Civil Engineering @
University of Toronto

Can IFC mentality be the basis of digital twins? NO.

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Professor
Director, Intelligent Buildings Digital Twin @ UofT

14 October 2021

Key points

Acknowledgement

- It is all about semantics, meaning and learning
- Learned from extraordinary colleagues

Alain Zarli

This presentation is "in" French themes

What we learned from the French Revolution

A priest, a lawyer, and an engineer go to the guillotine

The lesson: engineers do not just love modeling, they *quickly* <u>default</u> to modeling

Nice Read: M. Tribus, ”…The engineer enters the public arena handicapped by personality and training," in *IEEE Spectrum*, vol. 15, no. 4, pp. 48-51, April 1978,

Not anti-modeling or pro the no-model; just want to try it

Phenomenology:

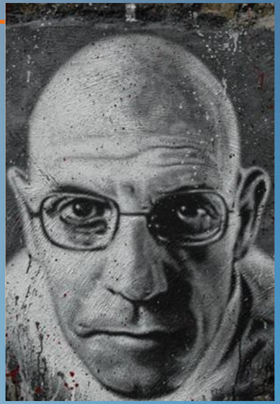
We are living and functioning well without models in many aspects of our lives

“all models are wrong [never match reality] the scientist cannot obtain a "correct"

one by excessive elaboration. On the contrary, following William of Occam, [we]

should seek an economical description of natural phenomena (Box 1976)”

The power of conformance



Michel Foucault

Truth is produced by power

Power is not a tool that we use; we are tools of power

- BIM is about telling people what is “the knowledge”
    - What is floor area?
    - How to model a parking space?

The pragmatics

Everyone wanted an IFC extension--Amore, Eindhoven 2015

"Unless each information exchange within construction project workflows has its specific contents and level of detail defined, the breadth and flexibility of the IFC schema leave room for errors (Eastman et al. 2010)".

Robert Amor

Let them have "ontology"

Constant manipulation to conform

- Context
    - Physical environment
    - Project delivery system
    - The design
    - Our learning
- Knowledge dynamics (varying relationships)
- Knowledge evolution

Cannot be enough: CYC

Mary Antoinette

Too many: 70+5; Conversion: 700 rules

My “project”; not your (BSI) model

To be effective, a model has to attempt three conflicting objectives — capturing the (essence of knowledge and) and conceptualization of a domain; completeness of representation; and the flexibility of use under project-specific needs. This was essentially impossible (see Hartmann et. al, 2017)

Timo Hartmann

BuildingSmart: not a promotor/gatekeeper; rather, a facilitator

See

Kondyli, V., Bhatt, M., & Hartmann, T. (2018). Precedent based design foundations for parametric design. Adv. Comput. Des, 3, 30.

Matos Castaño, J., Hartmann, T., Dewulf, G. P., & van Huffelen-de Kort, I. A. (2015). ‘What is going on and what should we do? ’Divergent frames in multifunctional projects. Engineering project organization journal, 5(1), 36-48.

It is the epistemology

- Normative thinking

- Structuralism
- Foundationalism
- Object-orientation

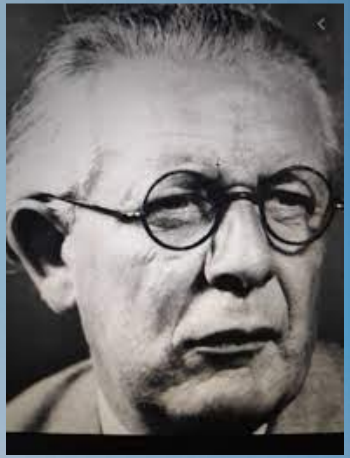
From foundationalism to consistency … to Coherentism!

"Therefore, several correct but different models may and should exist. Future software architectures in AEC should not be built on a unified, centralized model but, on a combination of models, which may not be standardized but whose schemas are encoded in a standard manner (Turk 2020)".

Ziga Turk

Constructivism: Who has the ontological agency?

- Synthesis vs analysis
- Learning and co-creation
- Evolution (things change)
- Emergence (new things are created)



Jean Piaget

Standardization is for interoperability

Turk, Ž. (2020). Interoperability in construction–Mission impossible?.

Developments in the Built Environment, *4*, 100018.

Pieter Pauwels

Non-default alternative(s)

(one) Model thinking; model correspond to reality, stakeholders have limited ontological agency

No (universal) model thinking; stakeholders have ontological agency

Conformance

No-learning mode	Learning mode
Top-down modeling	Bottom-up modeling
Memory-less systems	Who has the ontological agency

Analysis; simplifying complexity (no

dualism

Prototyping-falsification cycle

Difference

UofT Intelligent Buildings Digital Twin

Ron Saporta, Director, F&S

Can I see my work orders “process” within BIM

BIM?ML

A digital twin is

Business intelligence

Analytics

Access & Visualization

Input

Technical analytics

Ifc

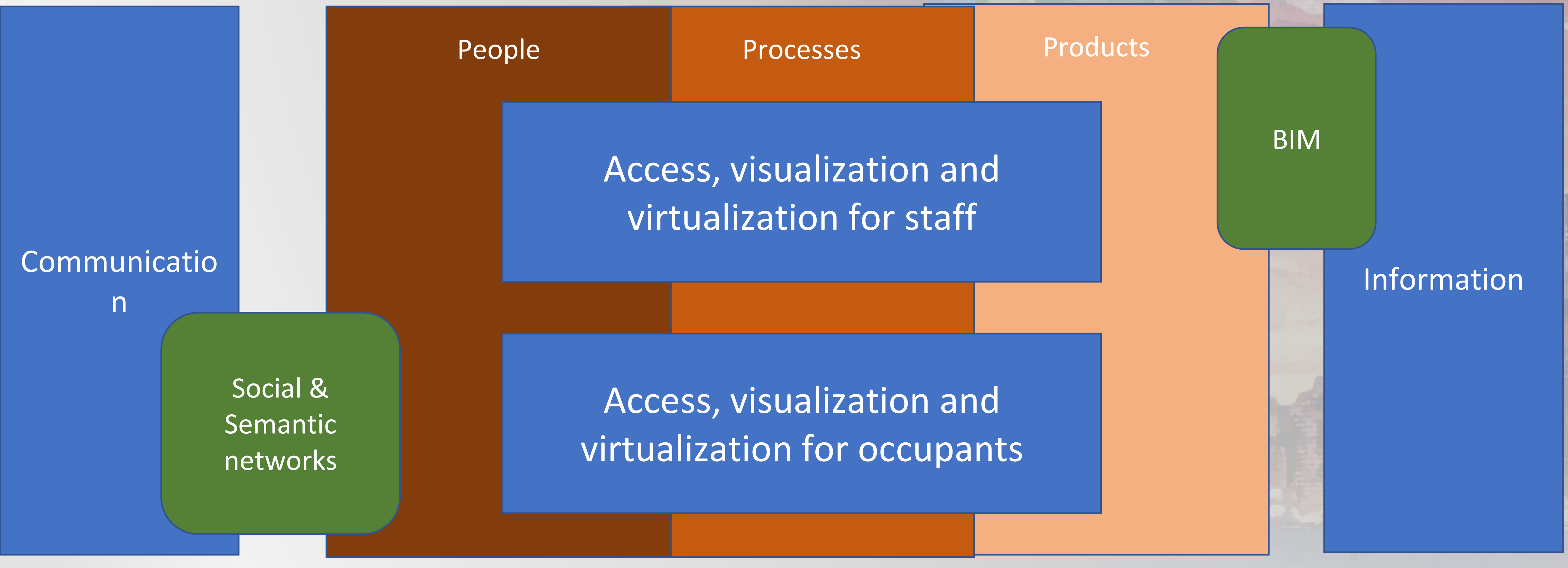
Ontologies

Socio-economic issues

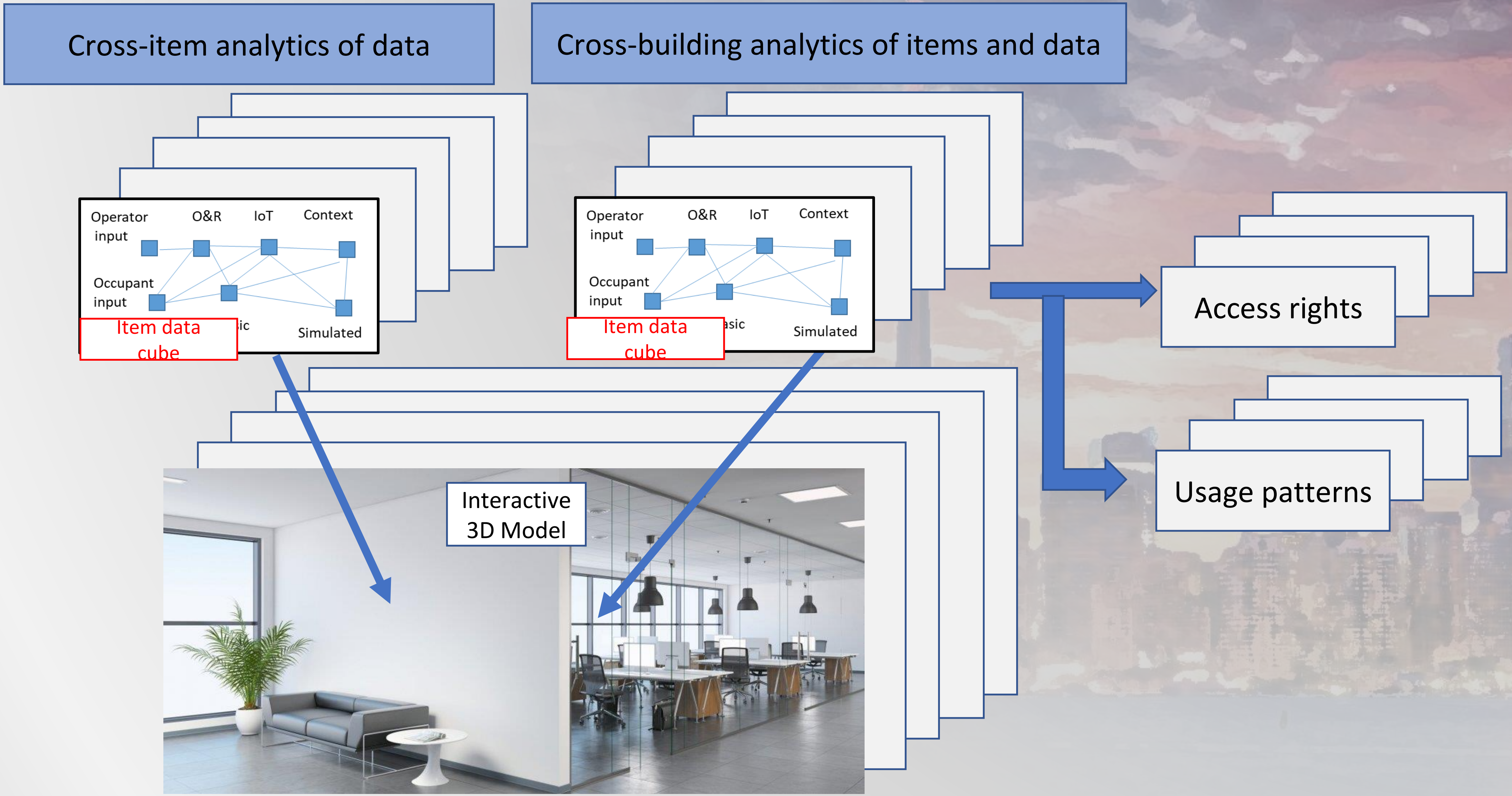
Social networks

Semantic networks

A digital twin value proposition: virtualization not visualization



Full visualization of raw data/reports



[Learn, bottom-up, from] what is going on?

Stakeholders hold evolutionary, contextualized knowledge

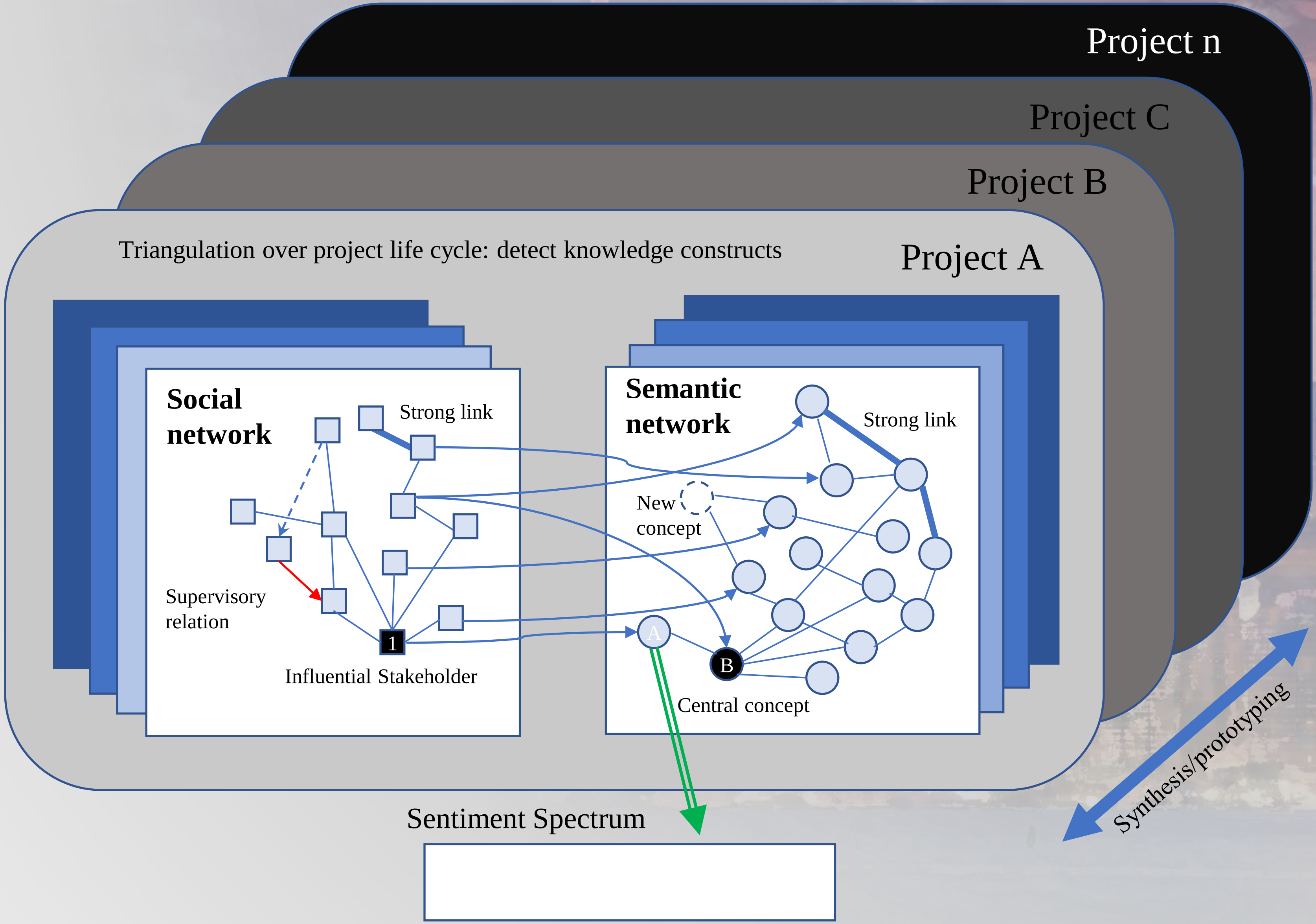
Stakeholder's communication mobilize their knowledge

Capture communication and present as social and semantic networks

Use network measures to capture possible constructs

Synthesize the use of construct and nominate prototypes

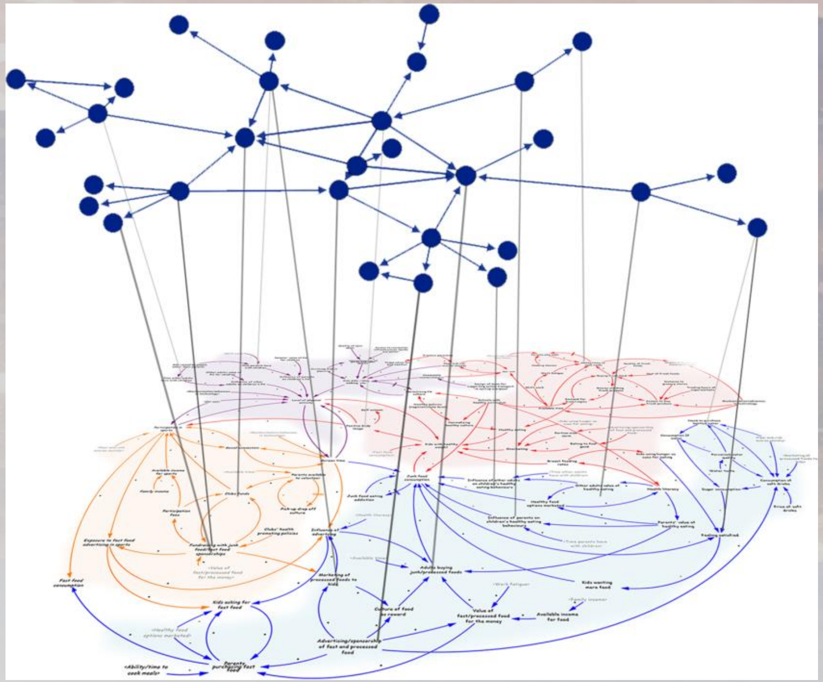
Update the mosaic



Socio-semantic networks

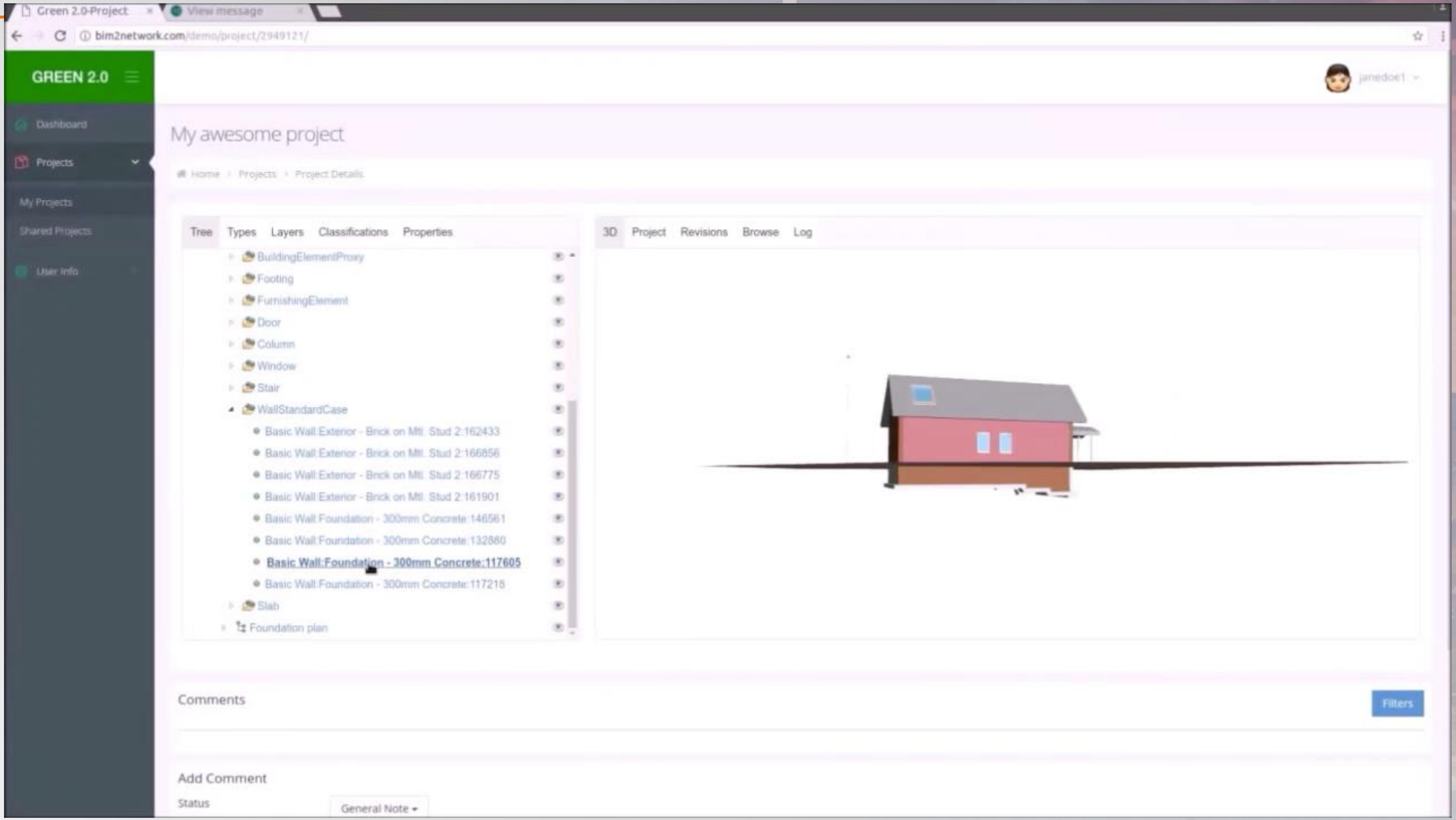
- The action research process is an iterative cycle of observation, identification of problems, development of technical solutions, and implementation of the developed solutions (Eden and Ackermann 2018).
- Ethnographic research requires frequent reviews and discussions of findings with project members (Hartmann, T.)

- How social systems inform the design of the technologies.
- How to understand the ways by which project team members interpret experiences and how do they co-learn.
- How do AEC professionals create, exchange, and communicate information during their work routine and what artifacts do they use to do so?
- What is their thinking process and how to customize the project information systems to that?



Example 1: BIM for visualization+communication

Demo

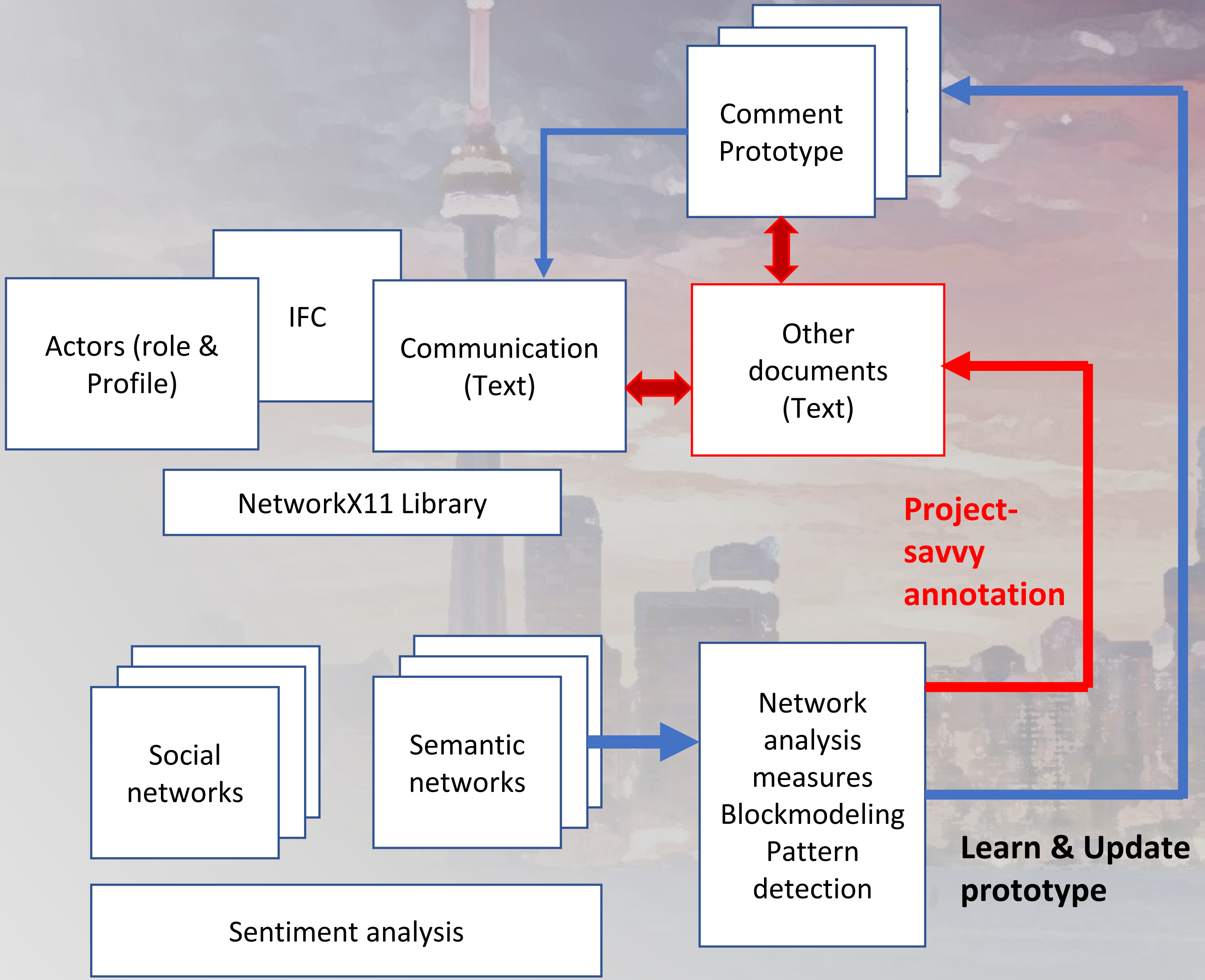

Green 2.0-Project
View message
bim2network.com/demo/project/2949121/
GREEN 2.0
Dashboard
Projects
My Projects
Shared Projects
User Info
My awesome project
Home › Projects › Project Details
Tree
Types
Layers
Classifications
Properties
BuildingElementProxy
Footing
FurnishingElement
Door
Column
Window
Stair
WallStandardCase
Basic Wall:Exterior - Brick on Mtl. Stud 2:162433
Basic Wall:Exterior - Brick on Mtl. Stud 2:166856
Basic Wall:Exterior - Brick on Mtl. Stud 2:166775
Basic Wall:Exterior - Brick on Mtl. Stud 2:161901
Basic Wall:Foundation - 300mm Concrete:146561
Basic Wall:Foundation - 300mm Concrete:132880
Basic Wall:Foundation - 300mm Concrete:117605
Basic Wall:Foundation - 300mm Concrete:117216
Slab
Foundation plan
3D
Project
Revisions
Browse
Log
Comments
Filters
Add Comment
Status
General Note

Demo (backup)

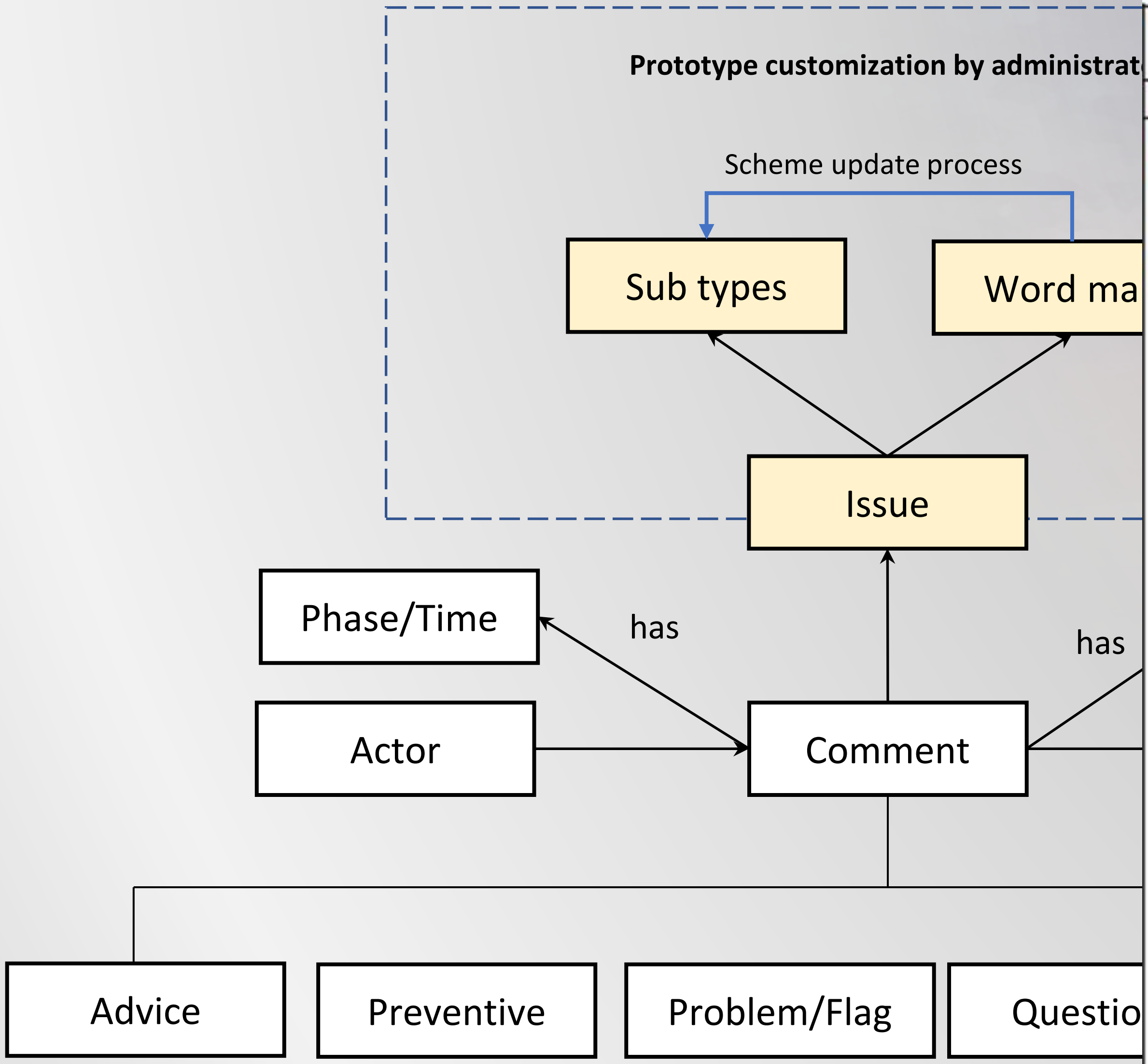

Element Discussion Networks
15
Total Comments
konomith
Top Commenter
66.9% neutral
Sentiment
STATUS DISTRIBUTION
COMMENT DISTRIBUTION
COMMENT WORDCLOUD
think
cool
wall
roof
great
maybe
Project Discussion Networks

The Centrality of participatory communication for learning

- Select a base comment prototype
- IFC provides product reference
- Social and semantic network analysis
- Update the prototype
  - User check and pick
  - Word cloud

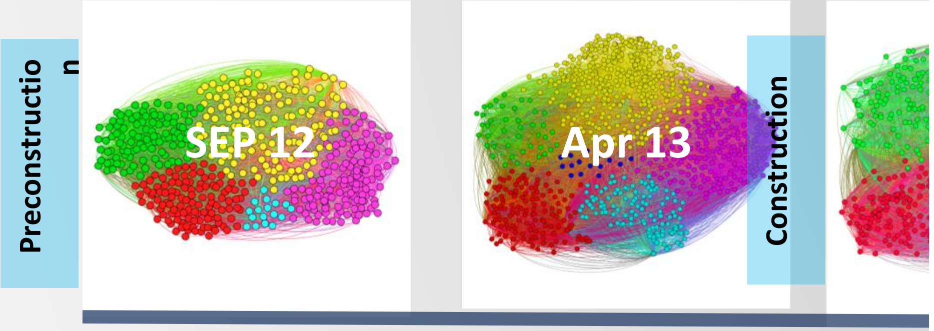


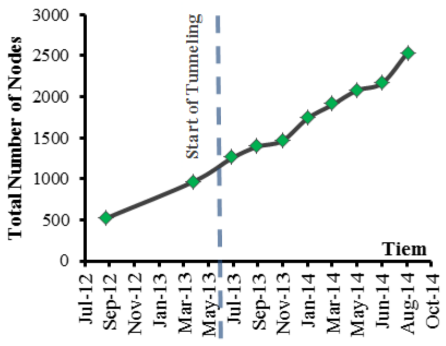
Example: prototyping comments (a simple construct)

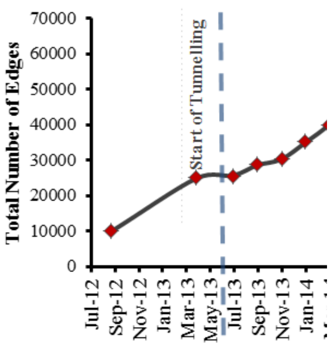


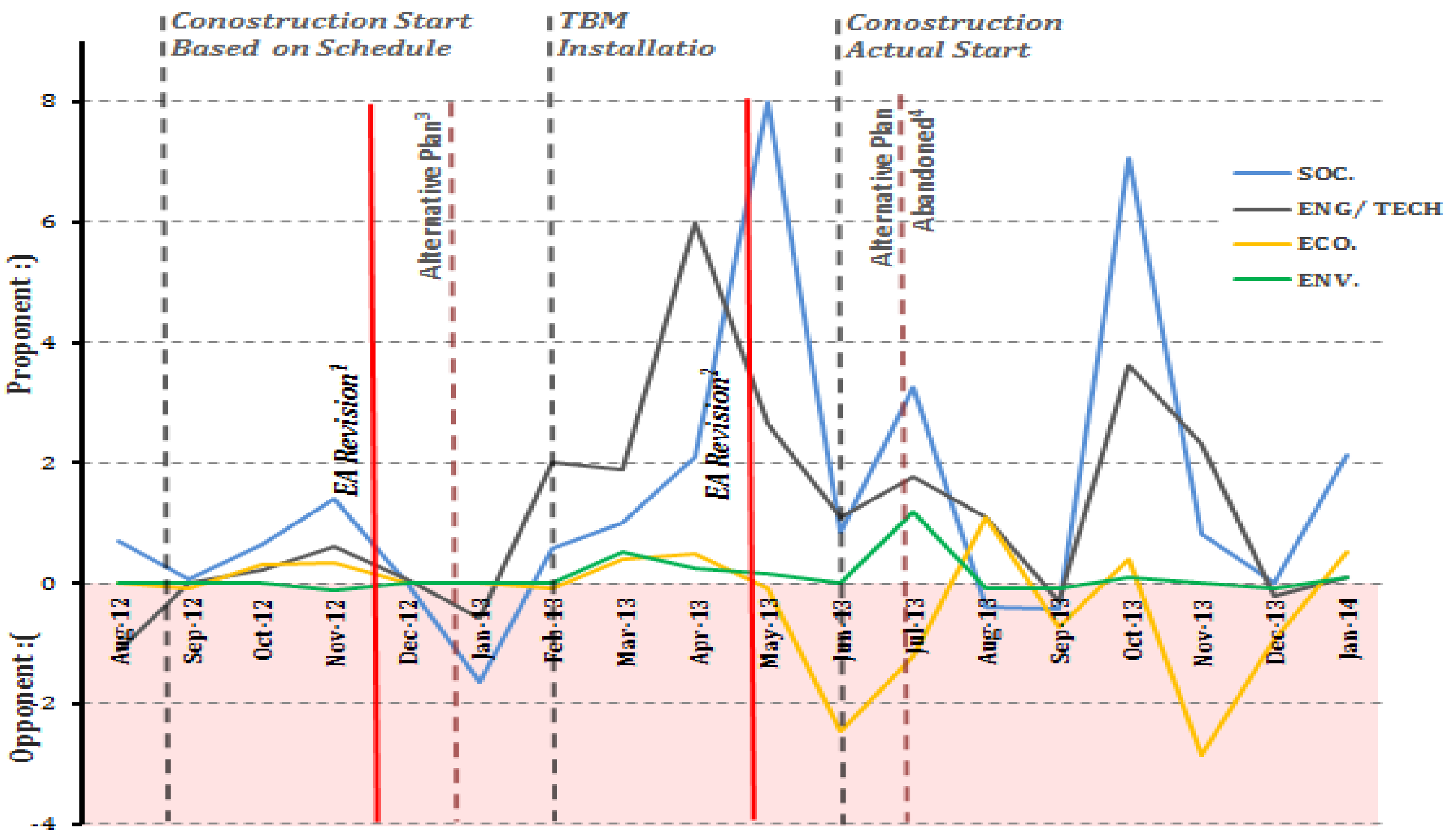
Comment Type	Directed To	Issue Type	Issue Sub-type	
[Menu]	[Text]	[Menu]	[Menu]	
Problem Question Solution Answer Recommendation Note		Code compliance	1 - General 3 - Fire Protection, Safety, Accessibility 4 - Structural 5 - Environmental Separation 6 - HVAC 7 - Plumbing 8 - Safety – Site, Demolition 9 - Housing, Small Buildings	[Text - Enter code reference]
		Appearance	Style Shape Finish Color Other	
		Constructability & Estimating	Supply Chain/Mat'l Availability Intersections/Interference Customization/Standardization Symmetry /Similarity Life Cycle Labor Installation Phasing Installation Ease & Clearance Other	
		Program requirements & Design intent	Social Performance Sustainability Other	
		Schedule	Design phase Construction phase Other	Increase Decrease

The Value: As it happens Dashboard



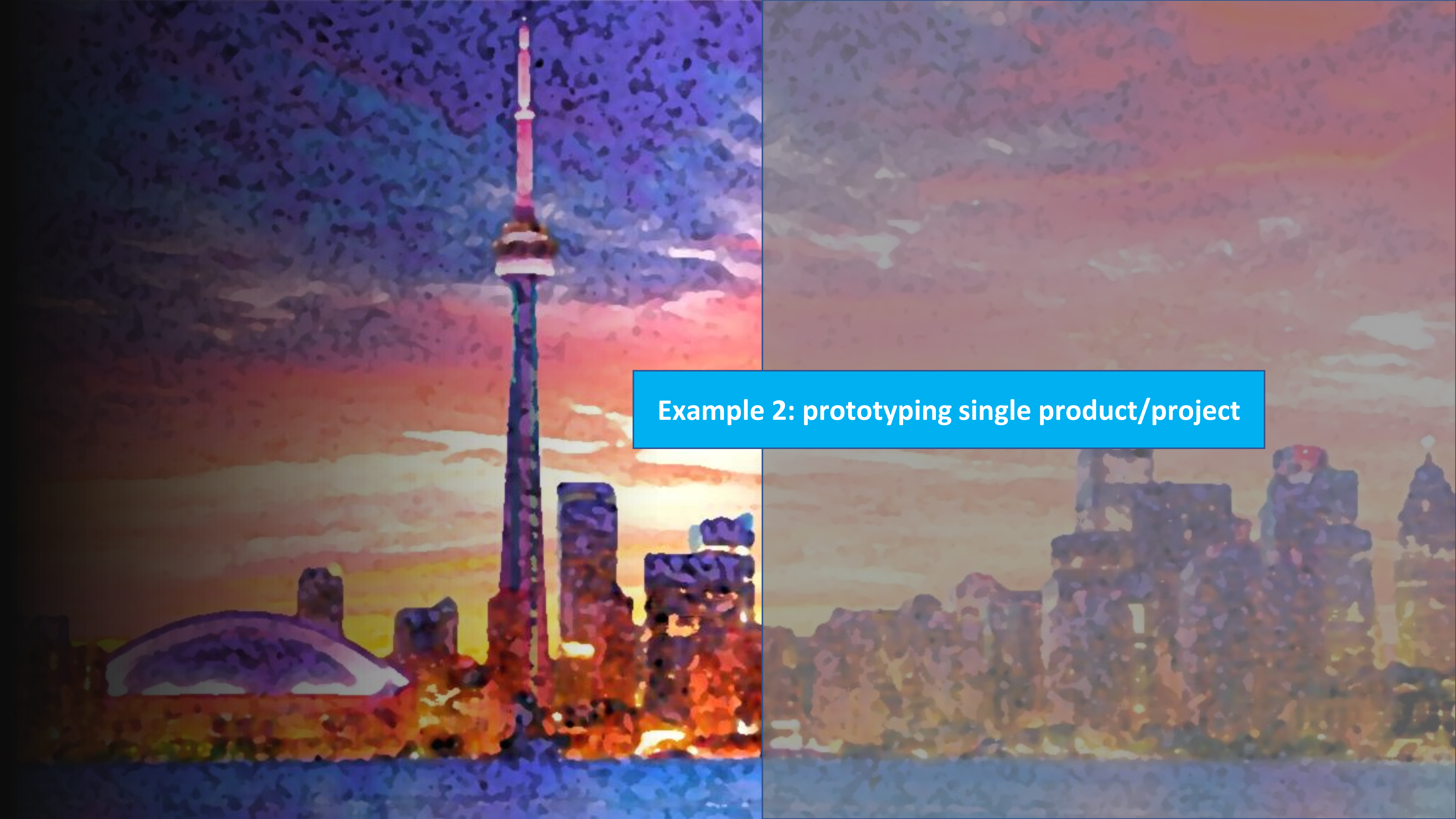






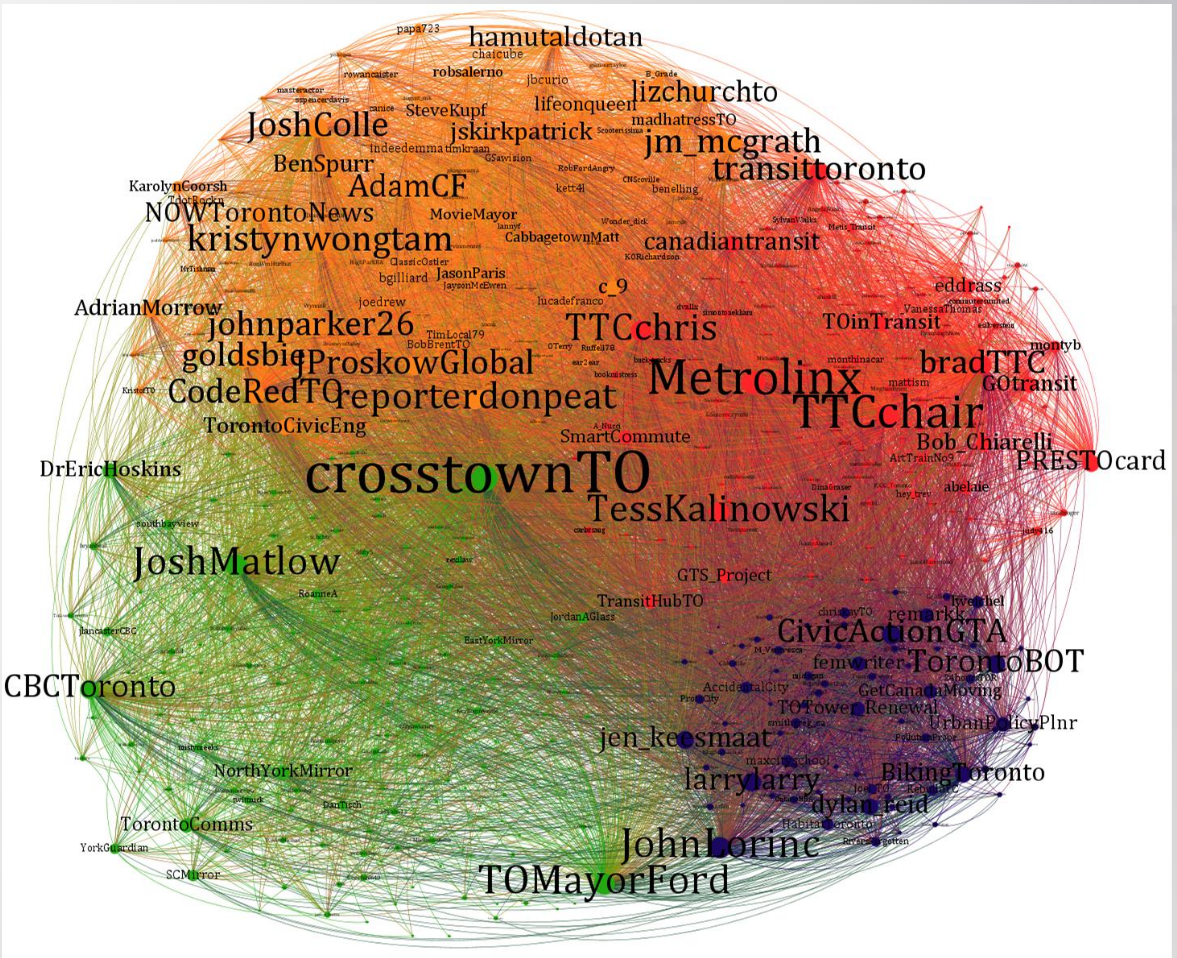
1. Extension of underground portion from east of Brentciffe to east of Don-Mills (Nov30, 2012)
2. Environmental Assessment was revised again after receiving community feedback, and was returned to the original EA. (May 2013)
3. Toronto City Councillors from Scarborough put forward an alternative plan to proceed with the construction of the Eglinton Avenue portion of the line as planned, but to exclude the Scarborough RT from the line (Jan 2013)
4. Plans for an "Eglinton-Scarborough Crosstown" line were abandoned, thereby reverting the entire line back to its originally conceived plan under Transit City (July 2013)

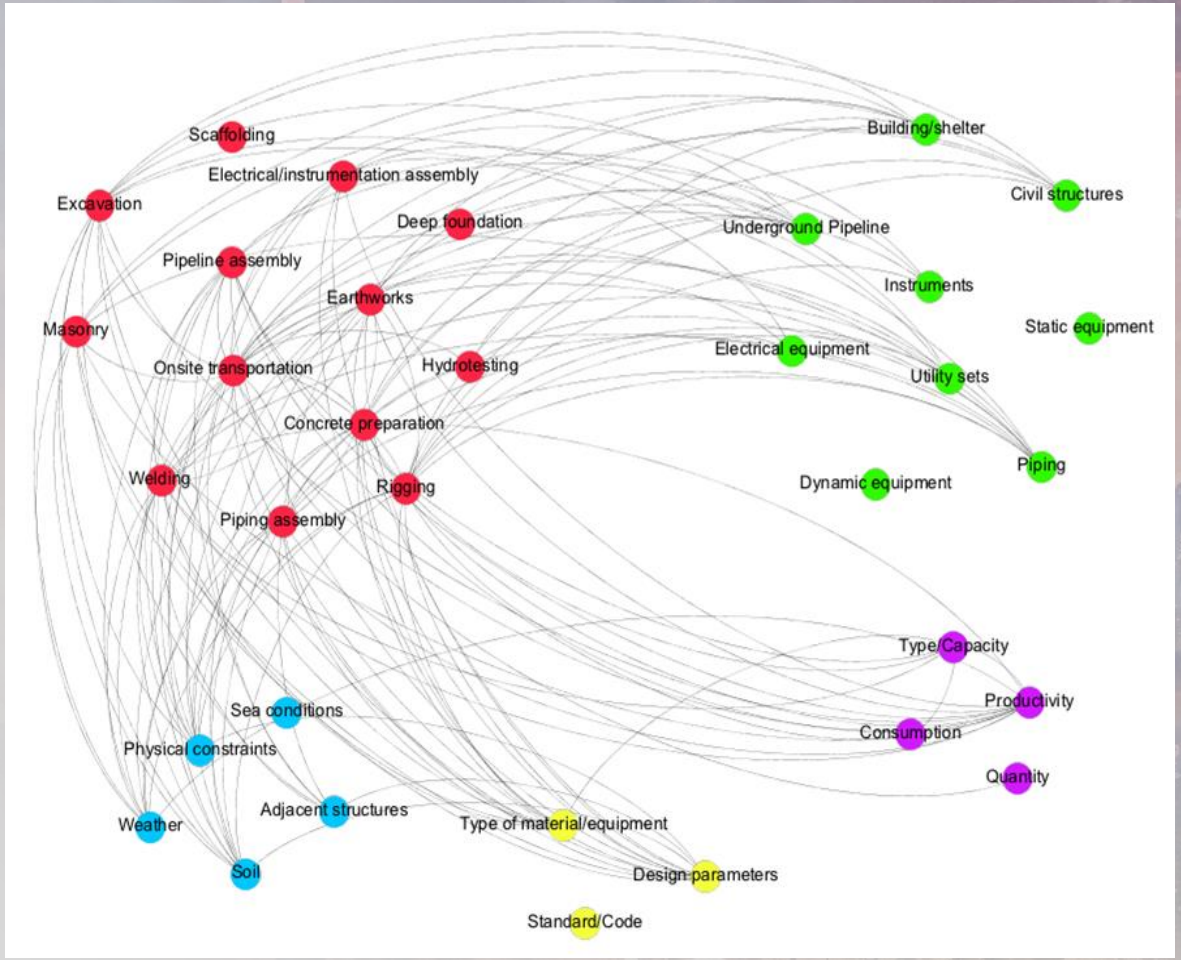
[Wikipedia]



Example 2: prototyping single product/project

Tell them what their knowledge is





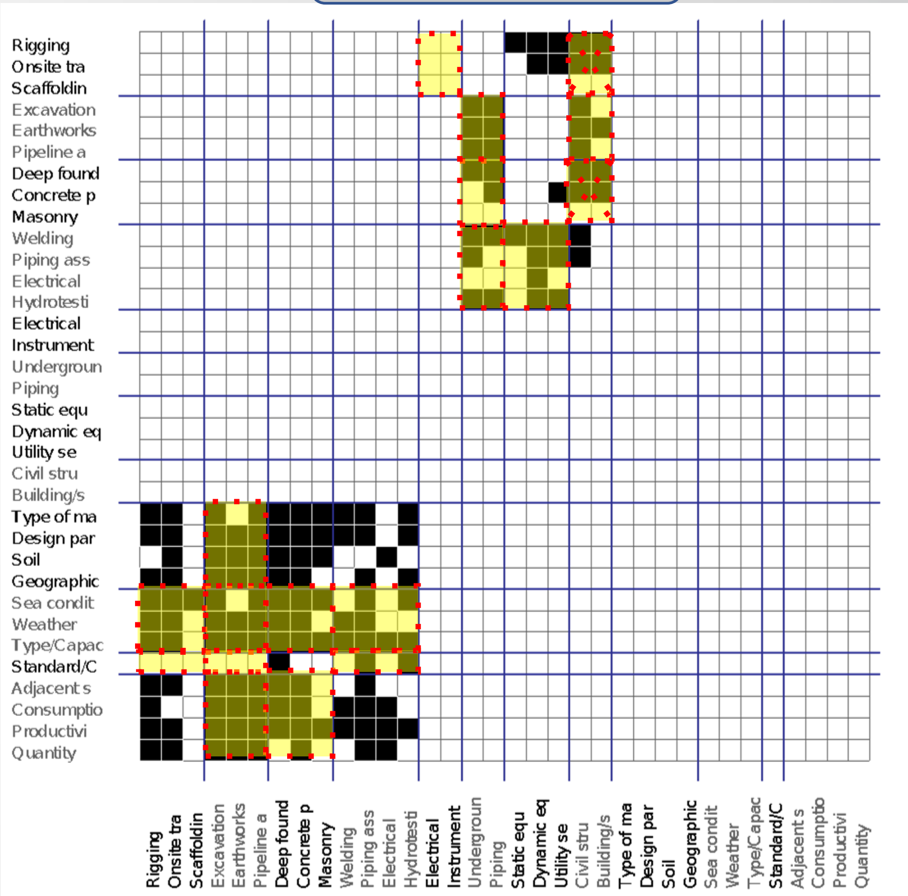
Tell them what their knowledge is

Clique #	Activities	Factors
1	Earthworks/Rigging/Onsite transportation	Design parameters/Soil
2	Earthworks/Rigging/Onsite transportation	Design parameters/Geographical location
3	Earthworks/Rigging/Onsite transportation	Weather/Productivity
4	Welding/Earthworks/Onsite transportation	Design parameters/Soil
5	Welding/Earthworks/Onsite transportation	Design parameters/Adjacent structures
6	Welding/Earthworks/Onsite transportation	Design parameters/Geographical location
7	Welding/Earthworks/Onsite transportation	Weather/Productivity
8	Piping assembly/Earthworks/Onsite transportation	Design parameters/Soil
9	Piping assembly/Earthworks/Onsite transportation	Design parameters/Geographical location
10	Piping assembly/Earthworks/Onsite transportation	Weather/Productivity
11	Welding/Pipeline assembly/Onsite transportation	Design parameters/Soil
12	Welding/Pipeline assembly/Onsite transportation	Design parameters/Adjacent structures
13	Welding/Pipeline assembly/Onsite transportation	Design parameters/Geographical location
14	Welding/Pipeline assembly/Onsite transportation	Weather/Productivity

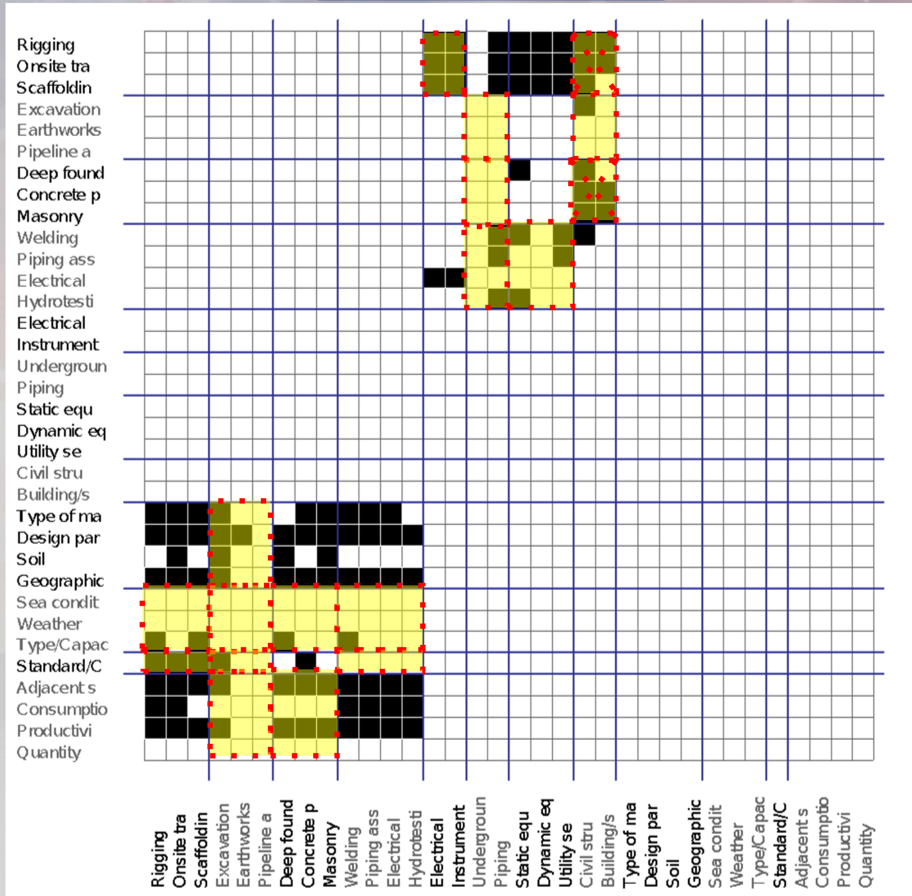
Activities/factors	Out-degree	In-degree	Betweenness	In-Eigenvector
Construction activities				
Onsite transportation	17	9	48.746	0.181
Welding	5	10	13.846	0.279
Rigging	7	8	10.796	0.279
Pipeline assembly	2	10	7.063	0.332
Concrete preparation	4	8	6.846	0.181
Excavation	5	8	6.496	0.181
Earthworks	8	8	5.796	0.181
Electrical/instrumentation assembly	3	6	4.500	0.181
Masonry	3	6	2.625	0.181
Piping assembly	2	8	2.033	0.279
Design factors				
Type of material/equipment	10	0	0.000	0.000
Design parameters	10	3	2.667	0.000
Standard/Code	0	0	0.000	0.000
Site characteristics				
Soil	11	0	0.000	0.000
Geographical location	11	0	0.000	0.000
Weather	10	0	0.000	0.000
Adjacent structures	6	0	0.000	0.000
Resources factors				
Productivity	10	3	21.500	0.152
Consumption	1	1	0.000	0.000
Quantity	1	0	0.000	0.000

Capturing prototypes; comparing projects

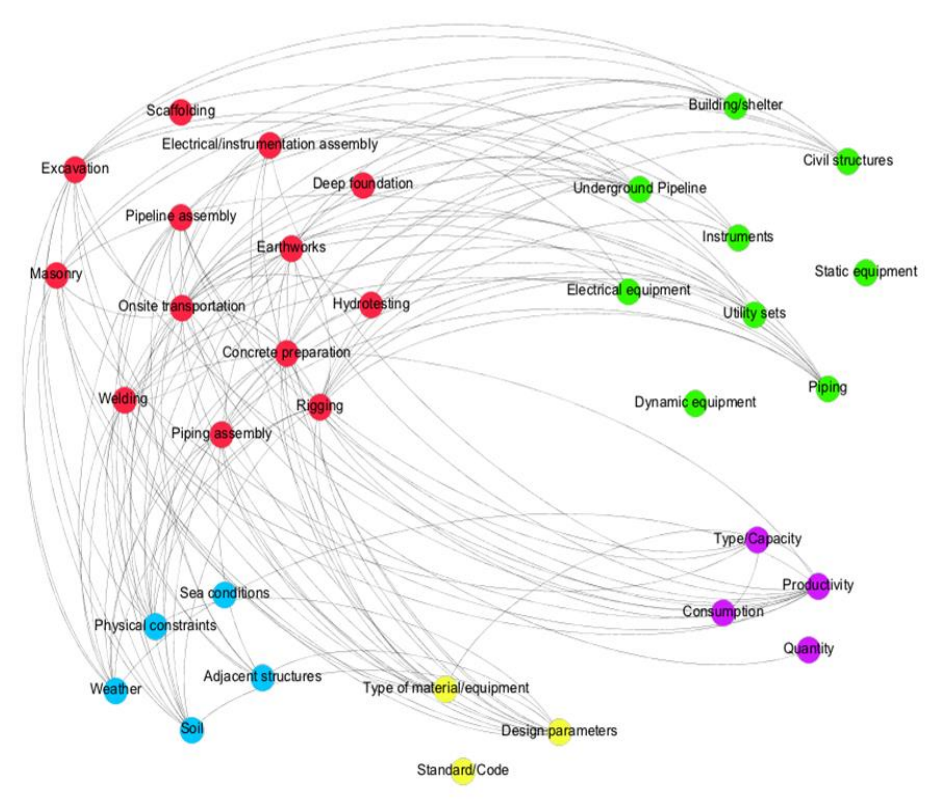
Baseline

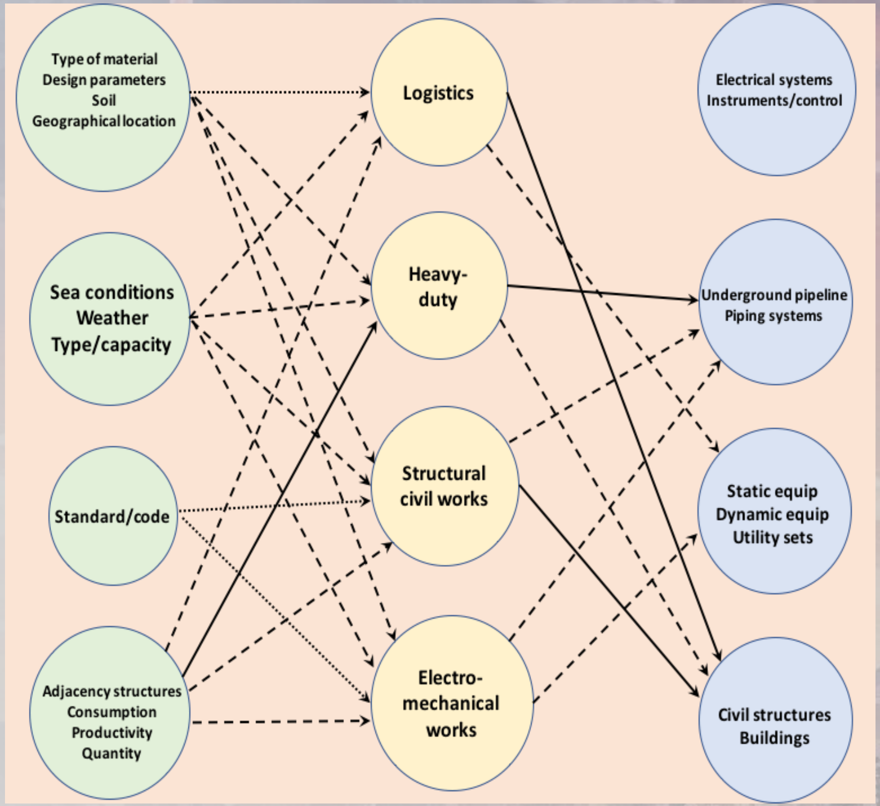


Case

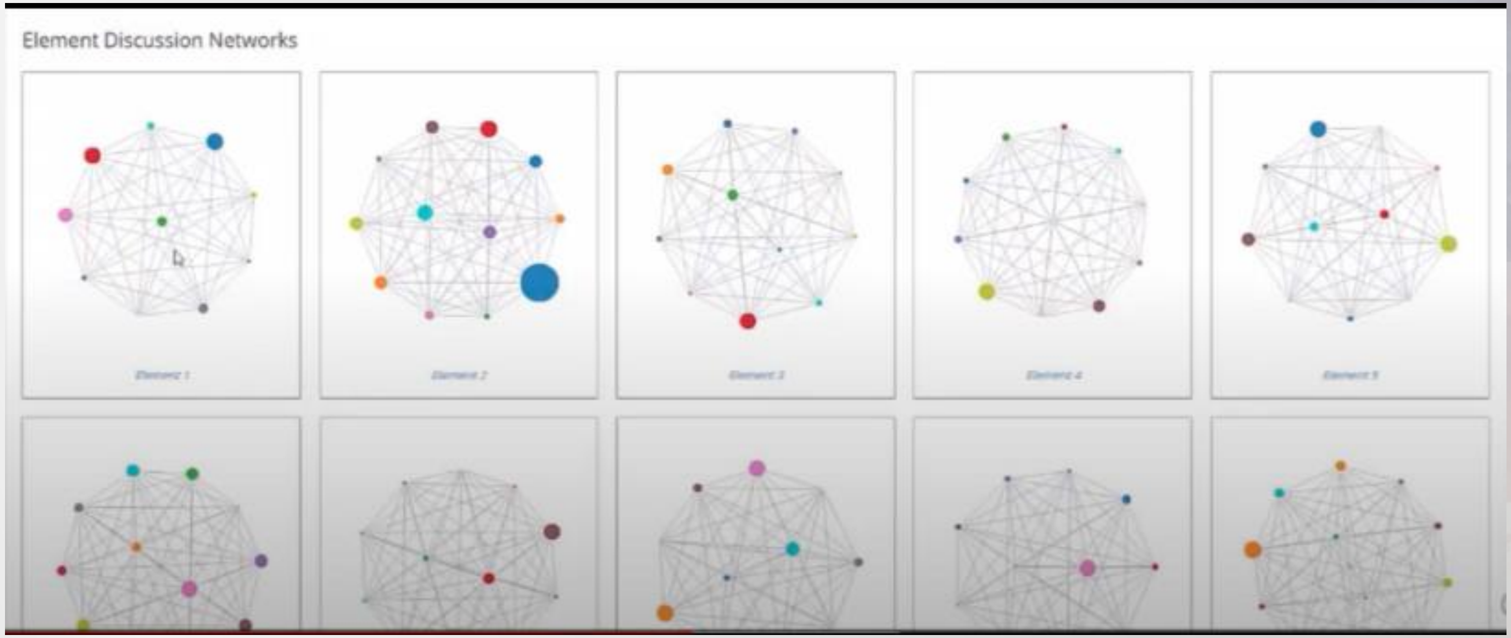


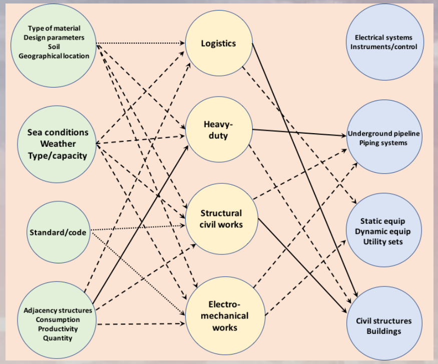
Possible prototype: terms and (some provisional) relationships



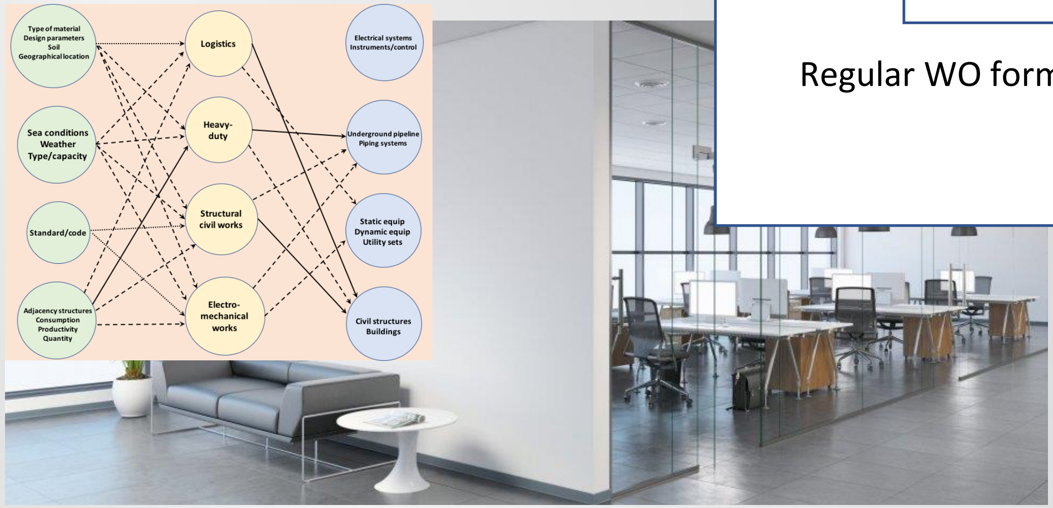


UofT BIM standards: Not just an IFC MVD; a signature for each IFC products





The work order problem



Regular WO form

WO with word cloud from previous comments

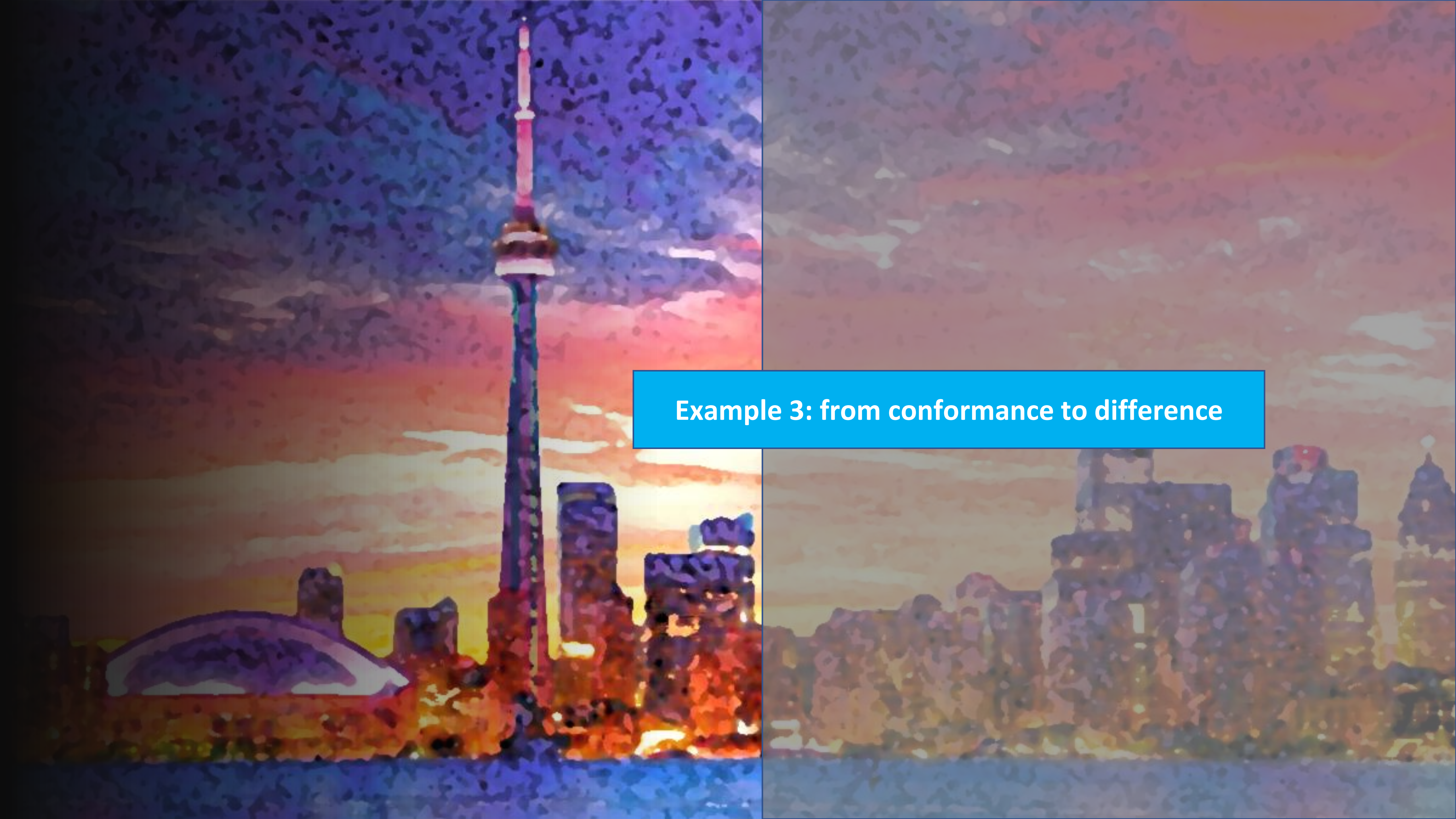
Recommender system
WO with concepts from the category prototype and the prototype of the ifcProduct

Anomalies

criticality

Trades’ schedule

Example 3: from conformance to difference

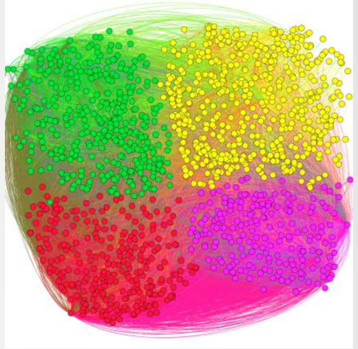


Creating possible worlds: Network algebra

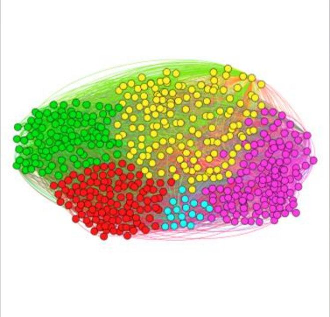
	Project A	Project B	Project C	Combined case 1	Combined case 2
Project A	1	0.516	0.309	0.720	0.695
Project B	0.516	1	0.333	0.690	0.728
Project C	0.309	0.333	1	0.502	0.433
Combined case 1	0.720	0.690	0.502	1	0.659
Combined case 2	0.695	0.728	0.433	0.659	1

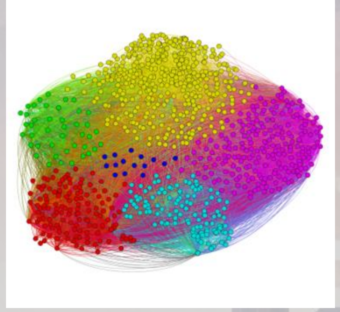
Cost prediction: boundary conditions as a driver

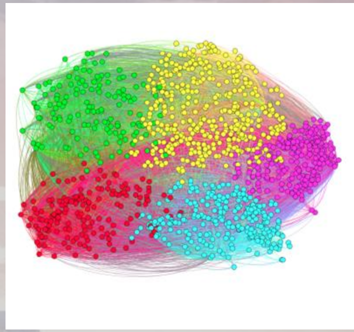
New work order

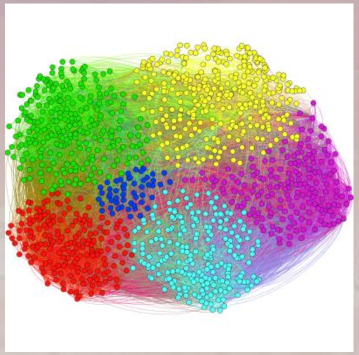


Similar work orders





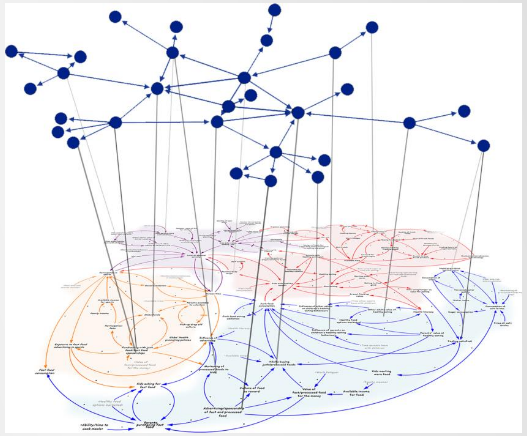




What was the different?

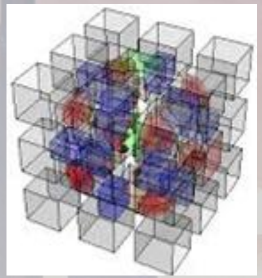

The main point

Prototyping a project mosaic: create “falsifiable” futures

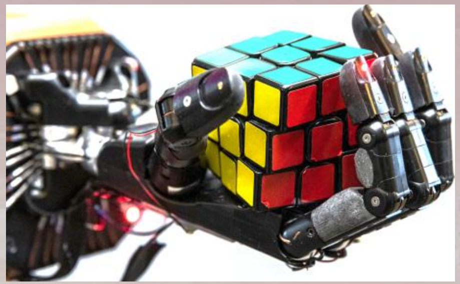


A world

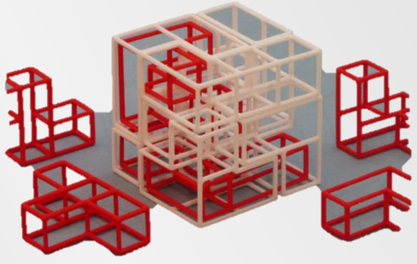
Incoherent



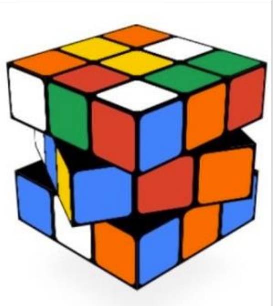
Theorized



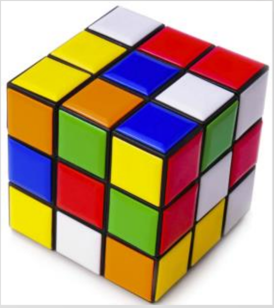
Artificially created



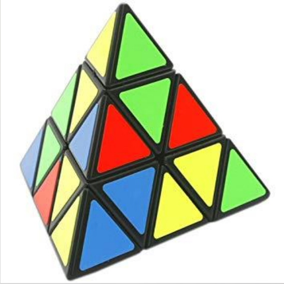
Potential



Forming



Complete, typical



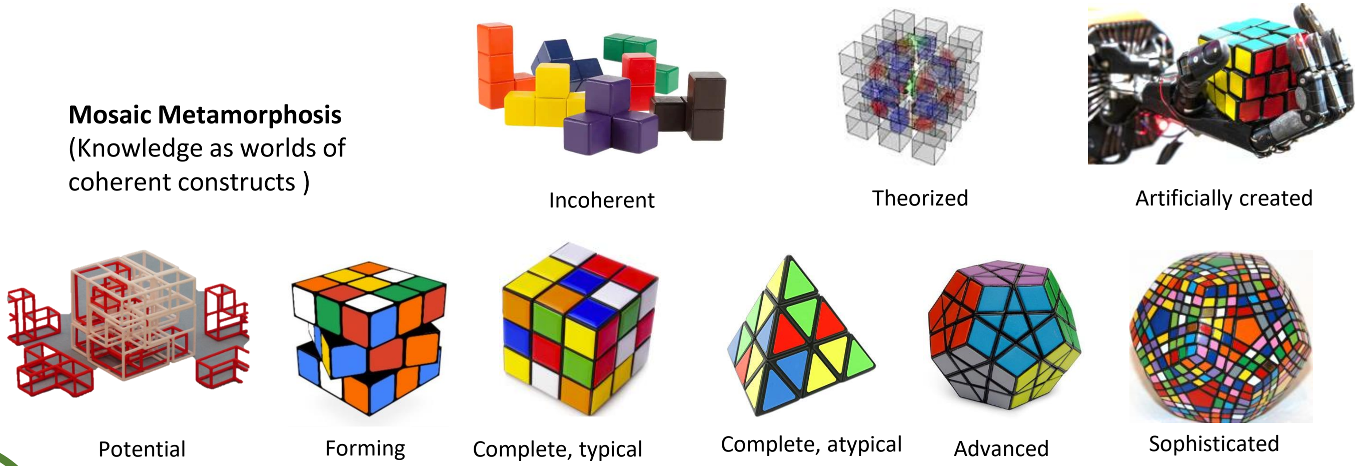
Complete, atypical

Advanced

Sophisticated

Learn-Prototype

Mosaic Metamorphosis
(Knowledge as worlds of coherent constructs)

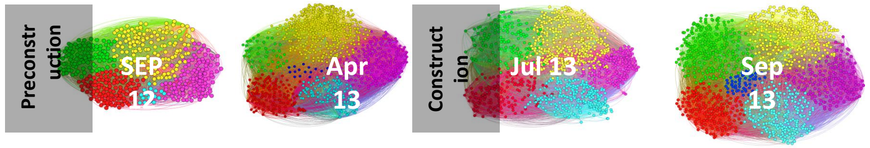


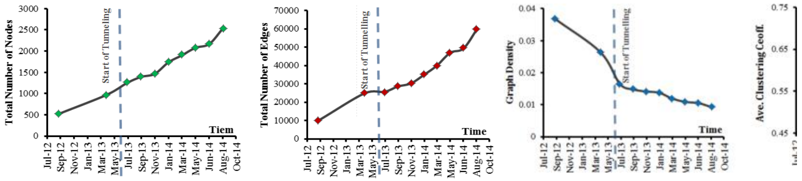
"Relative-to-model" thinking
(exposing "difference")

Knowledge is a social phenomenon

Co-creation & Emergence (humans, capturing context and innovation, update mosaic constructs)

Network Metamorphosis (externalize/capture knowledge constructs)

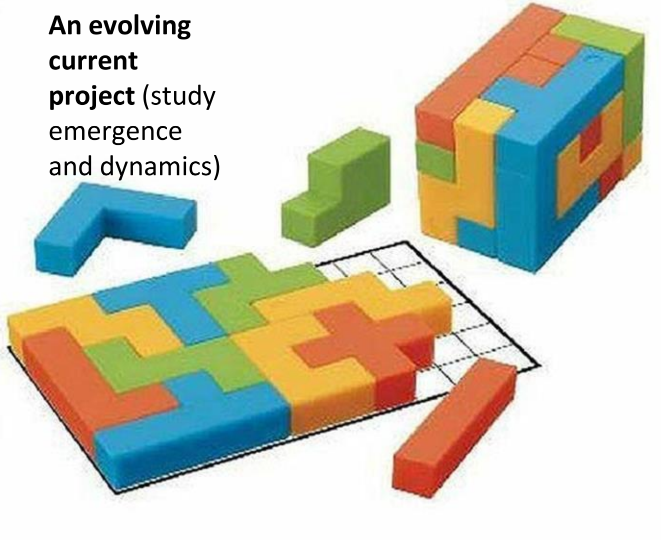




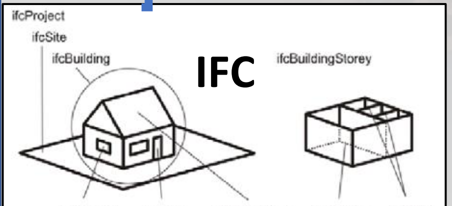
Social, semantic and sentiment analysis (capture the constructs)

Network measures (study evolution, emergence)

An evolving current project (study emergence and dynamics)



Support co-creation through communication and the use of
Semantically-rich CAD,
Recommender systems,
Business Intelligence services



Questions: who will do all of this? How will the system look like?

The answer, you guessed it, we are still learning

The project information officer

Design → construction → As-built

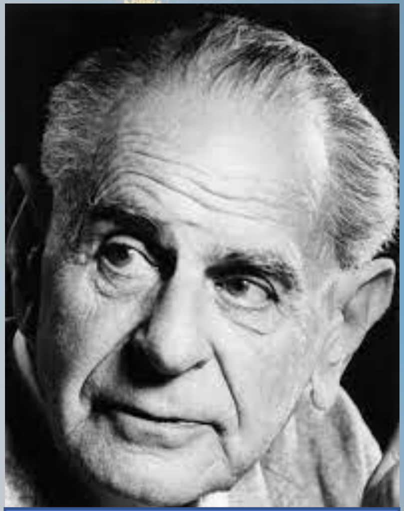
Know → communicate → As-learned

Thomas Froese

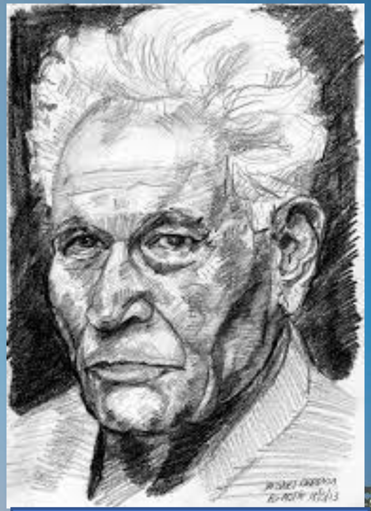
Dashboards and PaaS: The salesforce of construction/asset management

Deconstruction of parametric/ontological modeling

Motivation	learn	Tell people what they know	modularize	Create futures
Tools	Create Networks	Network analysis/algebra	Pattern analysis	Recommender systems



Karl Popper



Jacques Derrida

Finally

If you liked it, good; thanks; let us co-create together

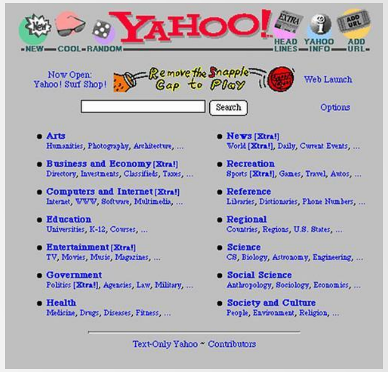
If not, sorry; please advance our knowledge by falsifying it; thank God: I work in a university

Come to Canada
(<u>the food is good</u>):

Looking to hire two post-doctoral fellows

Backup slides

High Tolerance (based on a presentation by Curry, T., W78, 2021)



- Manual, by humans
- Exact results

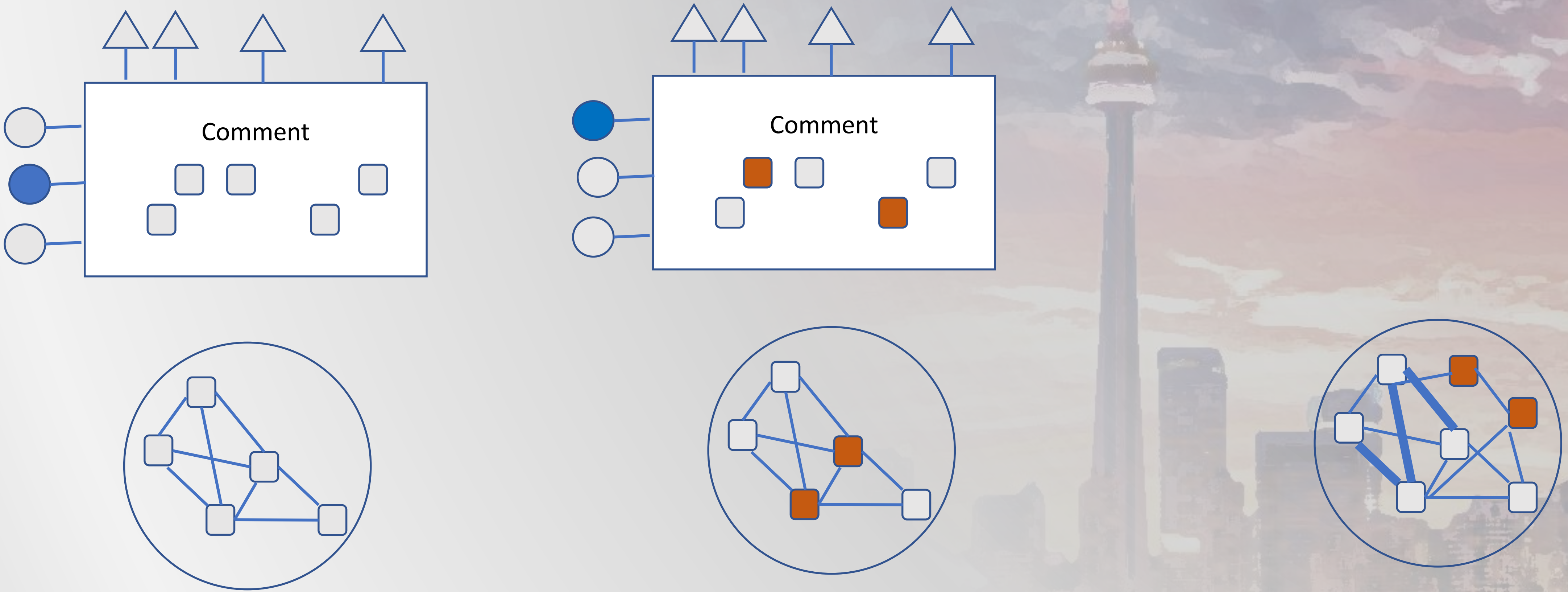
- Mathematical Complexity
- Optimization

- Search by an algorithm
- Approximate

- Network science
- Circumstantial

- Linguistic Reasoning
- Patterns

Develop the semantic network

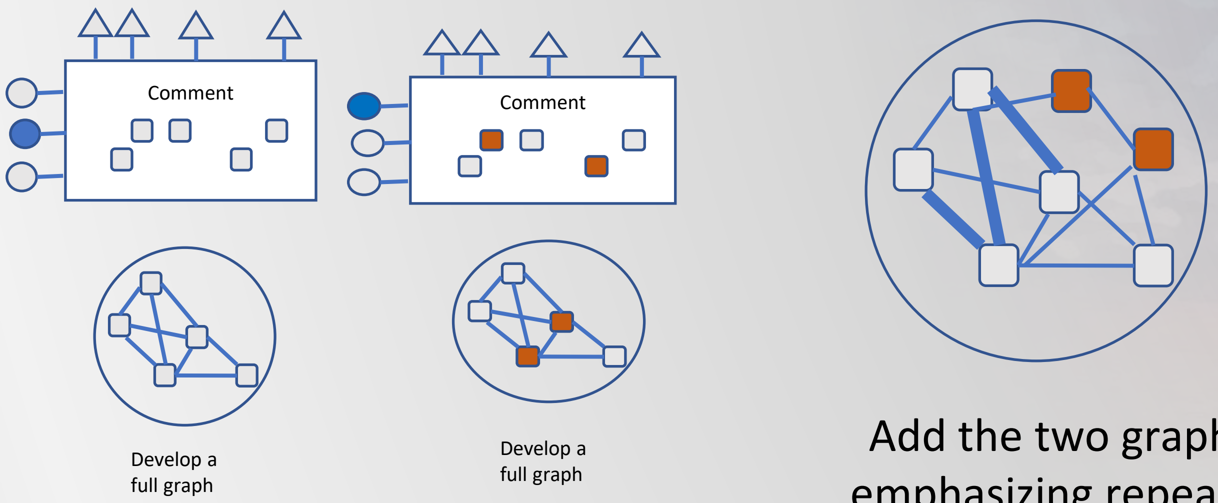


Develop a full graph

Develop a full graph

Add the two graphs, emphasizing repeated relationships

Develop the semantic network: advanced



Add the two graphs, emphasizing repeated relationships

Consider common actors

Consider influential actors

Consider tags

Consider base prototype

Consider prototypes with similar concepts

Use network similarity measures

blockmodeling

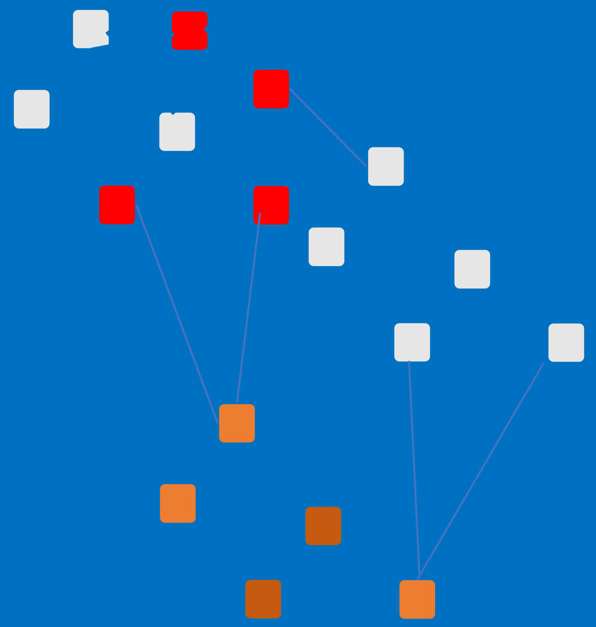
Consider Uniformat (for is_a)

Word cloud to semi-manual matrix

Categories	Types		Activities													Physical systems									Design features			Site characteristics					Resources features			
			Excavation (not included in earthworks)	Deep foundation preparation (drilling, hammering, etc.)	Welding	Piping assembly	Earthworks	Rigging	Concrete preparation (forming, rebar assembly, concrete pooring, etc.)	Electrical and instrumentation assembly	Underground pipeline assembly (stringing, bending, welding support, lowering, backfilling and	Hydrotesting	Masonry	Onsite transportation	Scaffolding	Civil structures	Building/shelter	Static equipment (tank or vessel)	Underground Pipeline	Piping	Electrical equipment	Instruments	Dynamic equipment (pumps, compressors, turbines, etc.)	Utility sets (generator, air compressor units, steam units, hydraulic units, etc.)	Type of material/equipment	Design parameters	Standard/Code	Soil	Ocean conditions	Weather	Adjacent structures	Geographical Location	Type/Capacity	Energy consumption	Productivity	Quantity
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Activities	Excavation (not included in earthworks)	1	x													x	x	x	x	x	x	x	x	x		e,f,l,m,o		j			i				a,c	
	Deep foundation preparation (drilling, hammering, etc.)	2		x												x	x	x	x	x	x	x	x	x		l,m,o		j							a,c	
	Welding	3			x											x	x	x	x	x	x	x	x	x		e,o							g		a,c,n	
	Piping assembly	4				x										x	x	x	x	x	x	x	x	x		o									a,c	
	Earthworks	5					x									x	x	x	x	x	x	x	x	x		o										
	Rigging	6						x								x	x	x	x	x	x	x	x	x		e,f,h,o							g		a,c	
	Concrete preparation (forming, rebar assembly, concrete pooring, etc.)	7							x							x	x	x	x	x	x	x	x	x		e,f,h,o									a,c	
	Electrical and instrumentation assembly	8								x						x	x	x	x	x	x	x	x	x		o									a,c	
	Underground pipeline assembly (stringing, bending, welding support, lowering, backfilling and crossings)	9									x					x	x	x	x	x	x	x	x	x												
	Hydrotesting	10										x				x	x	x	x	x	x	x	x	x		o									a,c	
	Masonry	11											x			x	x	x	x	x	x	x	x	x		e,f,o		j			i				a,c	
	Onsite transportation	12												x		x	x	x	x	x	x	x	x	x		e,f,h,o		j							a,c	
	Scaffolding	13													x	x	x	x	x	x	x	x	x	x		e,f,h,o							g		a,c	
Physical systems	Civil structures	14	0	0	0			0	0				0	0	0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Building/shelter	15						0	0				0	0		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Static equipment (tanks, pressure vessels, etc.)	16		0	0			0				0		0	0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Underground Pipeline	17														x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Piping	18			0	0		0				0		0	0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Electrical equipment	19						0		0				0	0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Instrument/control system	20						0		0				0	0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Dynamic equipment (pumps, compressors, turbines, etc.)	21						0						0	0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Utility sets (generator, air compressor units, steam units, hydraulic units, etc.)	22			0	0		0						0	0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Design	Type of material/equipment	23	x	x	x	x	x	x	x	x	x	x	x	x	x										x								x	x	x	x
	Design parameters (load, thickness, pressure, temperature, etc.)	24	x	x	x	x	x	x	x	x	x	x	x	x	x											x		l,m				l,m	x	x	x	x
	Standard/Code	25	x	x	x	x	x	x	x	x	x	x	x	x	x												x						x	x	x	x
Site characteristics	Soil	26	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Ocean conditions	27	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Weather	28	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Adjacent structures	29	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Geographical Location	30	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Resources	Type/Capacity	31														x	x	x	x	x	x	x	x	x						a			x			
	Energy consumption	32														x	x	x	x	x	x	x	x	x										x		
	Productivity	33														x	x	x	x	x	x	x	x	x									a,n		x	c
	Quantity	34														x	x	x	x	x	x	x	x	x												x

BIM+prototypes

Communication + Documents



A prototype (semantic network)

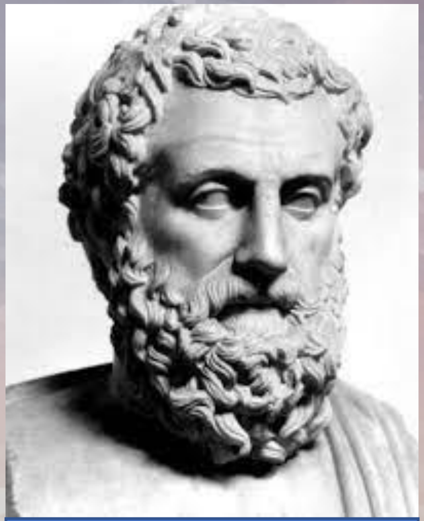
Masterformat

Ontologies

IFC

What is the difference between a semantic network and an ontology

- In a reductionist way: dumping the dreaded *is_a* relationship—more accurately, abandoned object-orientation for prototype-oriented thinking



Aristotle

Template

- Template

Template

Template