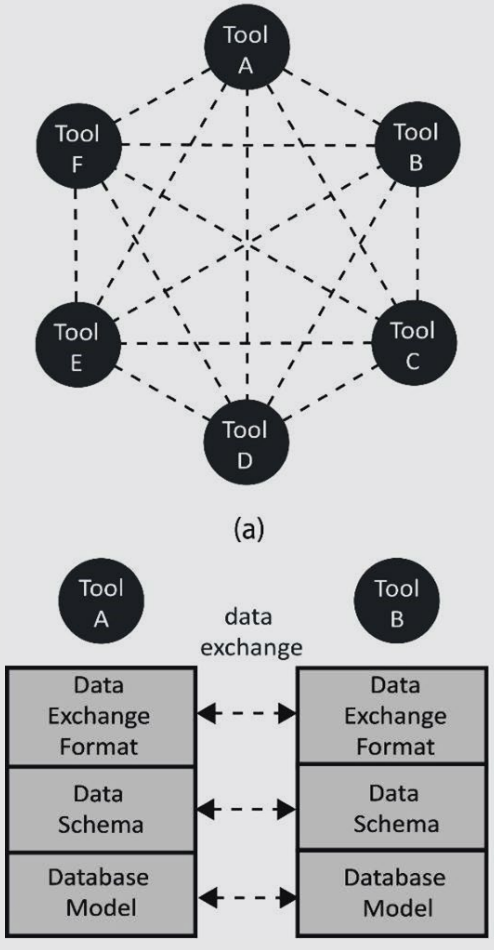
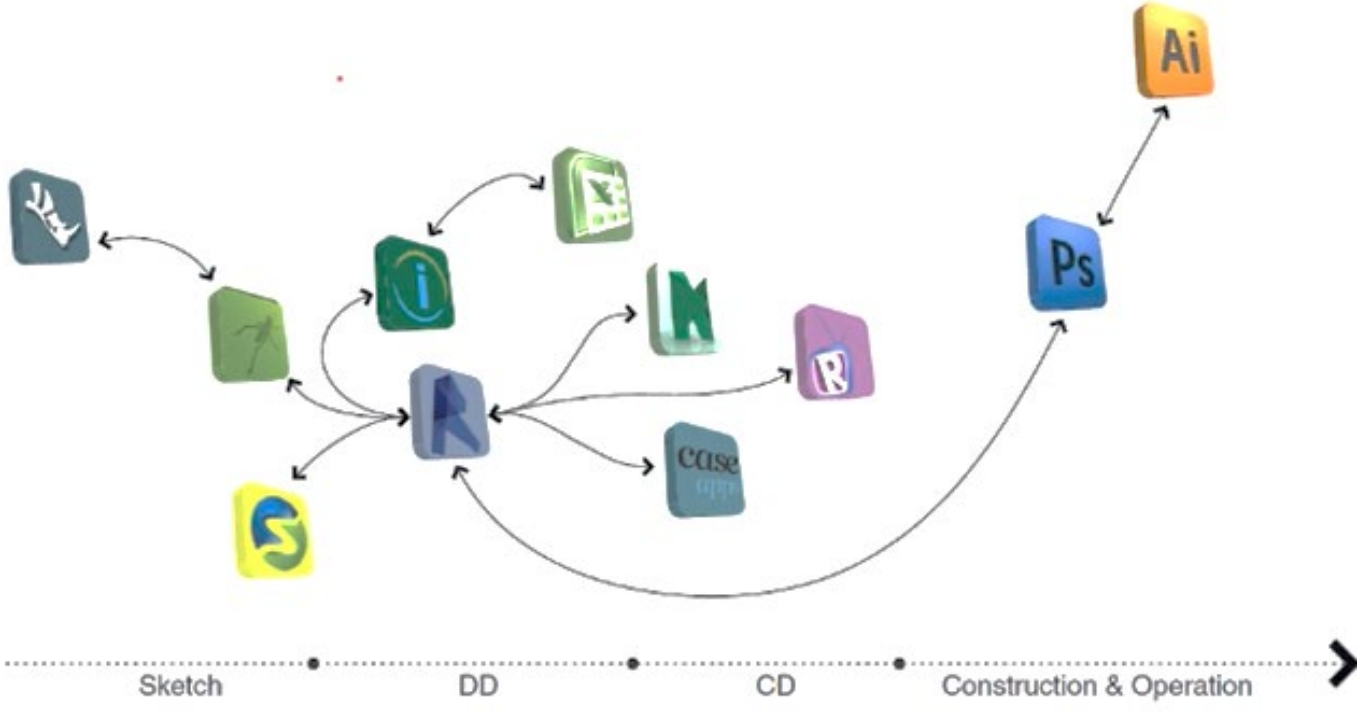
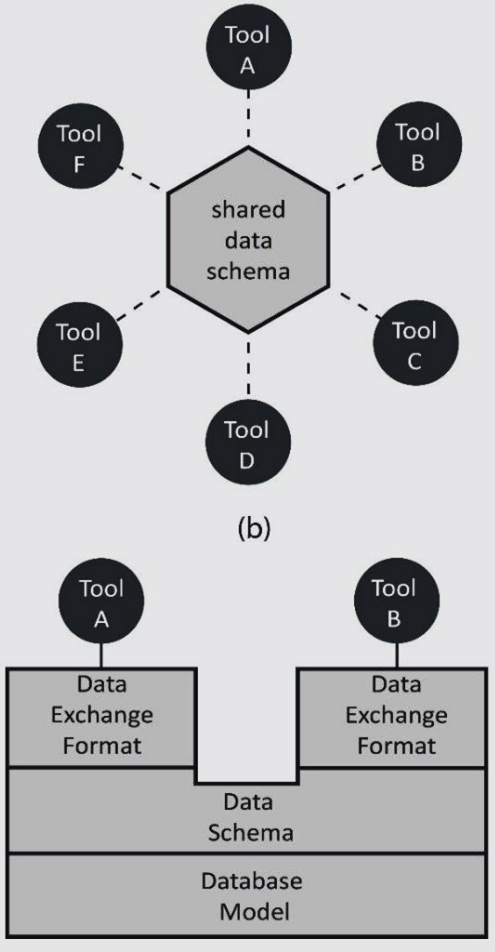
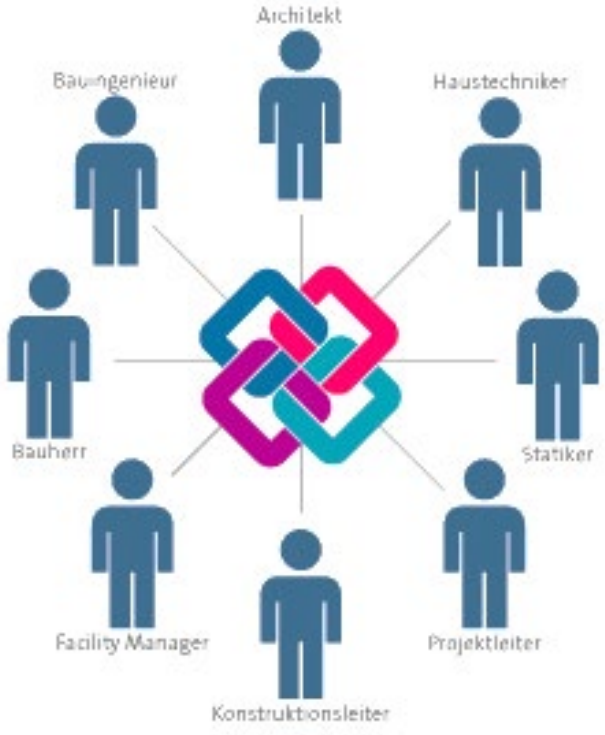
Distributed interoperability



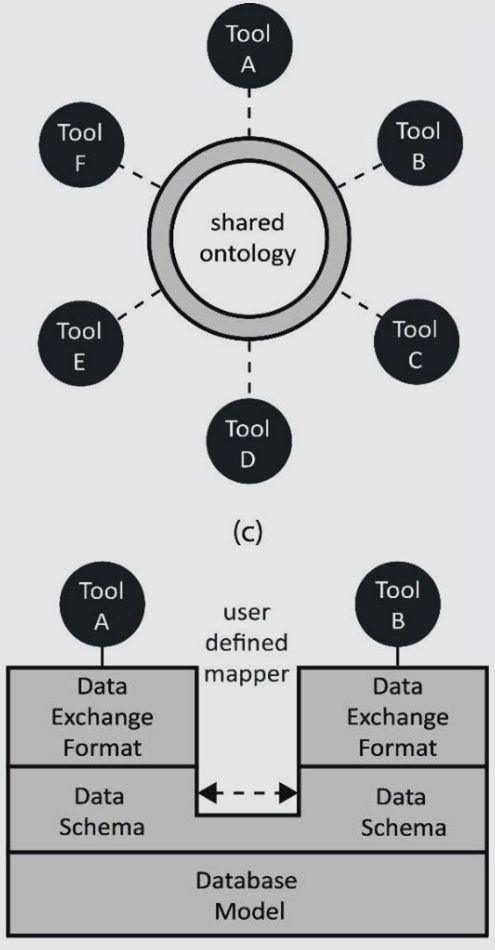


Centralized interoperability





Federated interoperability



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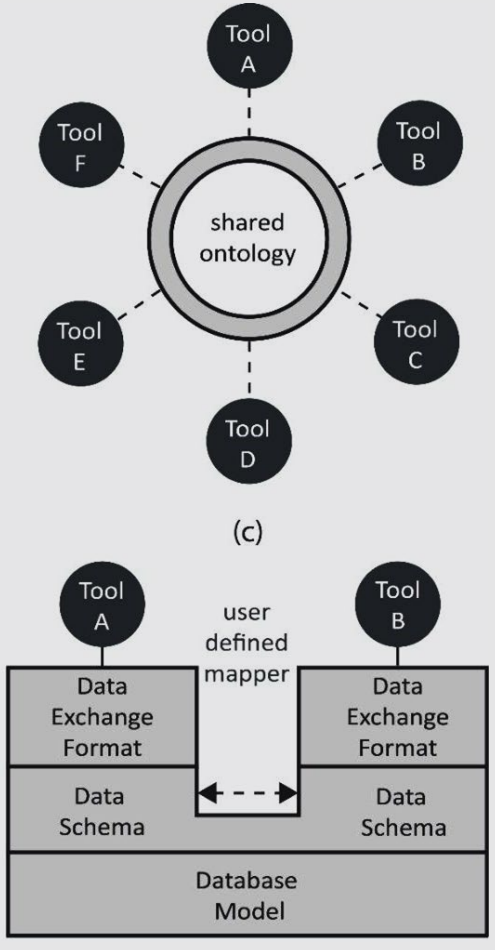
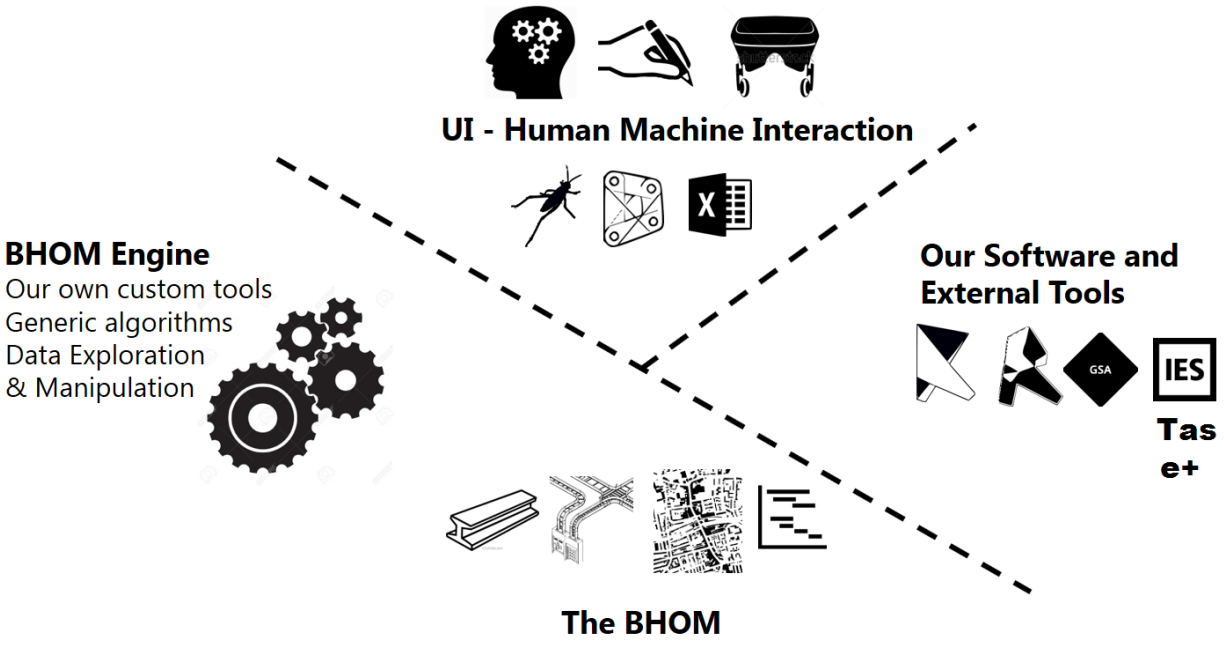
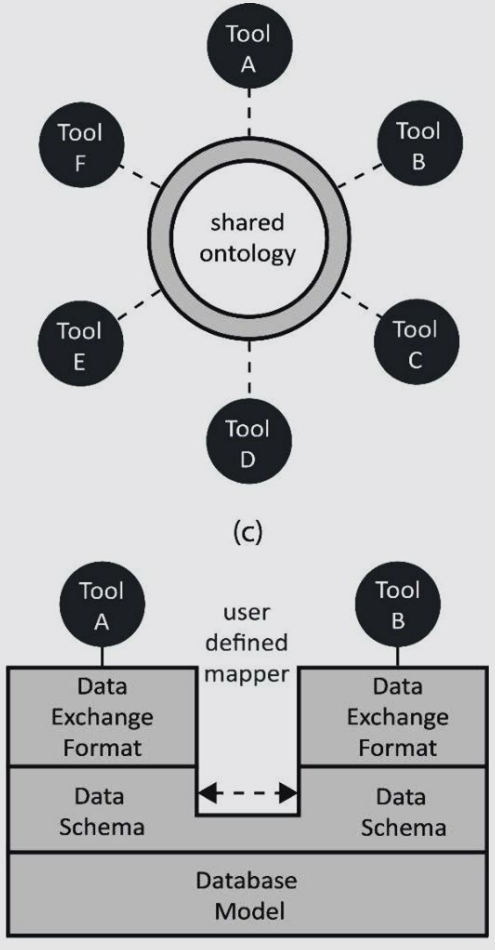




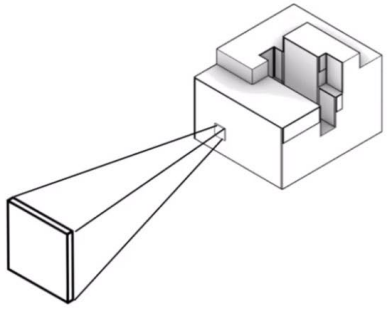
Source: Fischer A. et al. (2021) Buildings and Habitats object Model, github.com/BHoM

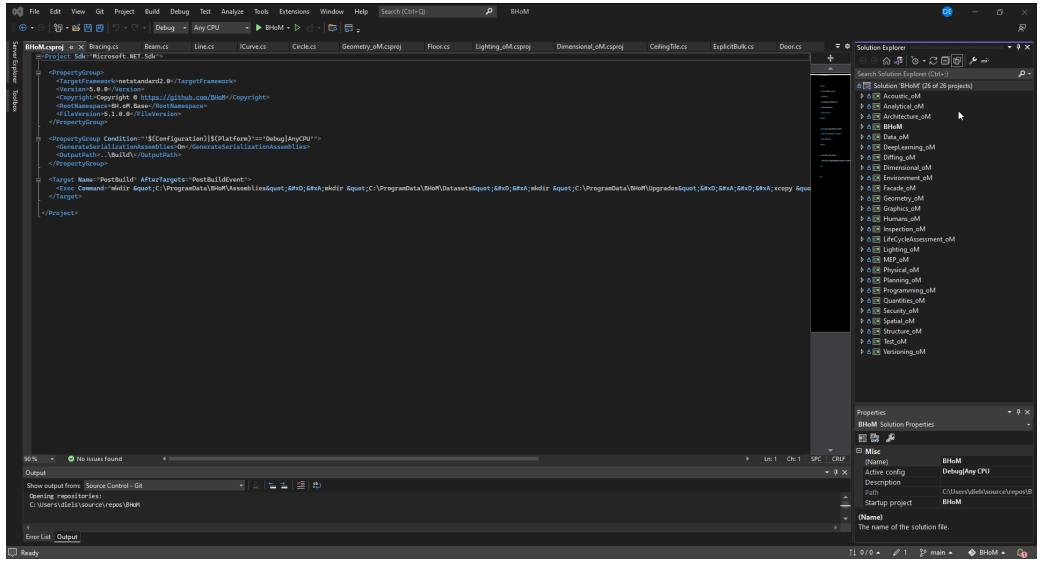
Federated interoperability



Common object Model (oM)
How to represent a "Wall"

Physical	BH.oM.Physical.Elements.Wall
Analytical	BH.oM.Facade.Elements.Panel BH.oM.Structure.Elements.Panel BH.oM.Environment.Elements.Panel BH.oM.Acoustic.Elements.Panel
Geometrical	BH.oM.Geometry.PlanarSurface BH.oM.Geometry.NurbsSurface BH.oM.Geometry.NurbsCurve
Graphical	BH.oM.Graphics.RenderMesh





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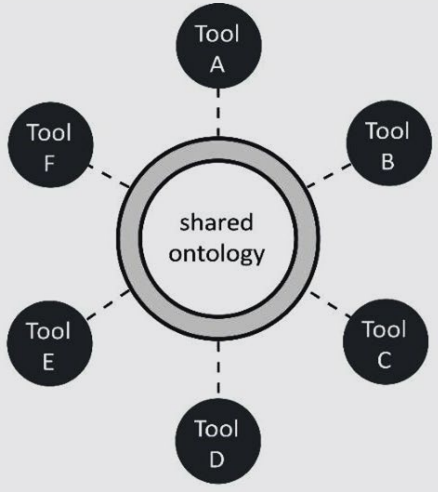
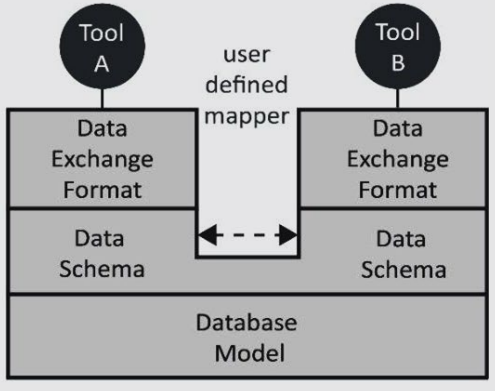


(c)



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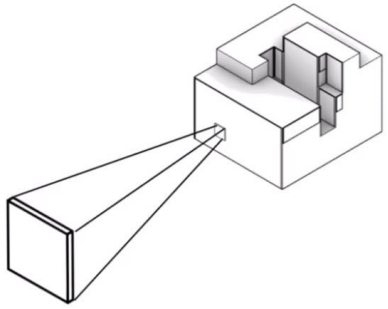
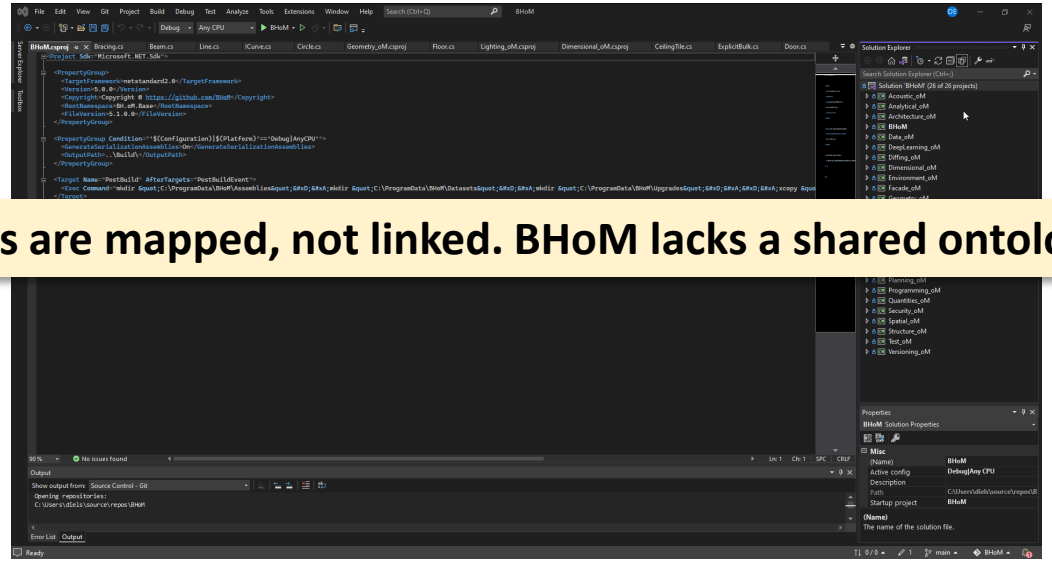


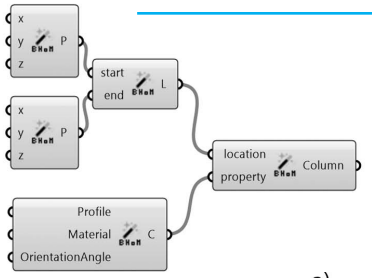


Objects are mapped, not linked. BHoM lacks a shared ontology

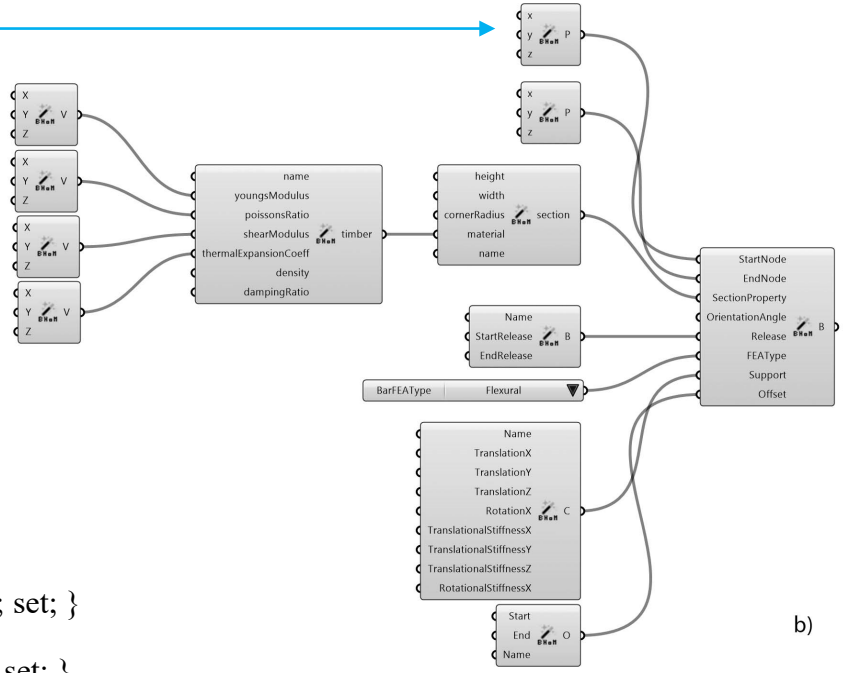
Source: BHoM, github.com/BHoM

How ontologies can support collaborative design tools

- Connect concepts
- Augment building elements with semantic information



a)



b)

physical oM Column

public virtual ICurve Location { get; set; } = new Polyline();

public virtual IFramingElementProperty Property { get; set; } = null;

structural oM Bar

public virtual Node StartNode { get; set; }

public virtual Node EndNode { get; set; }

public virtual ISectionProperty SectionProperty { get; set; } = null;

public virtual double OrientationAngle { get; set; } = 0;

public virtual BarRelease Release { get; set; } = null;

public virtual BarFEAType FEAType { get; set; } = BarFEAType.Flexural;

public virtual Constraint4DOF Support { get; set; } = null;

public virtual Offset Offset { get; set; } = null;

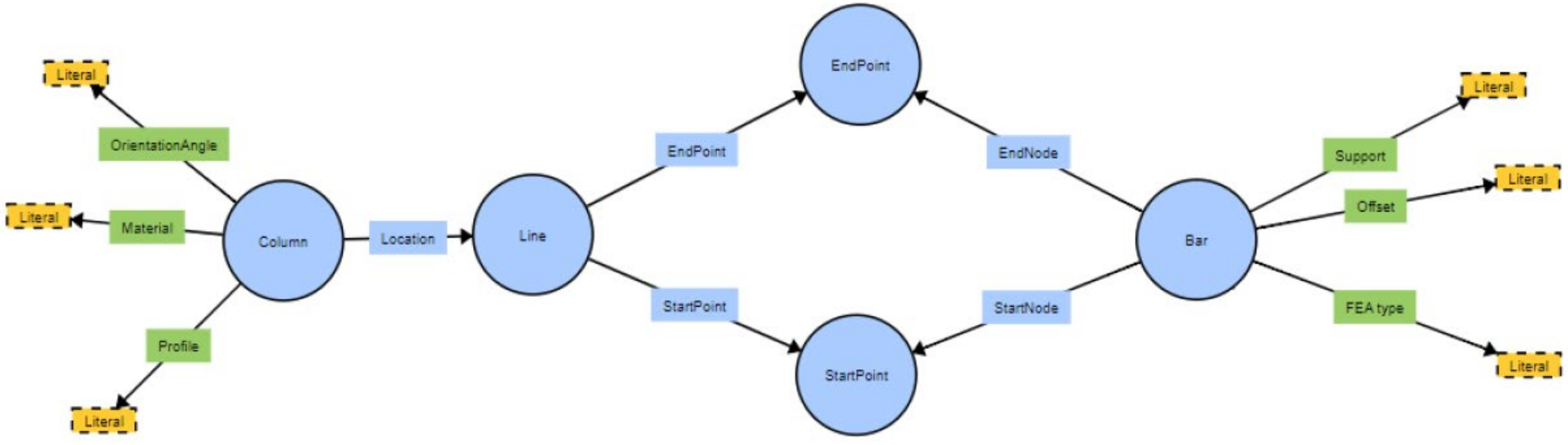
How ontologies can support collaborative design tools

- Connect concepts
- Augment building elements with semantic information

bhom:Column owl:sameAs bhom:Bar.
Bhom:lineStartNode owl:sameAs bhom:barStartNode

physical oM Column

structural oM Bar

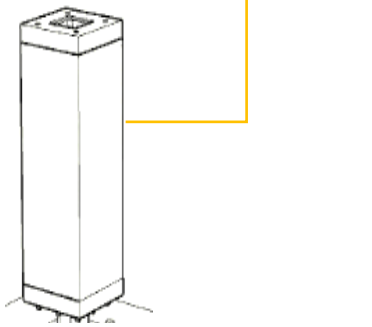


How ontologies can support collaborative design tools

- Connect concepts
- Augment/annotate building elements with semantic information

- Design building elements with design tools (Rhino 3D, grasshopper 3D, Revit, etc.); and
- Augment them with semantic information using ontologies.

Such function should be integrated in design tools.
BHoM allows such an approach, by also allowing extending data dictionaries, directly while designing.



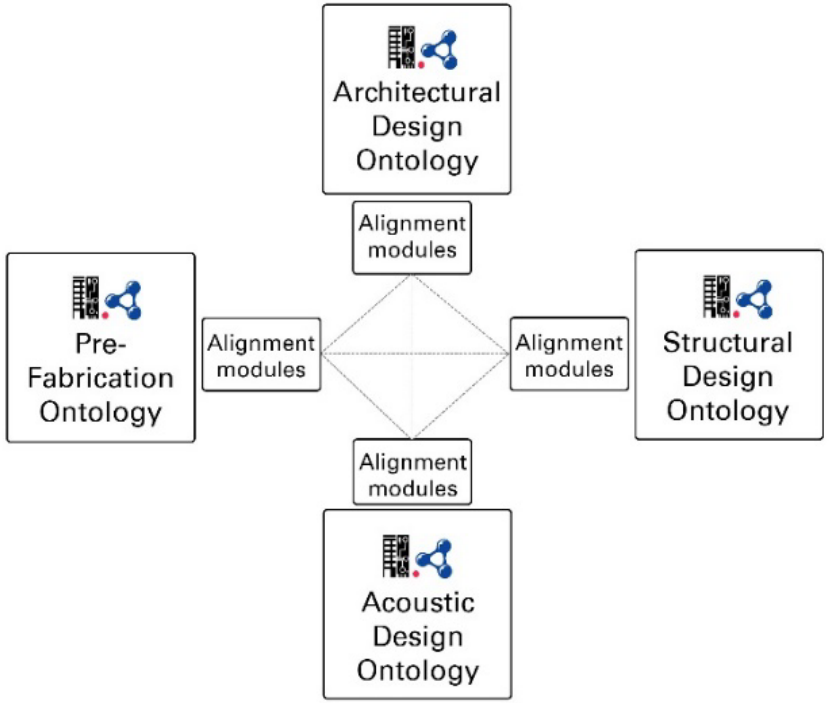
has_material
has_color
is_located
etc.

How ontologies can support collaborative design tools

- Connect concepts
- Augment/annotate building elements with semantic information
- Powerful queries
- Add rules, validate data, reasoning

has_material
has_color
is_located
etc.

Proposal: Using disciplinary ontologies with BHoM



Future Work

- convert BHoM's data model to OWL
- develop disciplinary ontologies with BHoM object models, as modular ones aligned with existing ontologies like BOT, TDY, etc.

More info in
https://bit.ly/3rTvVpL

Come join us in Stuttgart!
We are looking for a Computer Science Ph.D. Student to work in Knowledge Graphs and Semantic Web.