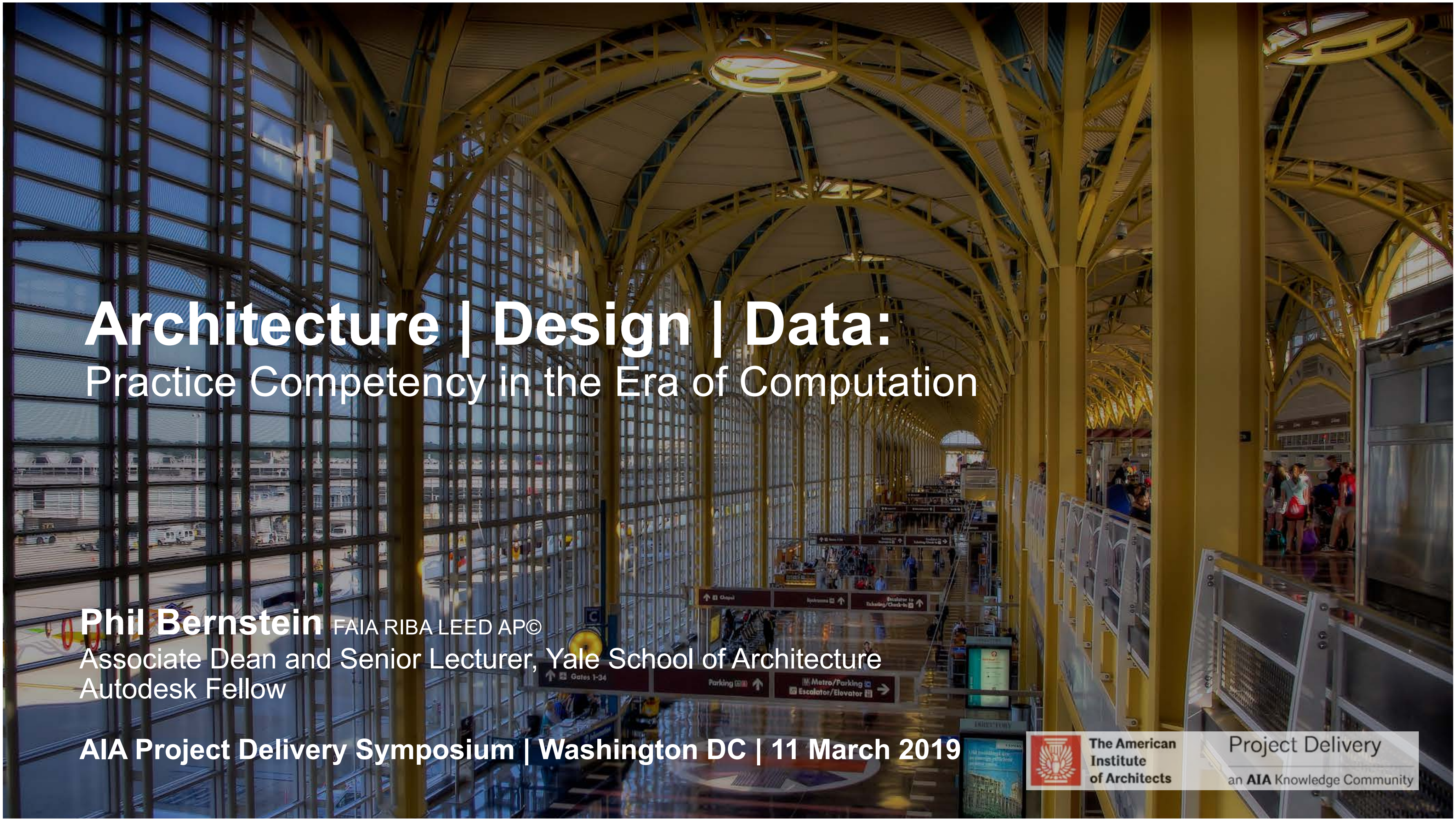

Architecture | Design | Data:
Practice Competency in the Era of Computation

Phil Bernstein FAIA RIBA LEED AP©
Associate Dean and Senior Lecturer, Yale School of Architecture
Autodesk Fellow

AIA Project Delivery Symposium | Washington DC | 11 March 2019

The American Institute of Architects
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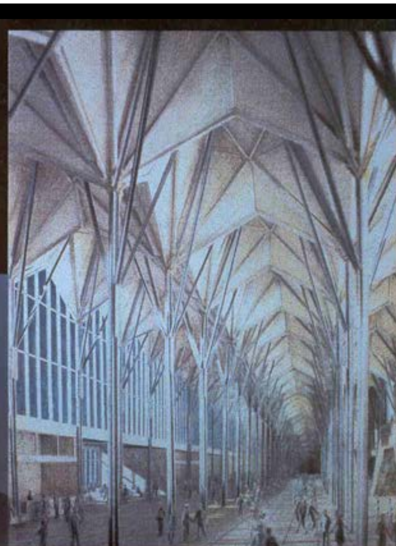
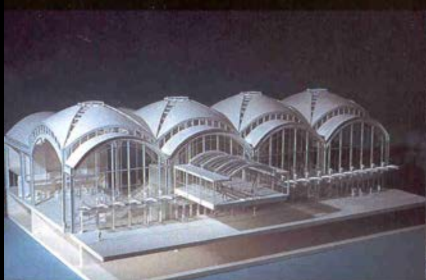
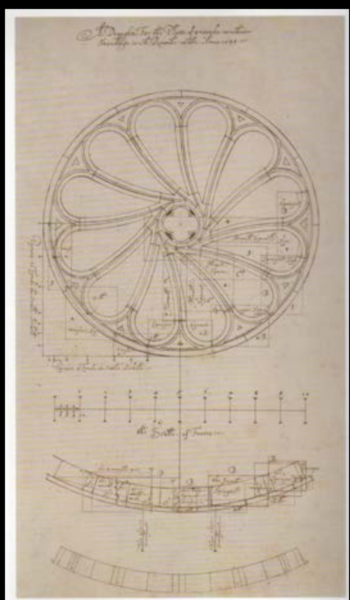






Evolution of Tools and Technologies



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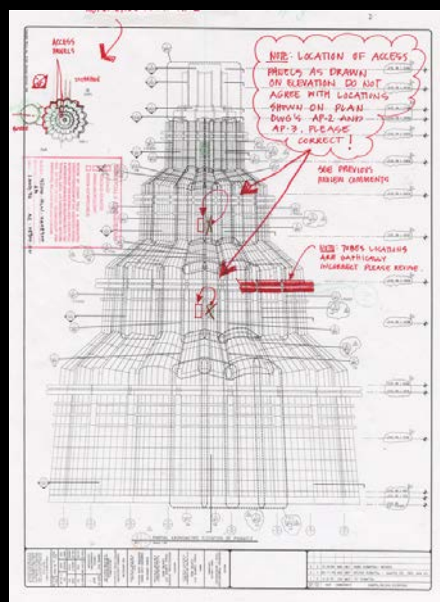

CAD

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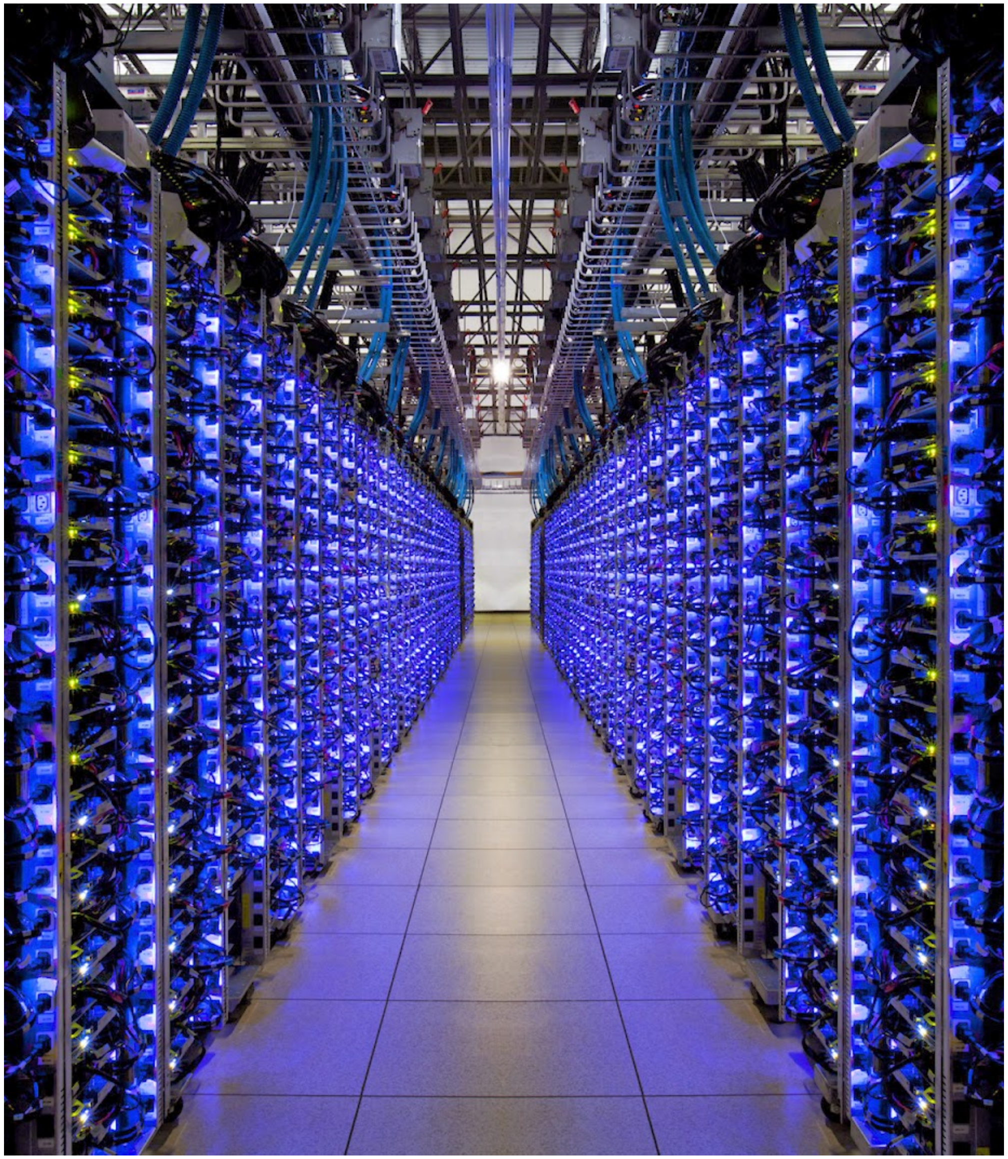


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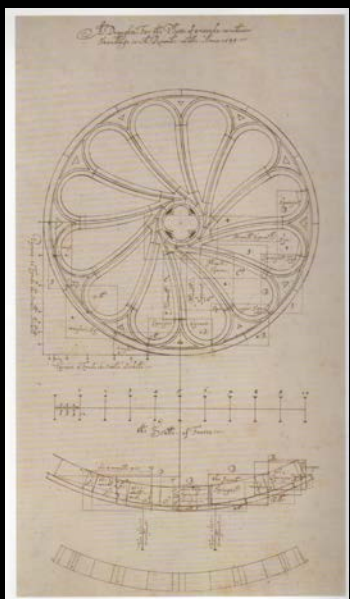
Evolution of Tools and Technologies



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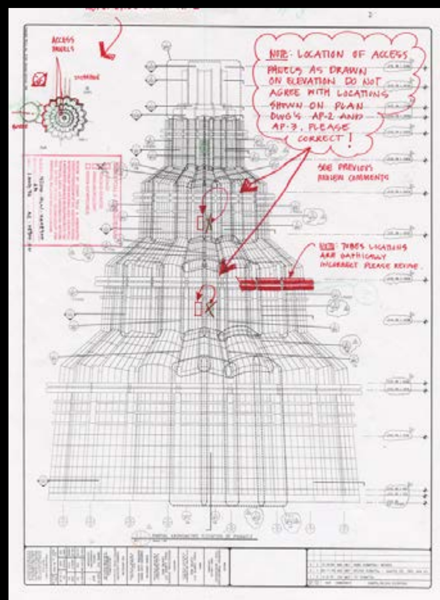

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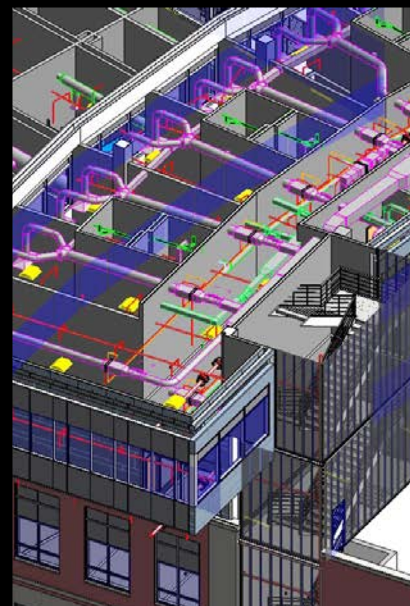

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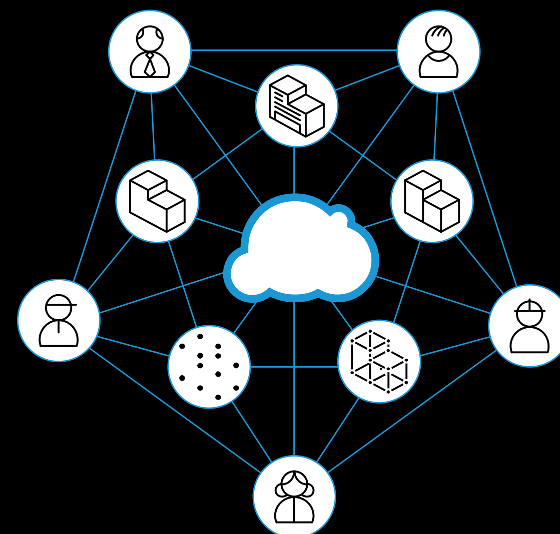
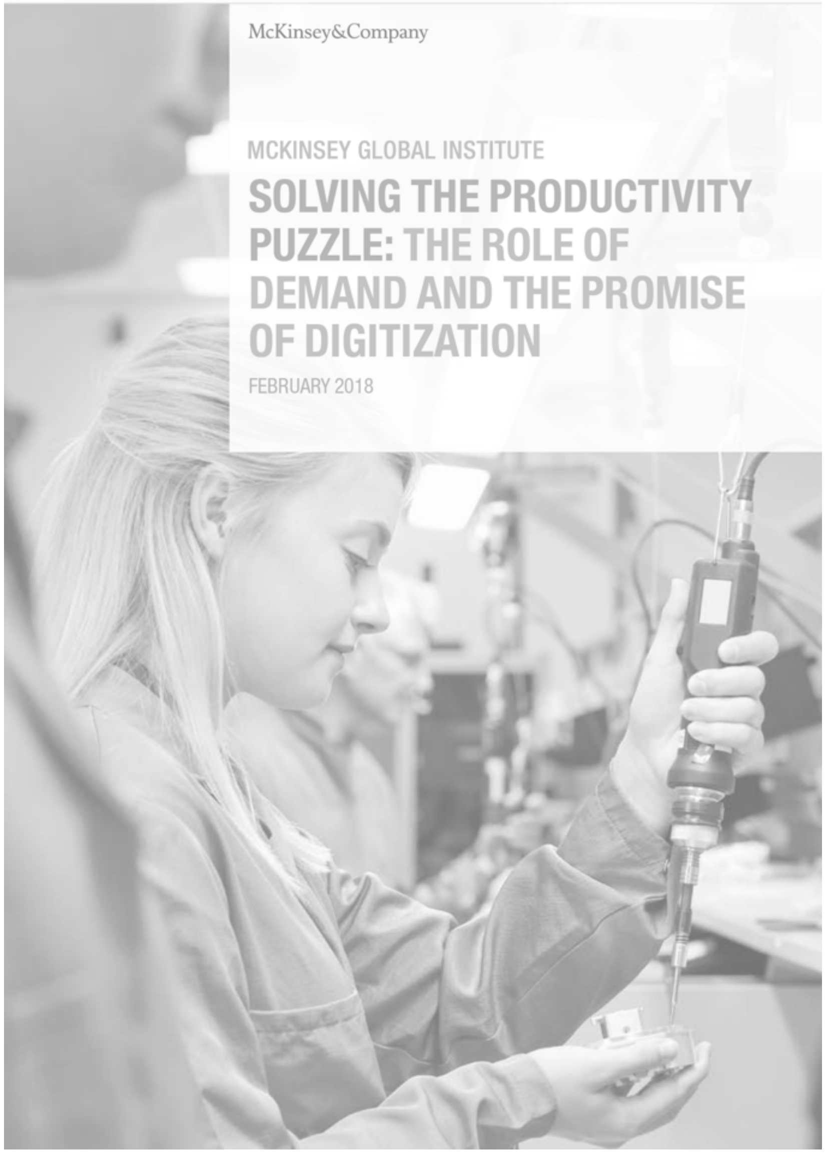


Connected BIM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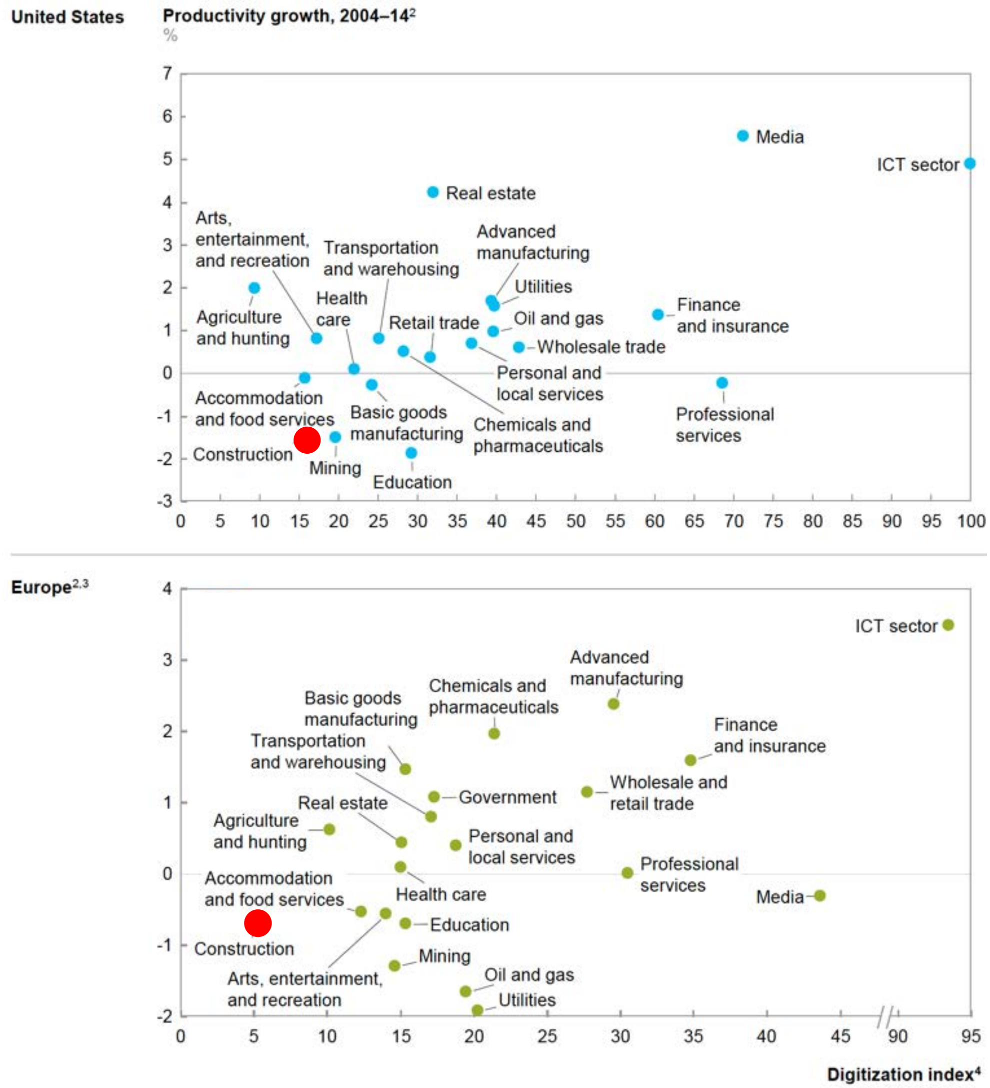
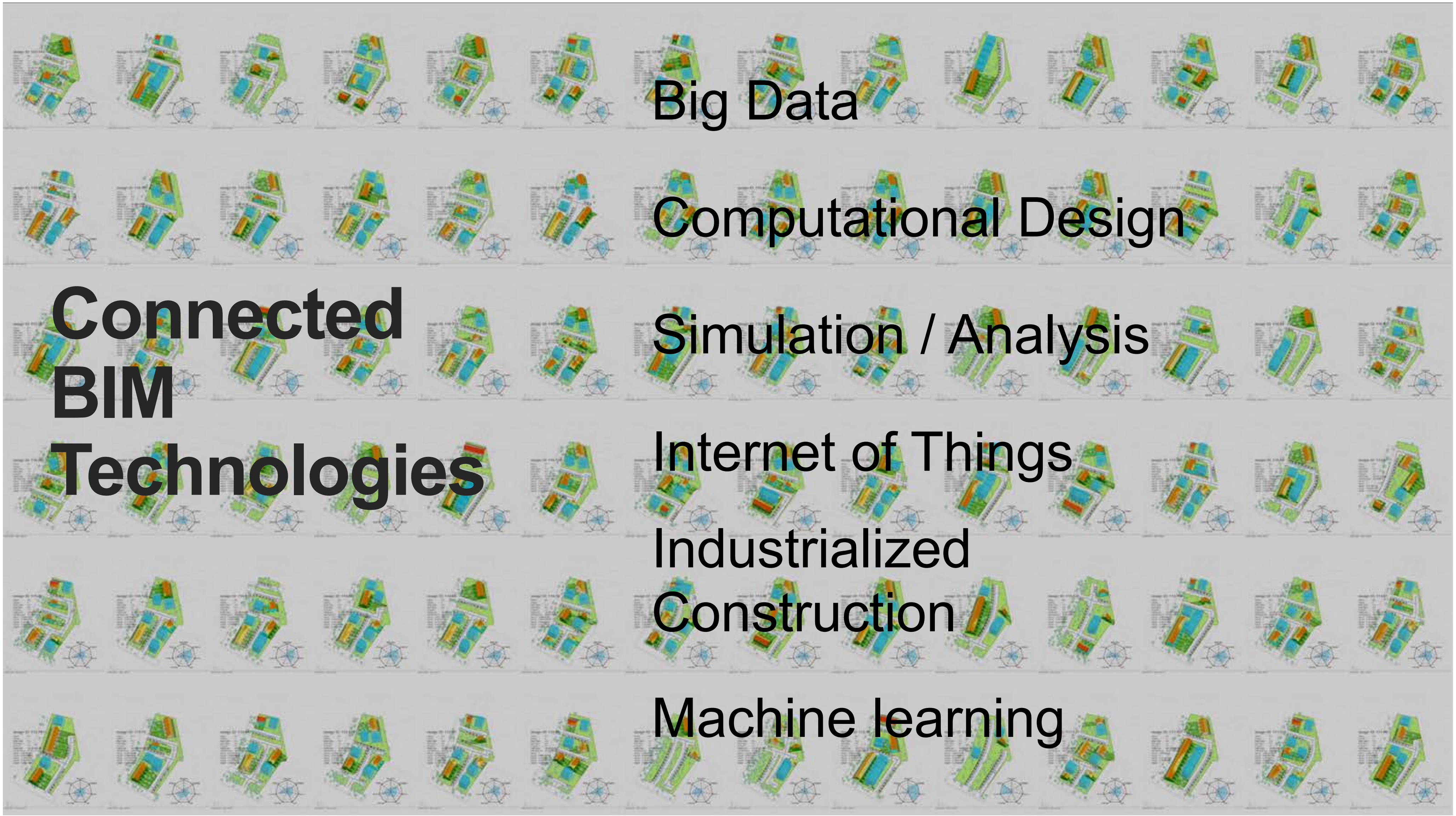
FEBRUARY 2018


United States
Productivity growth, 2004–14[2]
%
Media
ICT sector
Real estate
Arts, entertainment, and recreation
Transportation and warehousing
Advanced manufacturing
Utilities
Health care
Agriculture and hunting
Retail trade
Oil and gas
Finance and insurance
Wholesale trade
Personal and local services
Accommodation and food services
Basic goods manufacturing
Chemicals and pharmaceuticals
Professional services
Construction
Mining
Education
Europe[2,3]
ICT sector
Advanced manufacturing
Chemicals and pharmaceuticals
Basic goods manufacturing
Finance and insurance
Transportation and warehousing
Wholesale and retail trade
Government
Real estate
Agriculture and hunting
Personal and local services
Professional services
Accommodation and food services
Health care
Media
Education
Construction
Mining
Arts, entertainment, and recreation
Oil and gas
Utilities
Digitization index[4]



Connected BIM Technologies

Big Data

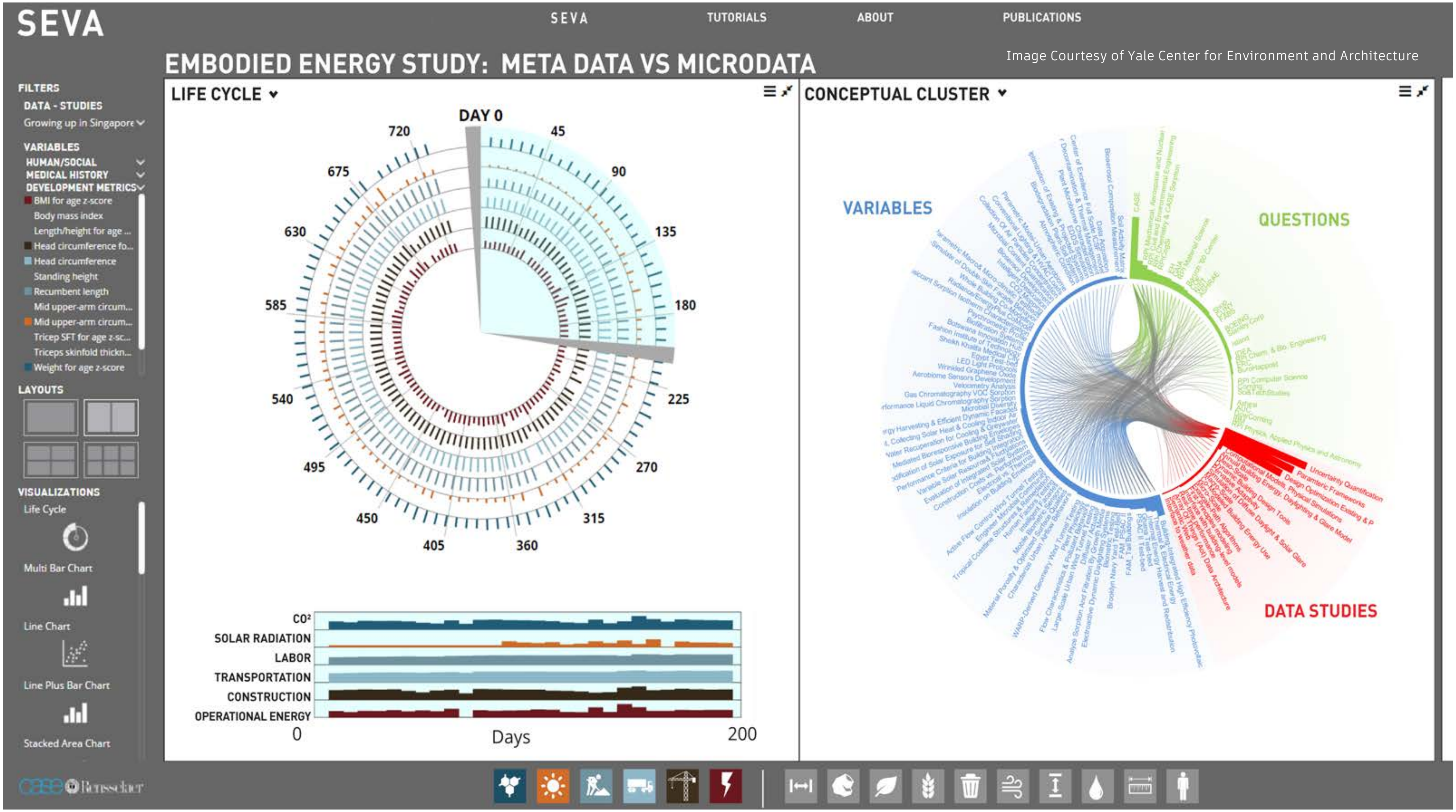
Computational Design

Simulation / Analysis

Internet of Things

Industrialized Construction

Machine learning



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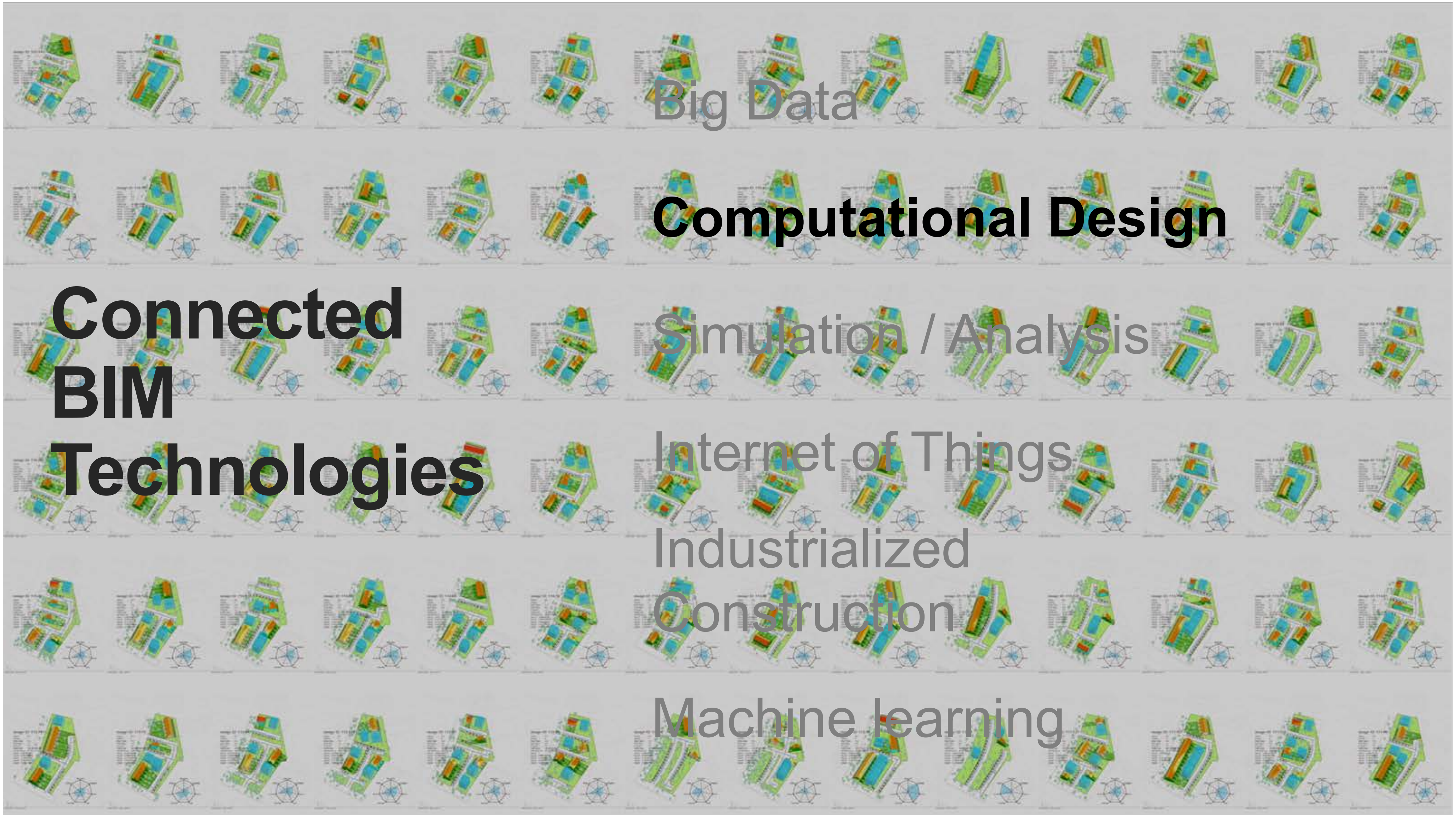

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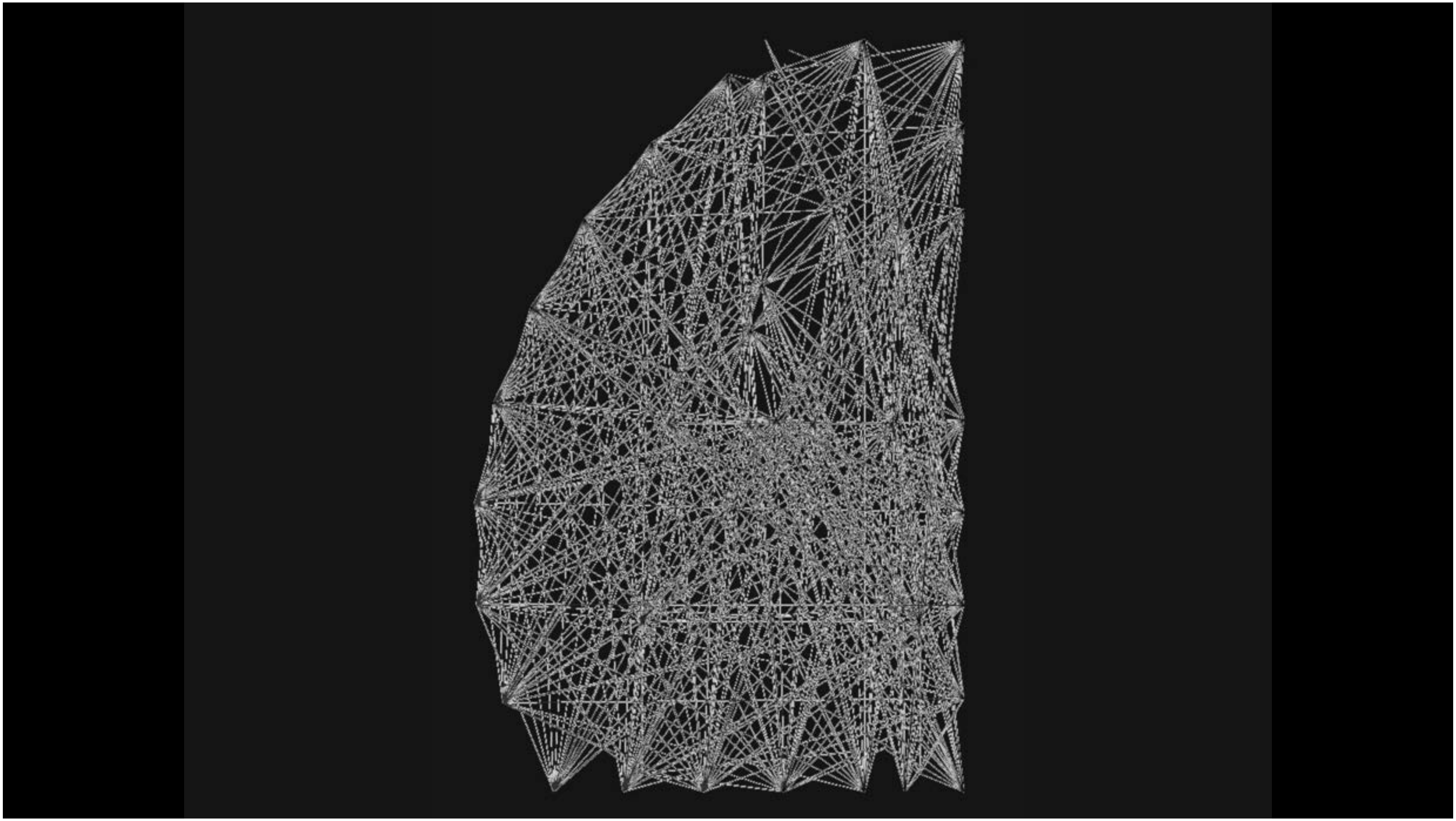
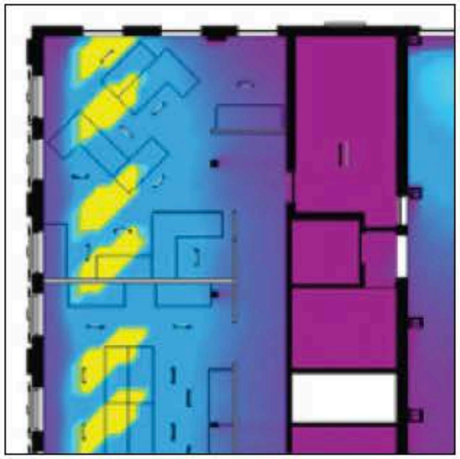


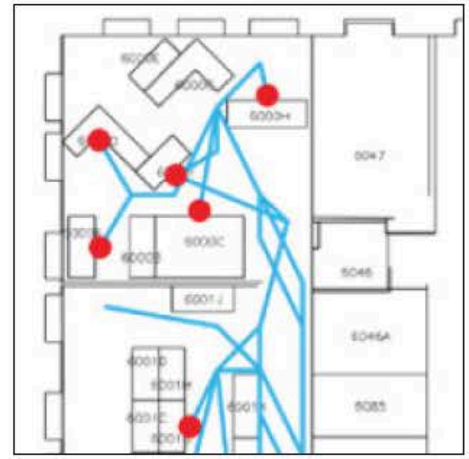

Connected
BIM
Technologies
Big Data
Computational Design
Simulation / Analysis
Internet of Things
Industrialized
Construction
Machine learning



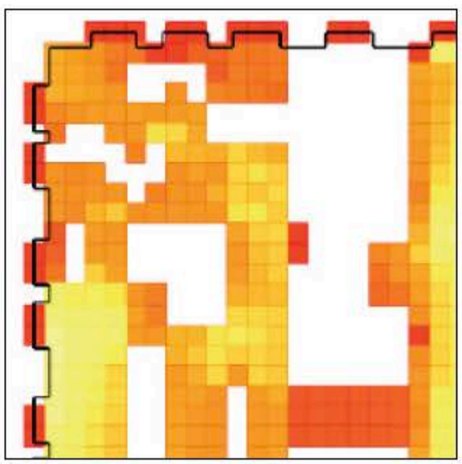
1. Daylight

2. Low Visual Distraction

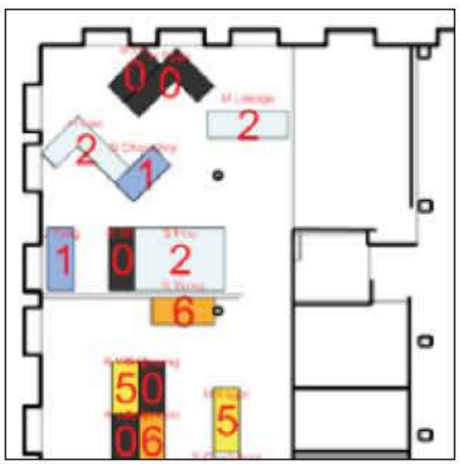
3. Views to Outside



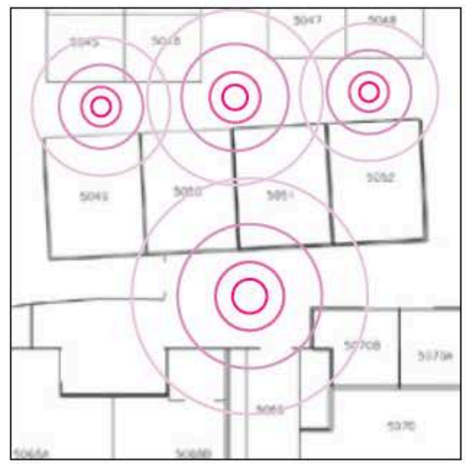
4. Adjacency Preference



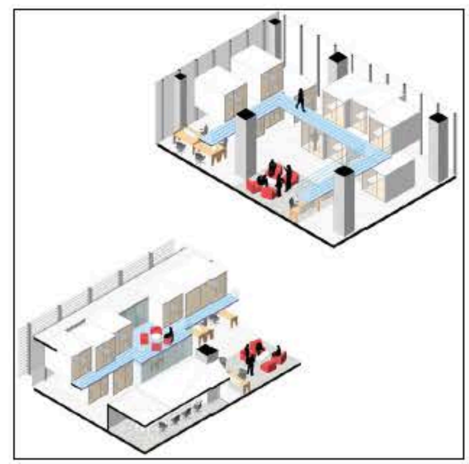
5. Circulation



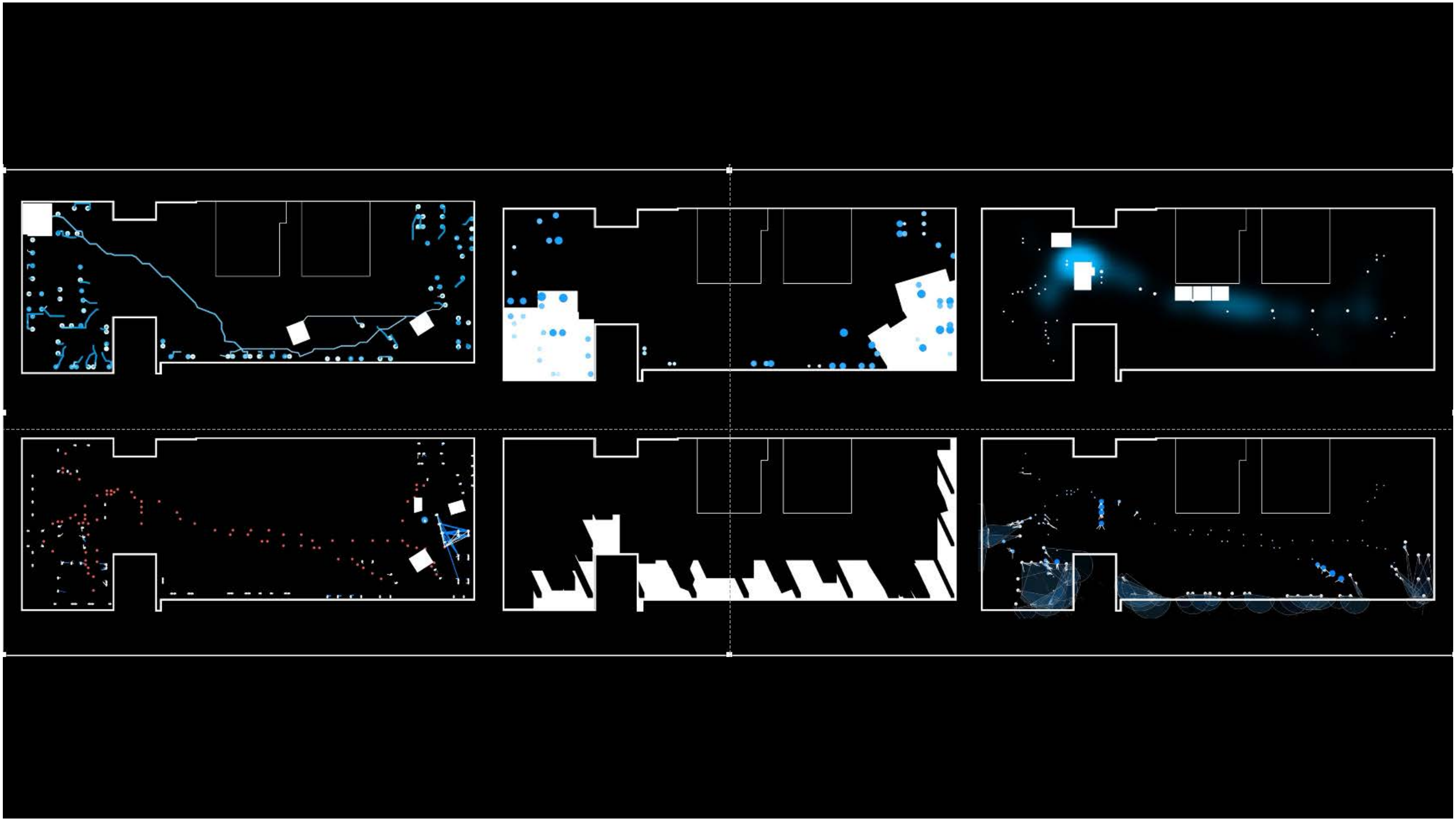
6. Work Styles

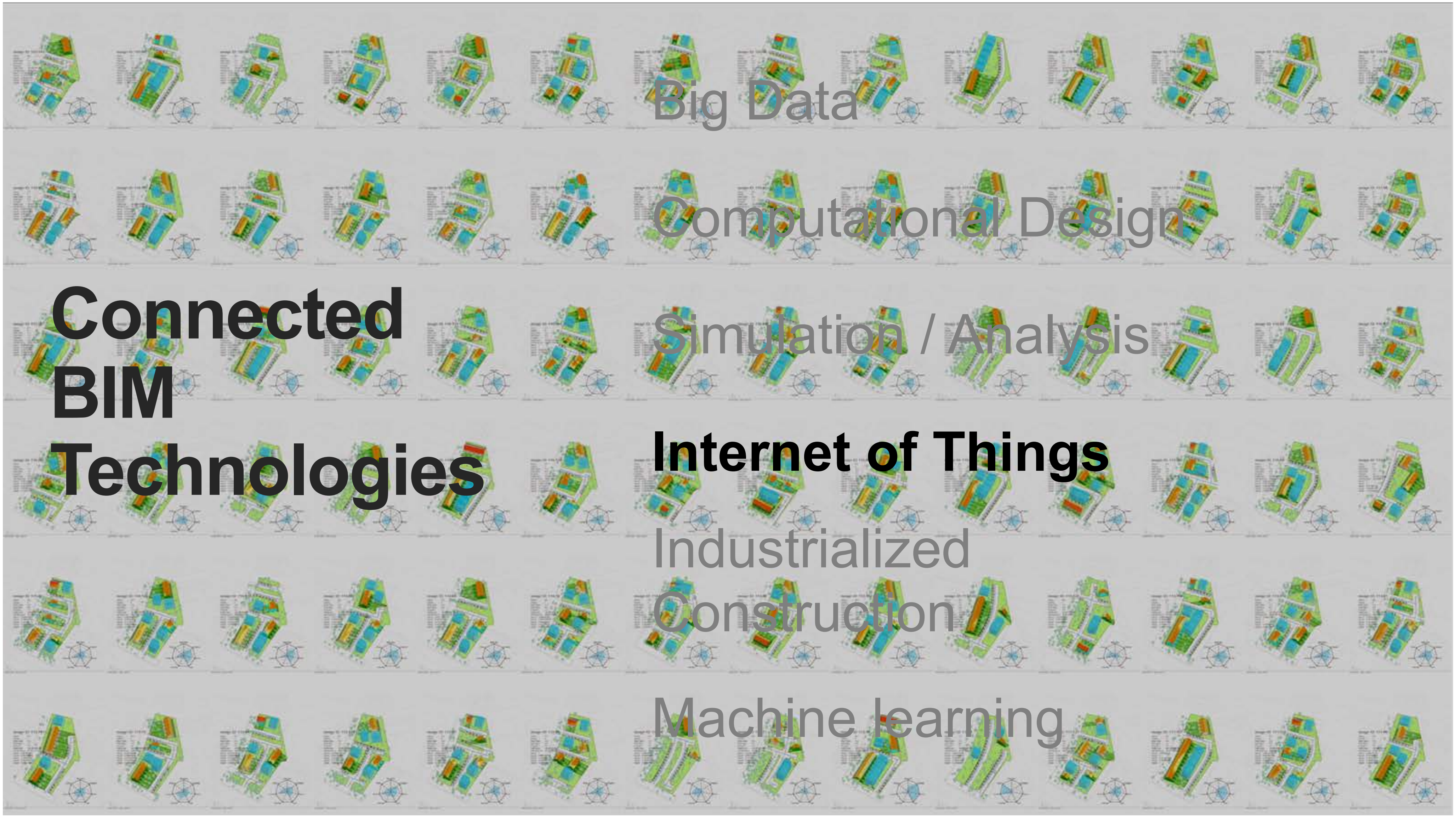


7. Low Acoustic Distraction



8. Low Density





Connected BIM Technologies

Big Data

Computational Design

Simulation / Analysis

Internet of Things

Industrialized Construction

Machine learning

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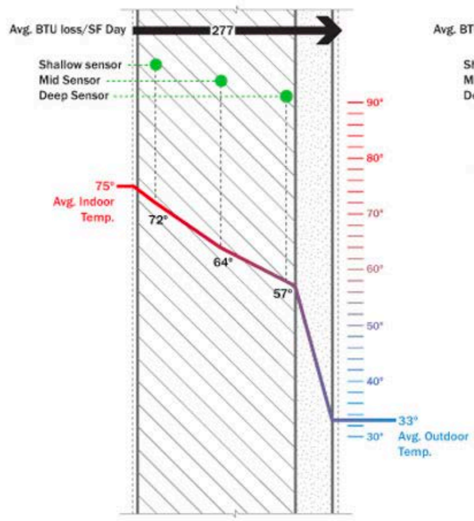
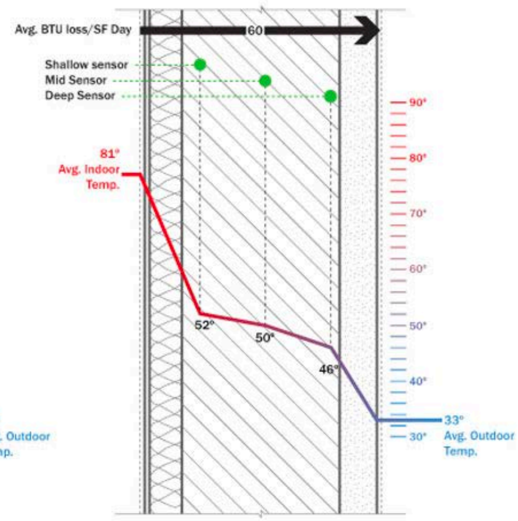
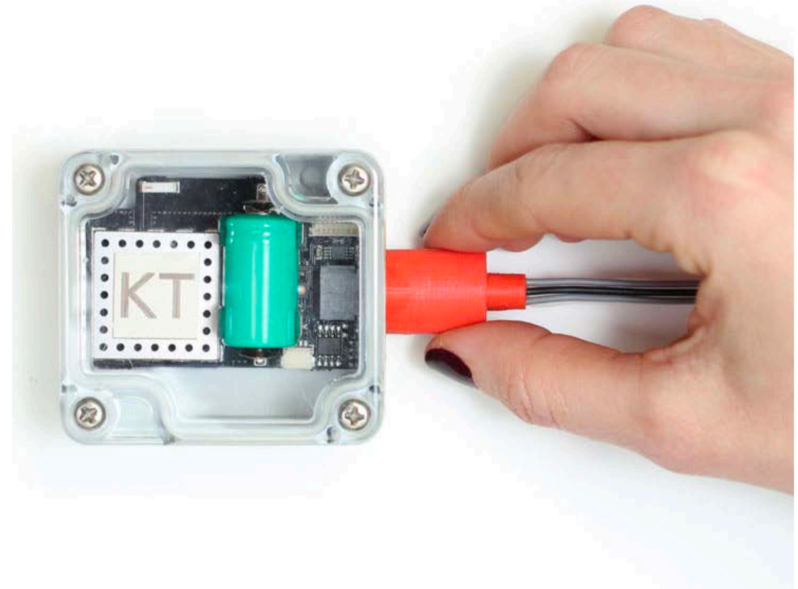
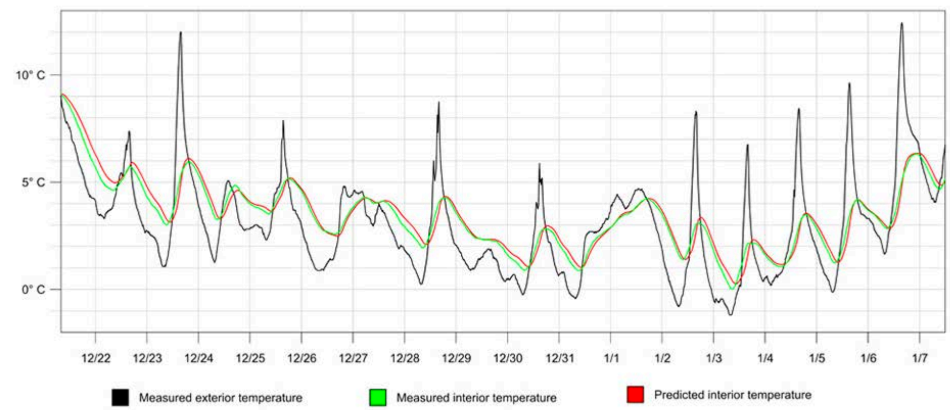


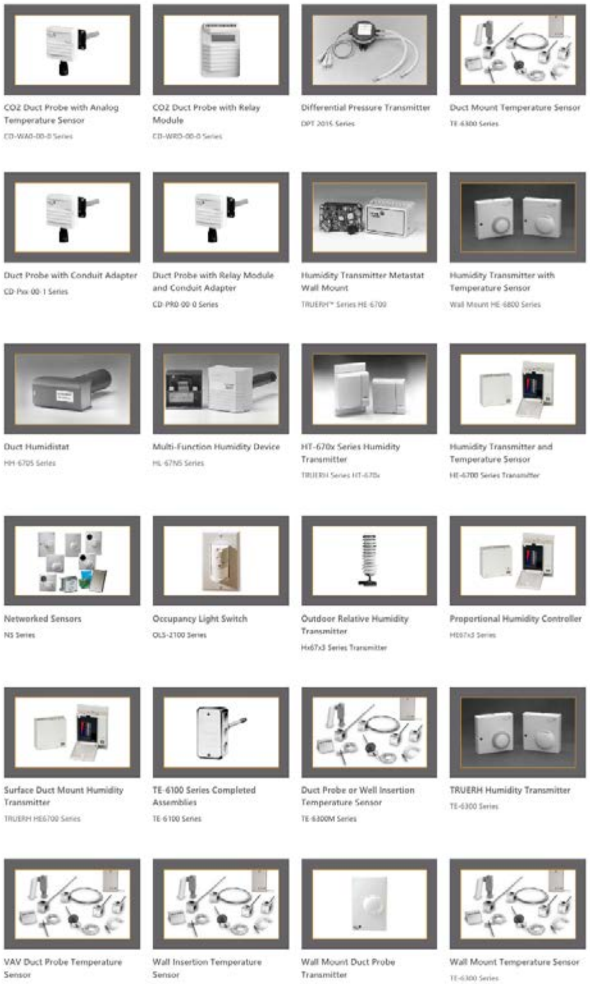
UNMODIFIED WALL SECTION



MODIFIED WALL SECTION







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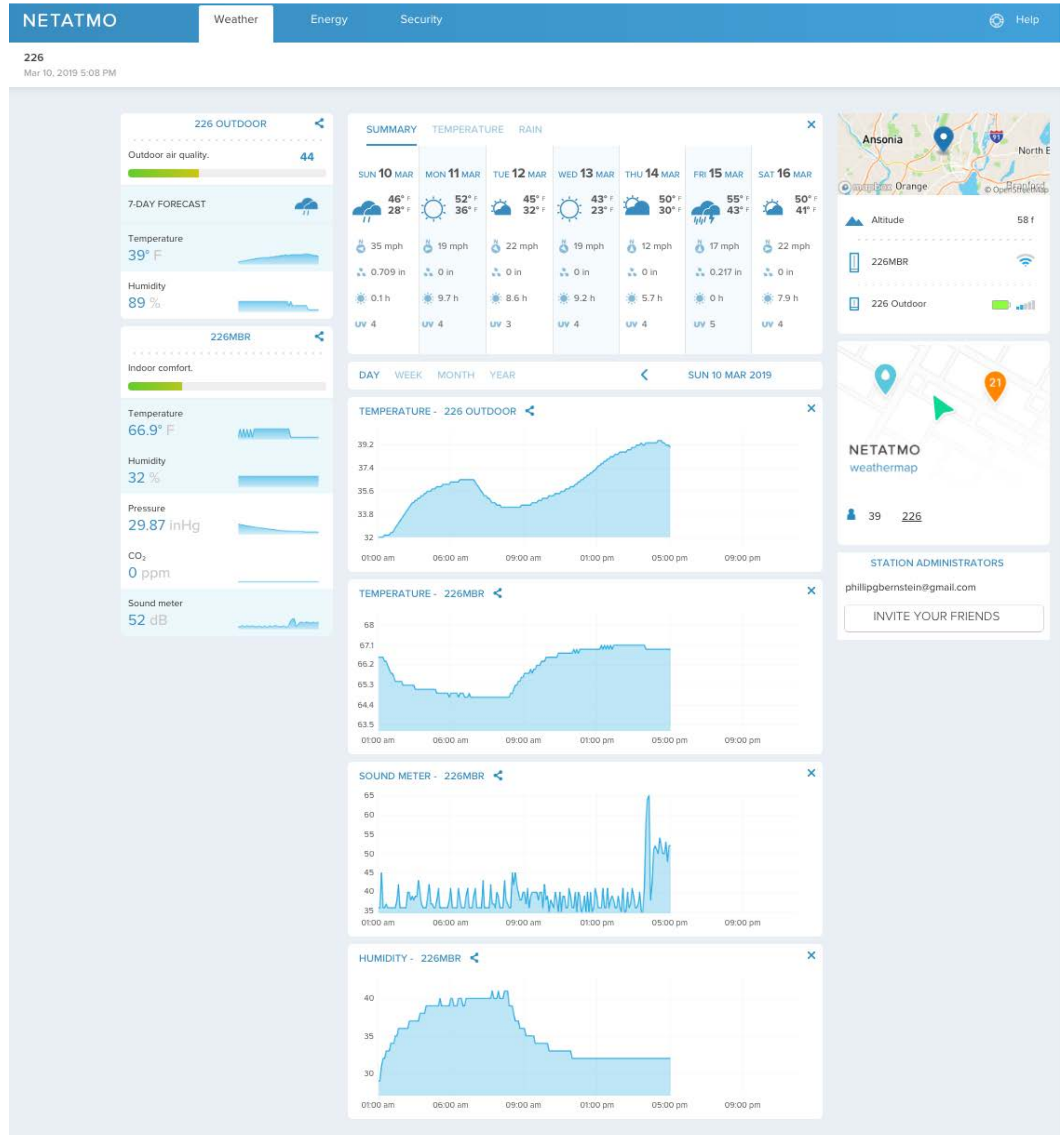

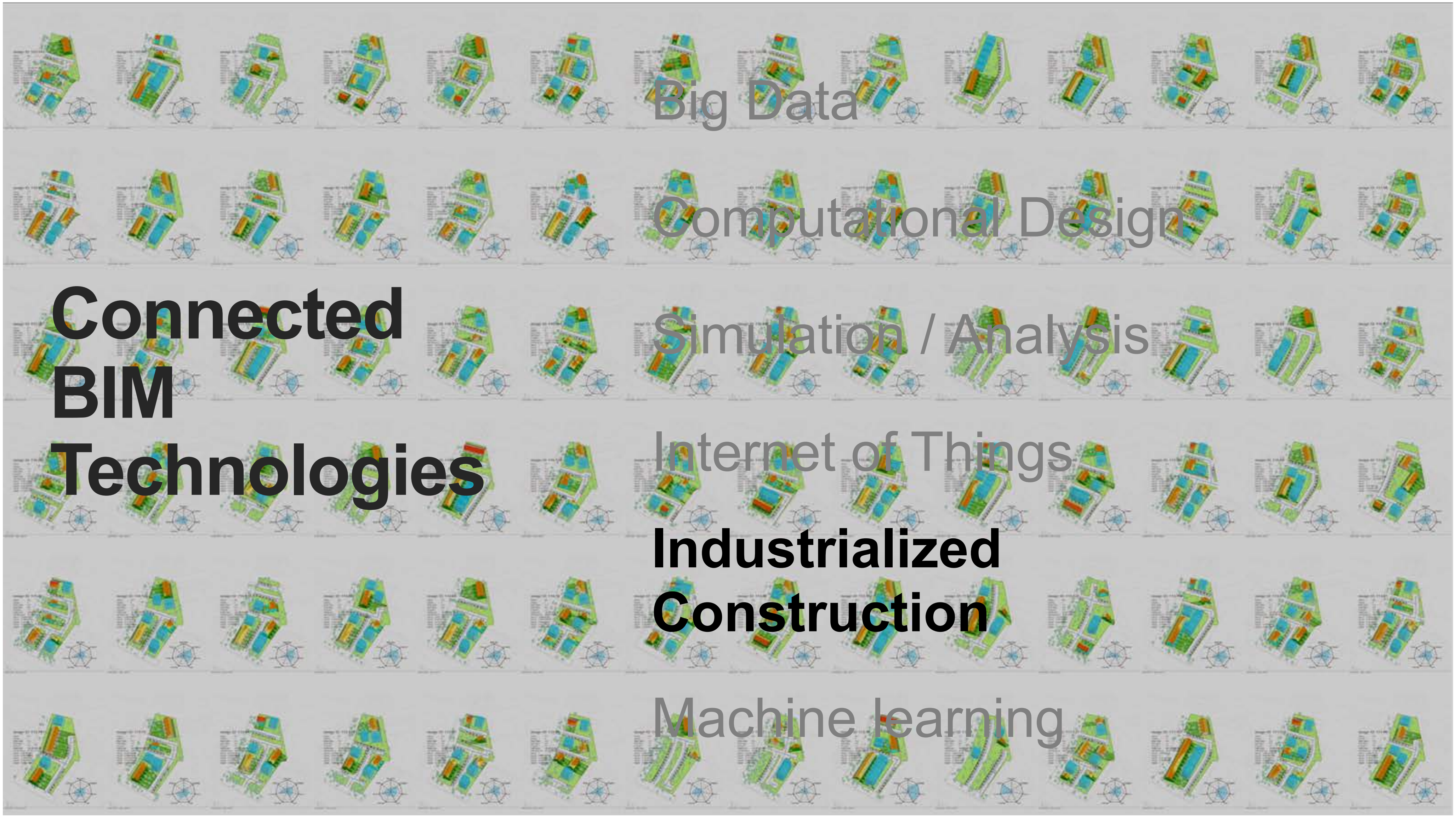
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Machine learning


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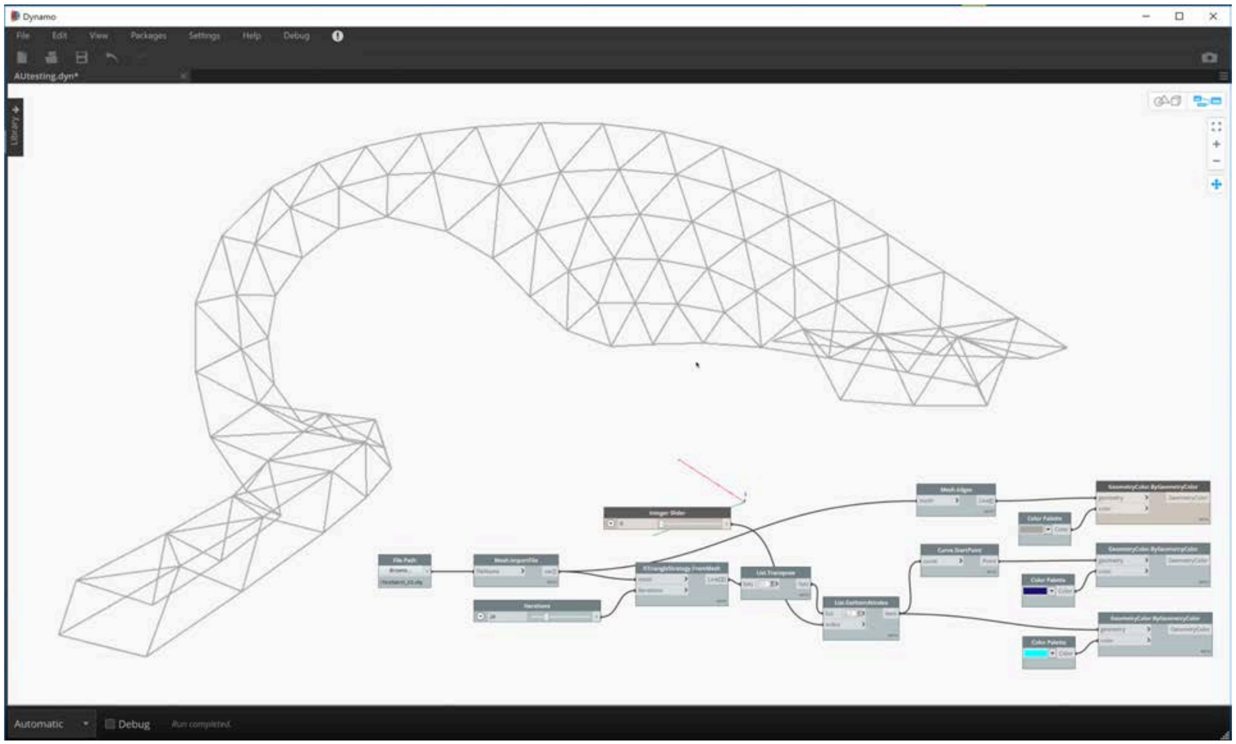
AUTODESK
BUILD SPACE



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Lines

Studs

Custom operations

Export for fab


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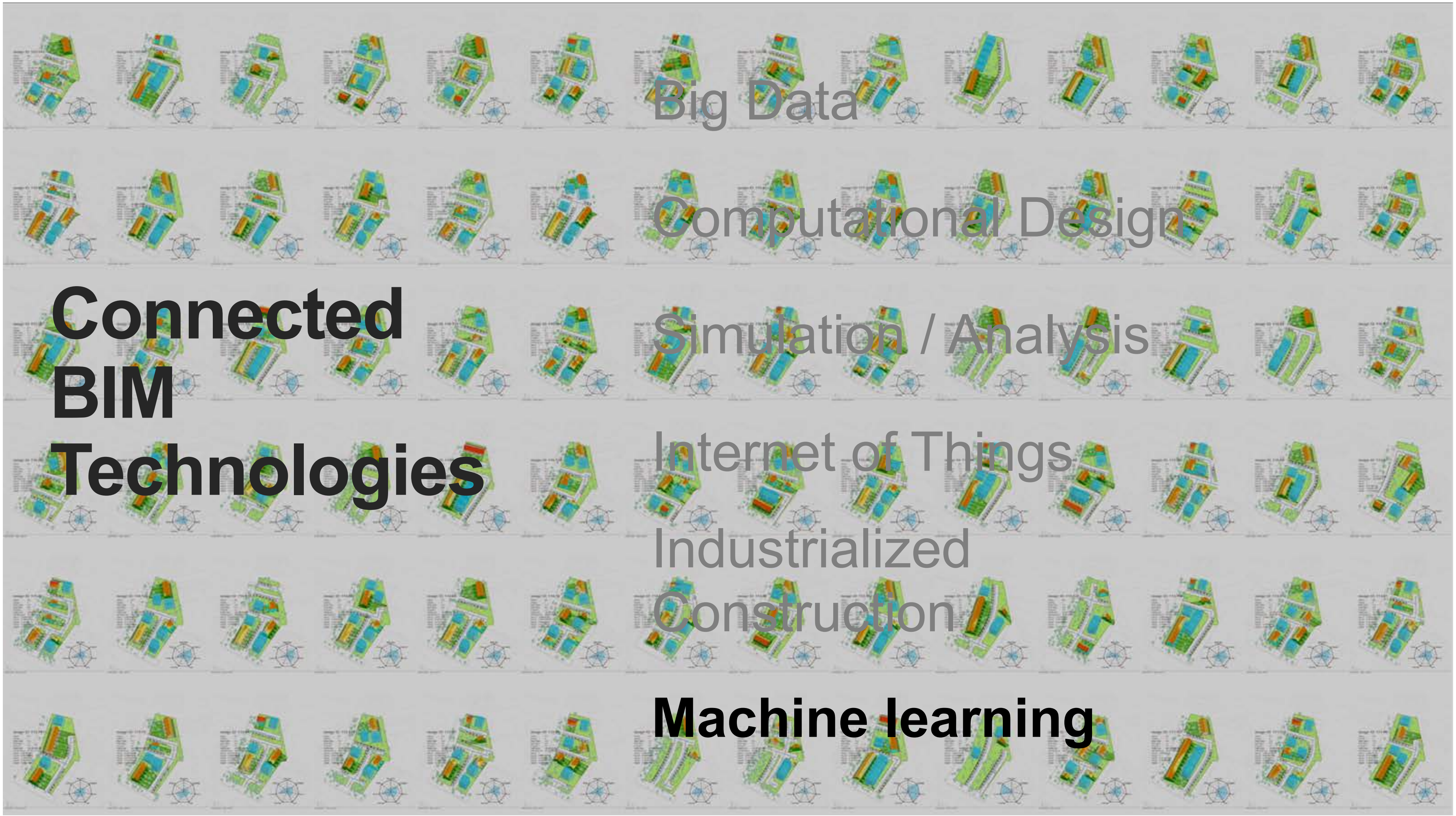

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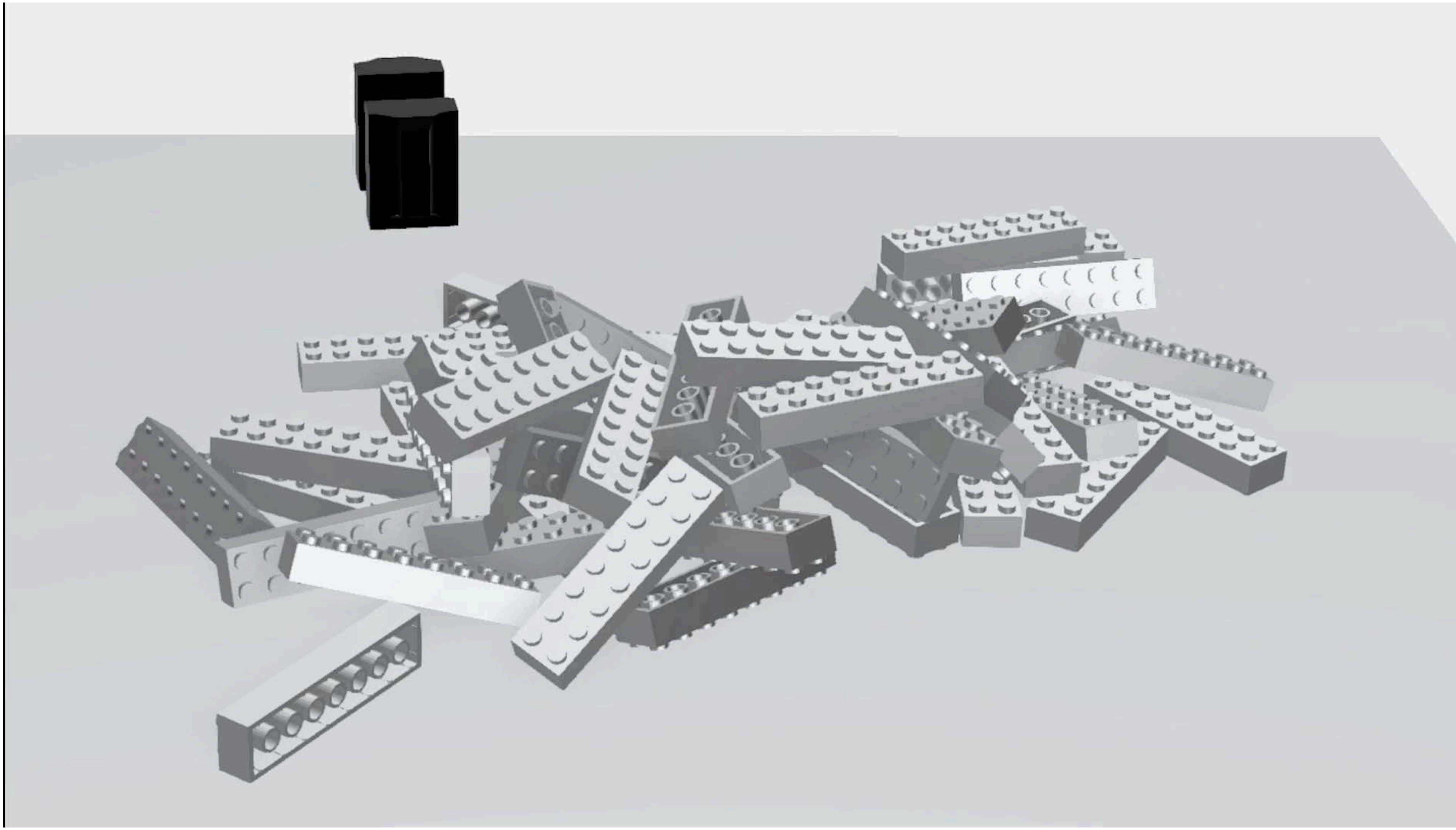
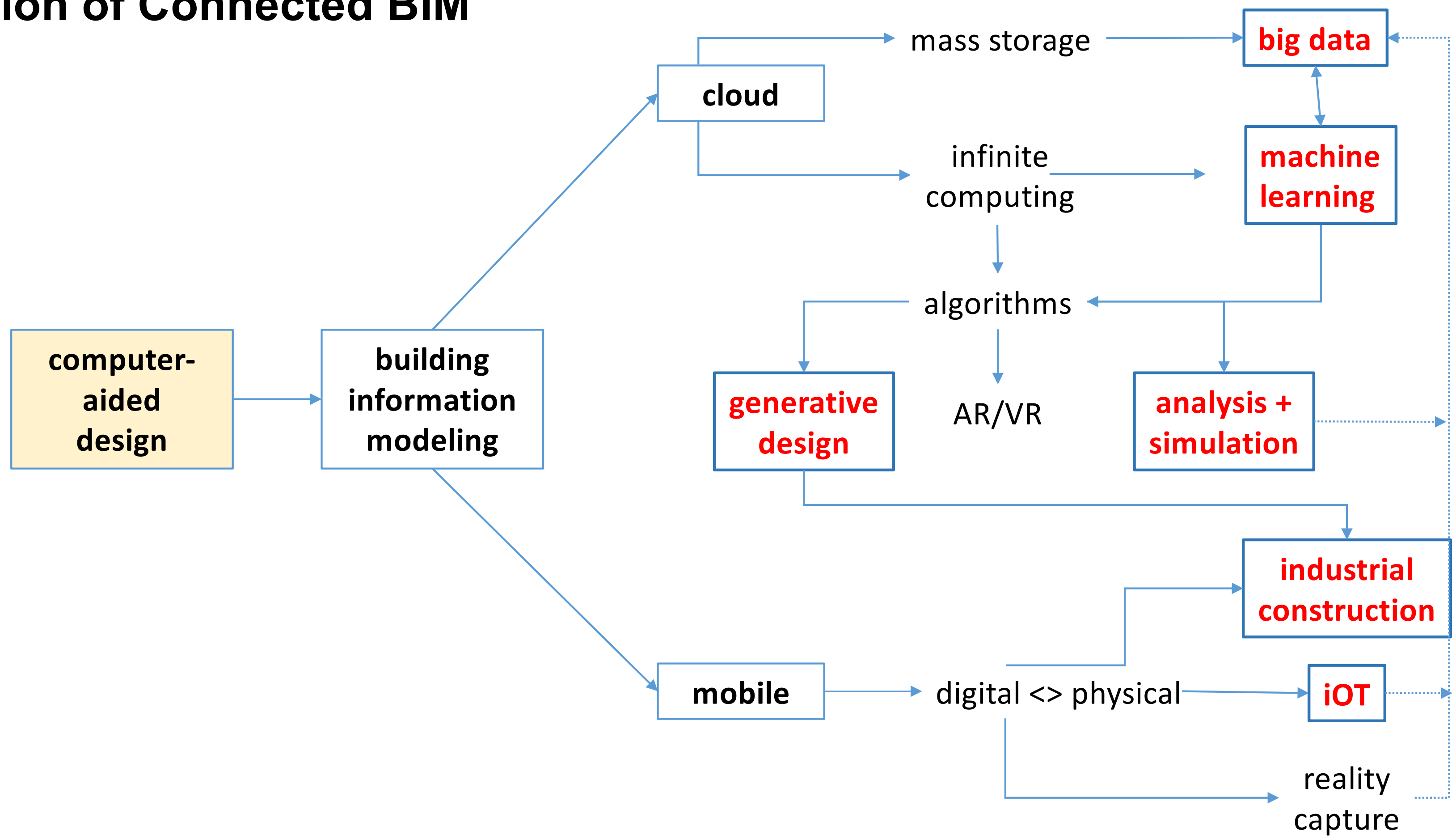
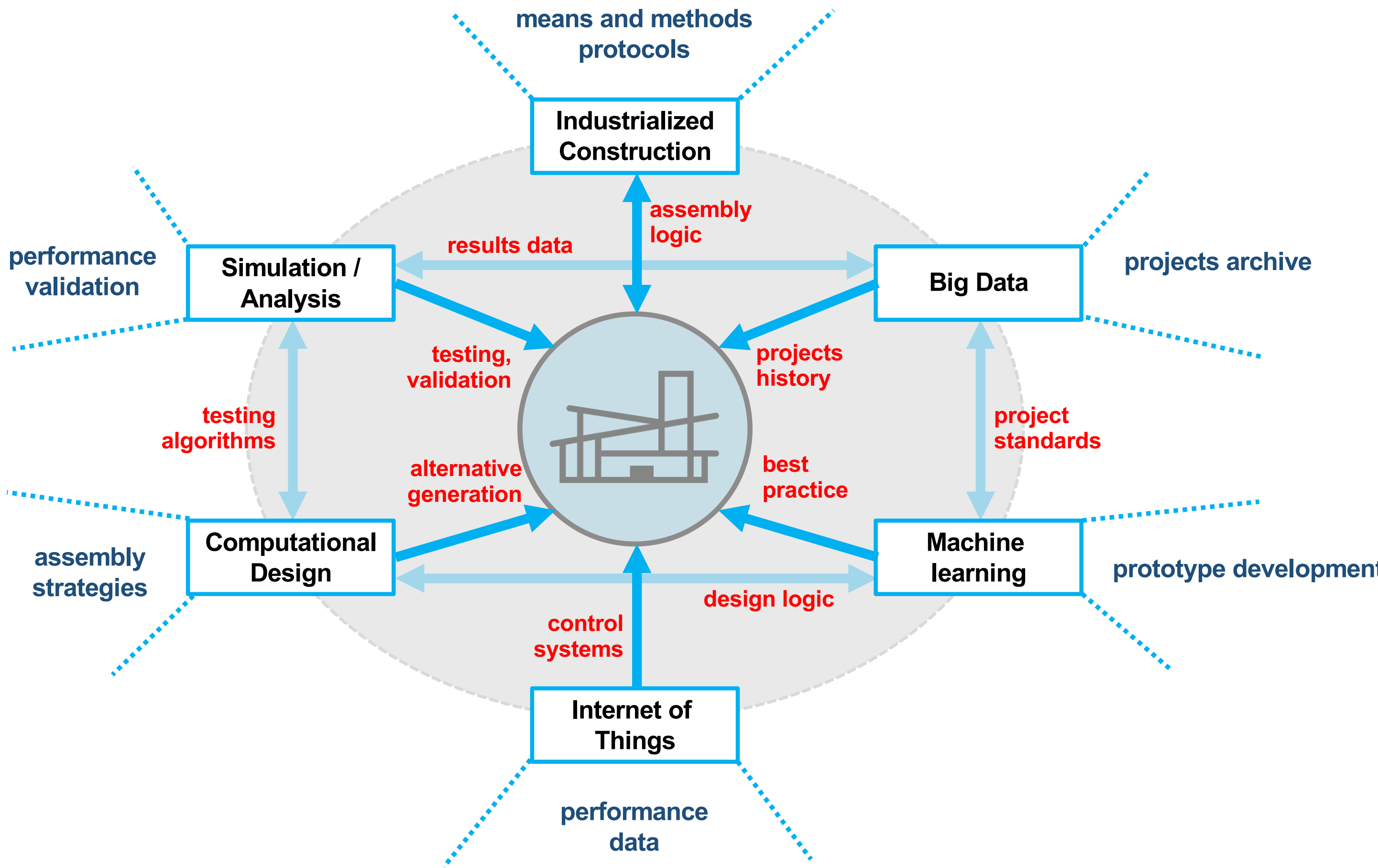
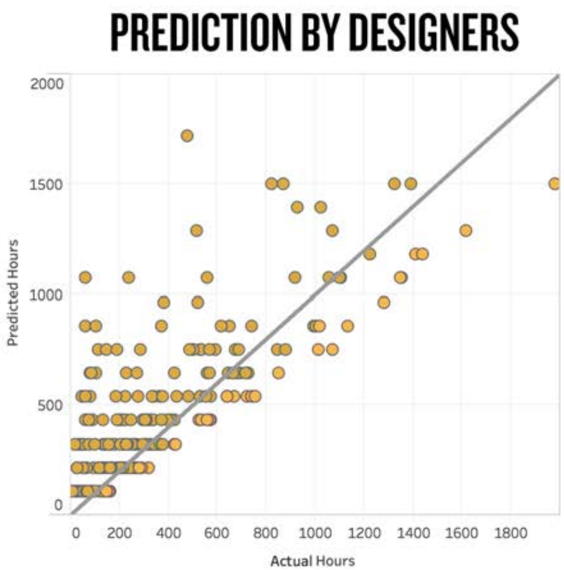


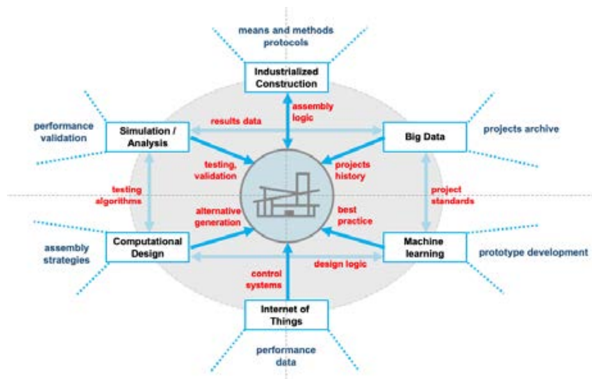
Evolution of Connected BIM

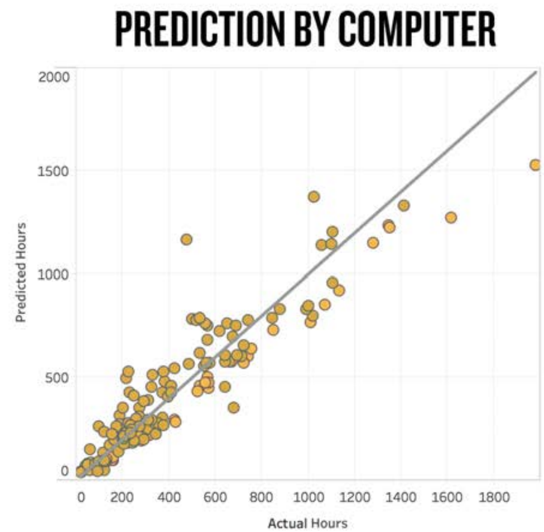


Technologic Integration

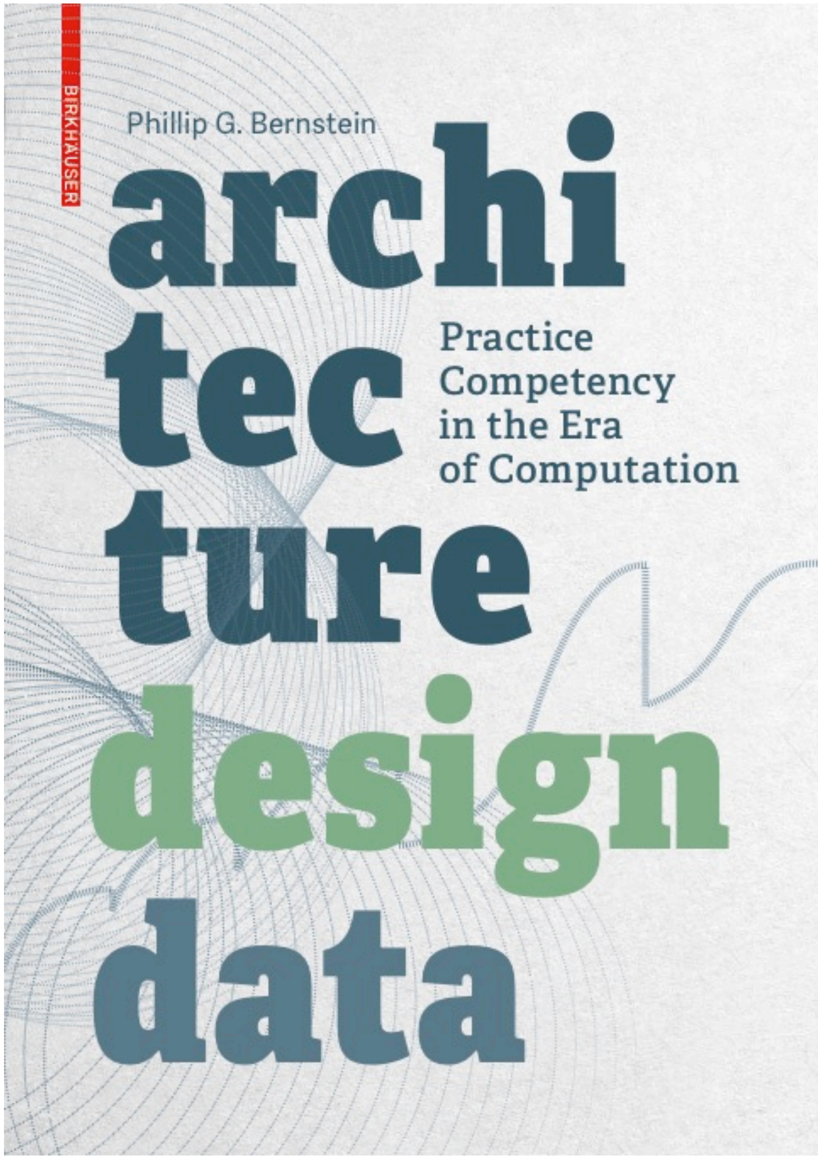








Measurement →Simulation → Prediction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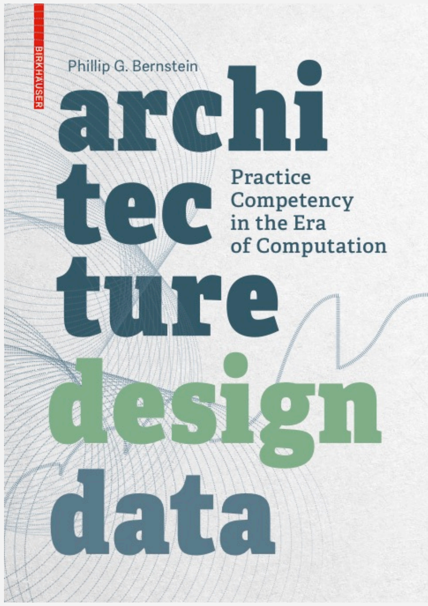
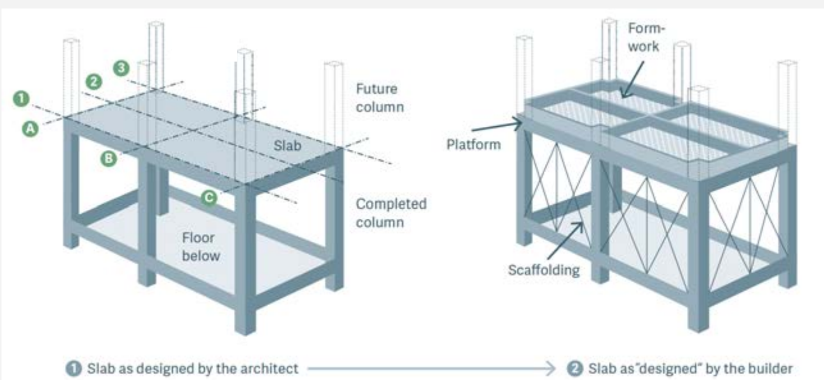
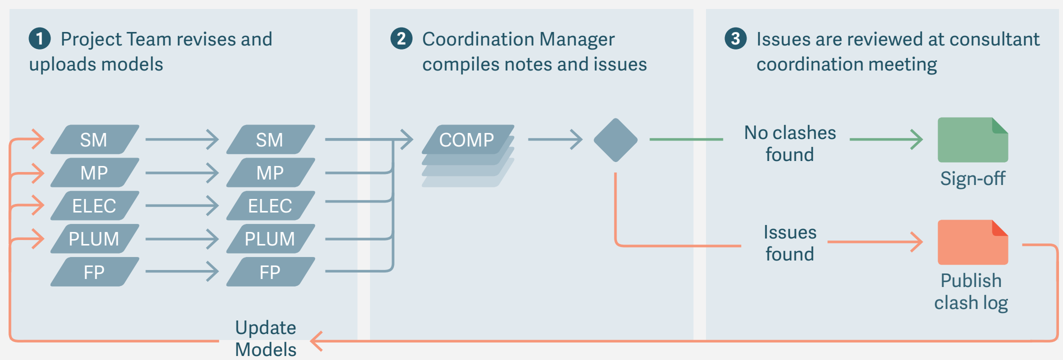


	Agency	Methodology	Value
Current State	Professional standards, defining "intent"	Iteration, intuition, fixed deliverables	Commodification, lowest first cost





Process Opportunities of Technology

1	Digital precision, optimization, simulation
2	Information coordination and control
3	Solving, selecting
4	Integrated lifecycle information
5	Intention to execution, digital making

Process Opportunities of Technology

1	Digital precision, optimization, simulation	*Digital simulation, big data and analysis allows architects to develop a design with higher levels of precision and insight and understand the technical implications of design decisions a priori.*
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3	Solving, selecting	
4	Integrated lifecycle information	
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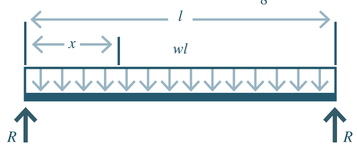
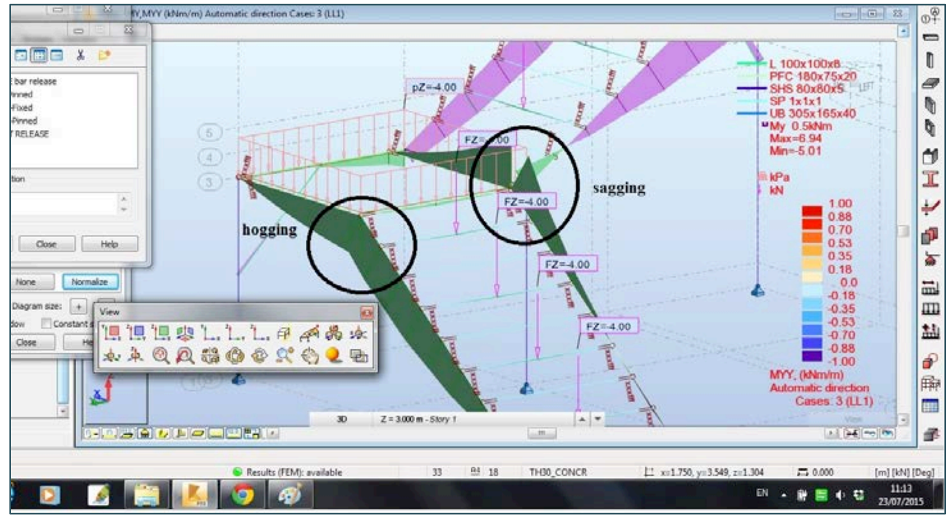
2.1.2 Analytical formulae

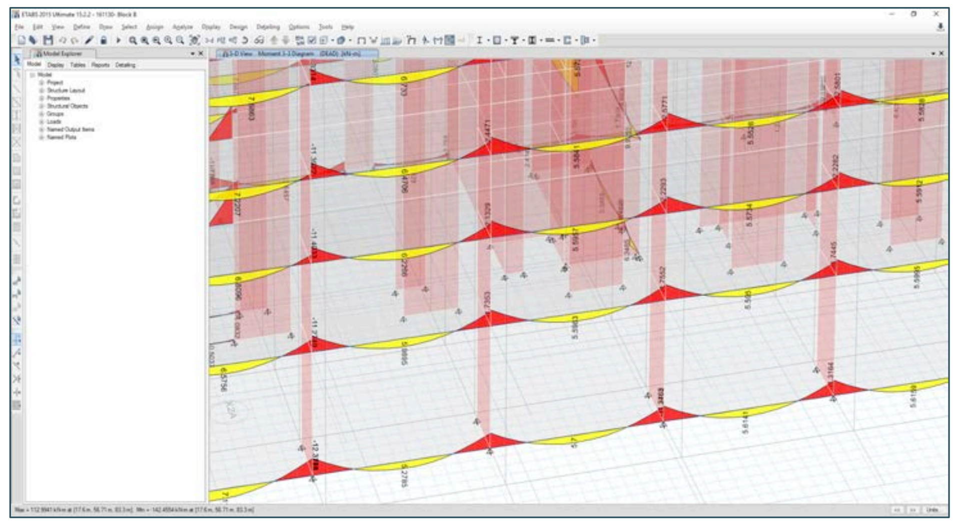
Problem to be solved	Example formula	Note
Compute moment in a simple beam, uniformly loaded	M_{max} (at center) . . . . $= \frac{wl2}{8}$ 	5
Flow resistance of air through a small opening in an exterior wall	$S_\delta(V) = \frac{p}{0{,}845 \cdot A^2} \cdot V$ where S_δ is the flow resistance [Pa · m³/s] p is the density of the air [kg/m³] A is the area of the hole [kg/m²]	6
Required capacity of rainwater downpipes and gutters	Qh = (a × i) × (ß × F) a = the reduction factor for the rain intensity for flat roofs a = 0.60 flat roof with ballast of gravel a = 0.75 for the other flat roofs As flat roofs discharge the water at a slower pace, for all other cases (therefore all pitched roofs) applies a = 1, i = rain intensity and is 1.8 (litre/minute)/m² ß = reduction factor for the roof width is determined by the pitch roof F = surface of the roof	7

5 American Forest and Paper Associatation, “Beam Design Formulas with Shear and Moment Diagrams,” http://www.awc.org/pdf/codes-standards/publications/design-aids/AWC-DA6-BeamFormulas-0710.pdf.

6 Axel Berge, Analysis of Methods to Calculate Air *Infiltration for Use in Energy Calculations, Thesis, Chalmers University, 2011*, http://publications.lib.chalmers.se/records/fulltext/147421.pdf.

7 Nedzink Company, “Determining the required capacity of rainwater downpipes and roof gutters,” http://www.nedzink.com/en/info-and-advice/roof-drainage-system/112/determining-the-required-capacity-of-rainwater-downpipes-and-roof-gutters.





Process Opportunities of Technology

1	Digital precision, optimization, simulation	*Digital simulation, big data and analysis allows architects to develop a design with higher levels of precision and insight and understand the technical implications of design decisions a priori.*
2	Information coordination and control	*Designing a building means coordinating both the physical artifact and the information flows necessary to generate it, including both geometry and metadata.*
3	Solving, selecting	
4	Integrated lifecycle information	
5	Intention to execution, digital making	

3.2 - Is the creation and control of information systems by architects necessary for the design and construction of buildings?

3.2.6 Model coordination timeline for an airport project

2.3.3 The constellation of applications in use by SOM, 2007

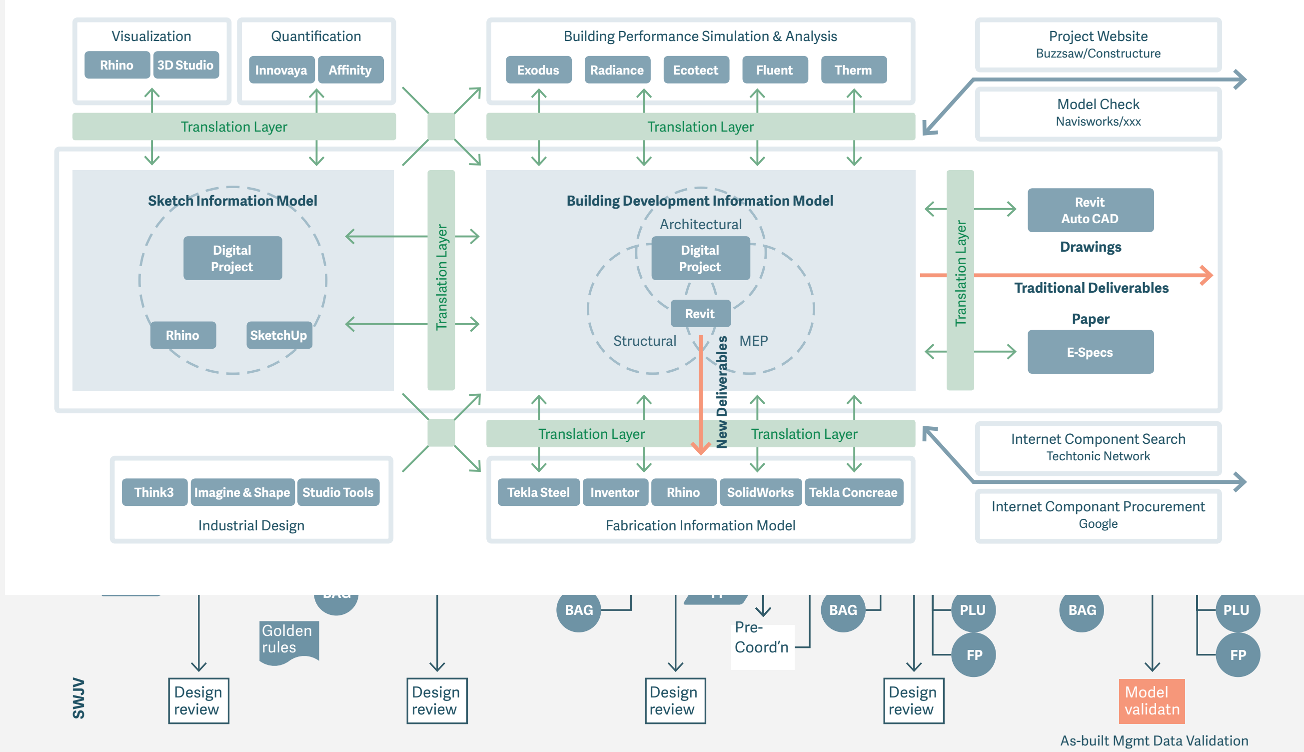


Image courtesy Pierce Reynoldson, SKANSKA

Process Opportunities of Technology

1	Digital precision, optimization, simulation	*Digital simulation, big data and analysis allows architects to develop a design with higher levels of precision and insight and understand the technical implications of design decisions a priori.*
2	Information coordination and control	*Designing a building means coordinating both the physical artifact and the information flows necessary to generate it, including both geometry and metadata.*
3	Solving, selecting	*Digital simulation and generative design, in combination, allows architects to more thoroughly explore options systematically, understand the results, and choose better solutions.*
4	Integrated lifecycle information	
5	Intention to execution, digital making	

3.3 - How do digital strategies for problem definition, generation, evaluation and optimization affect the architect's process and goals?

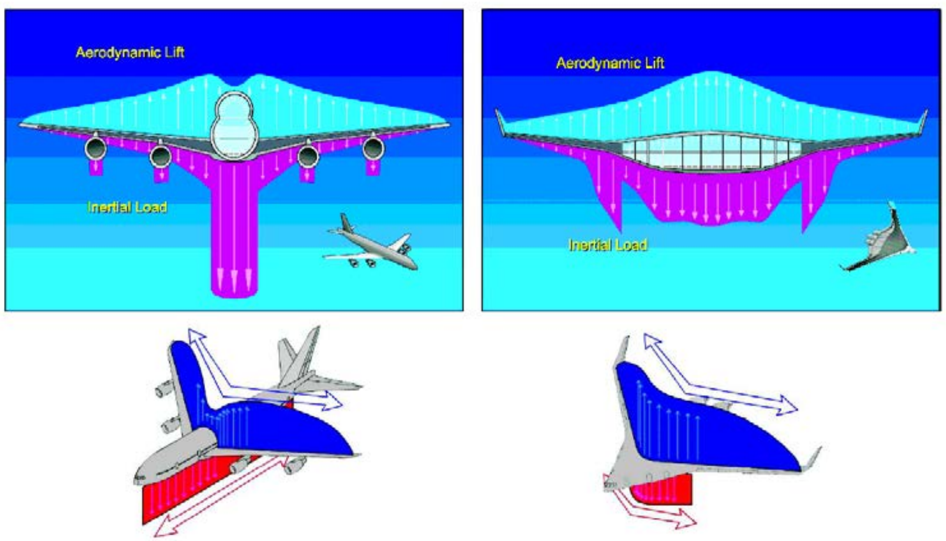


Fig. 19 Comparison of aerodynamic, inertial, and cabin pressure loads.

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.459.9447&rep=rep1&type=pdf

Process Opportunities of Technology

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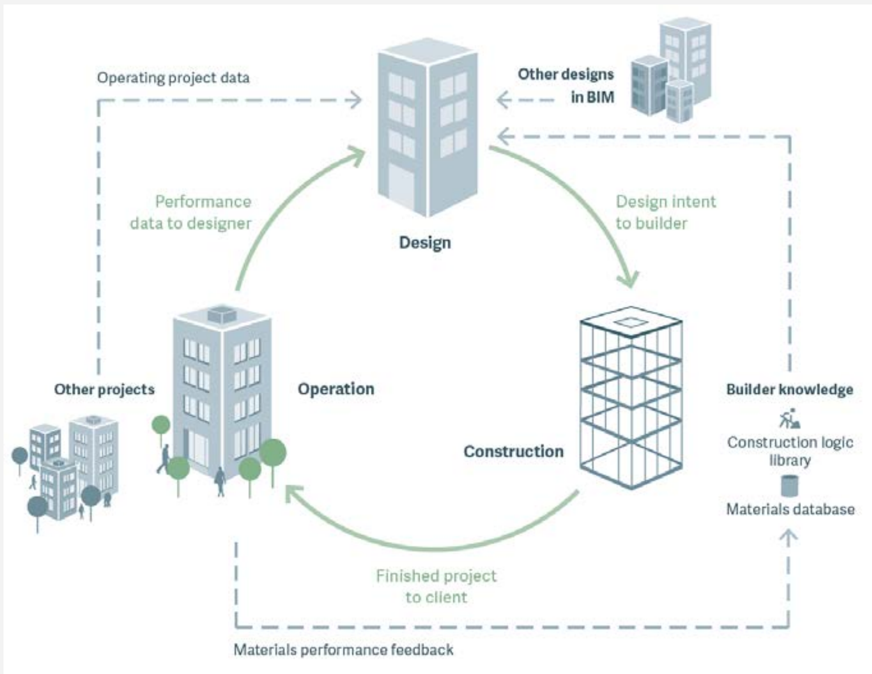
4	Integrated lifecycle information	*The information that is the basis for design can support improved construction process and building operation, and creates* a virtuous cycle of data *that can be used to build insight and improve results.*
5	Intention to execution, digital making	

3.4 - Is architectural design representation obliged to support and integrate into post-design activities such as construction and building operation, and if so, how does that affect design generation?



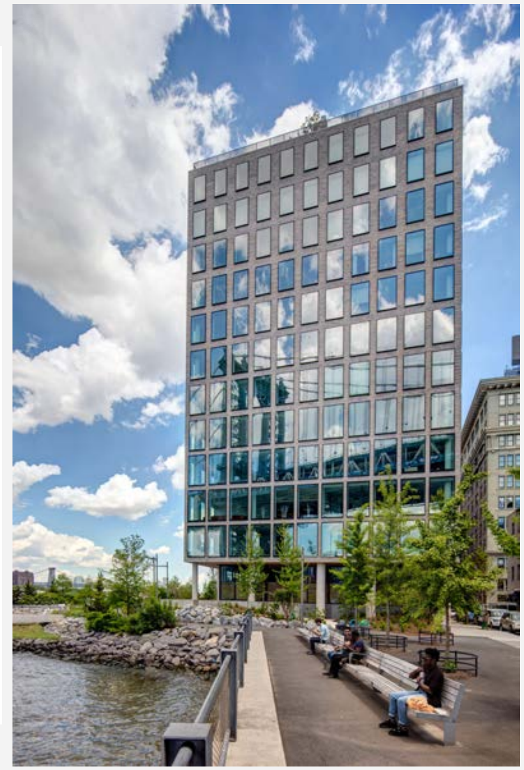


Image courtesy ALLOY Development

Process Opportunities of Technology

1	**Digital precision, optimization, simulation**	***Digital simulation, big data and analysis allows architects to develop a design with higher levels of precision and insight and understand the technical implications of design decisions a priori.***
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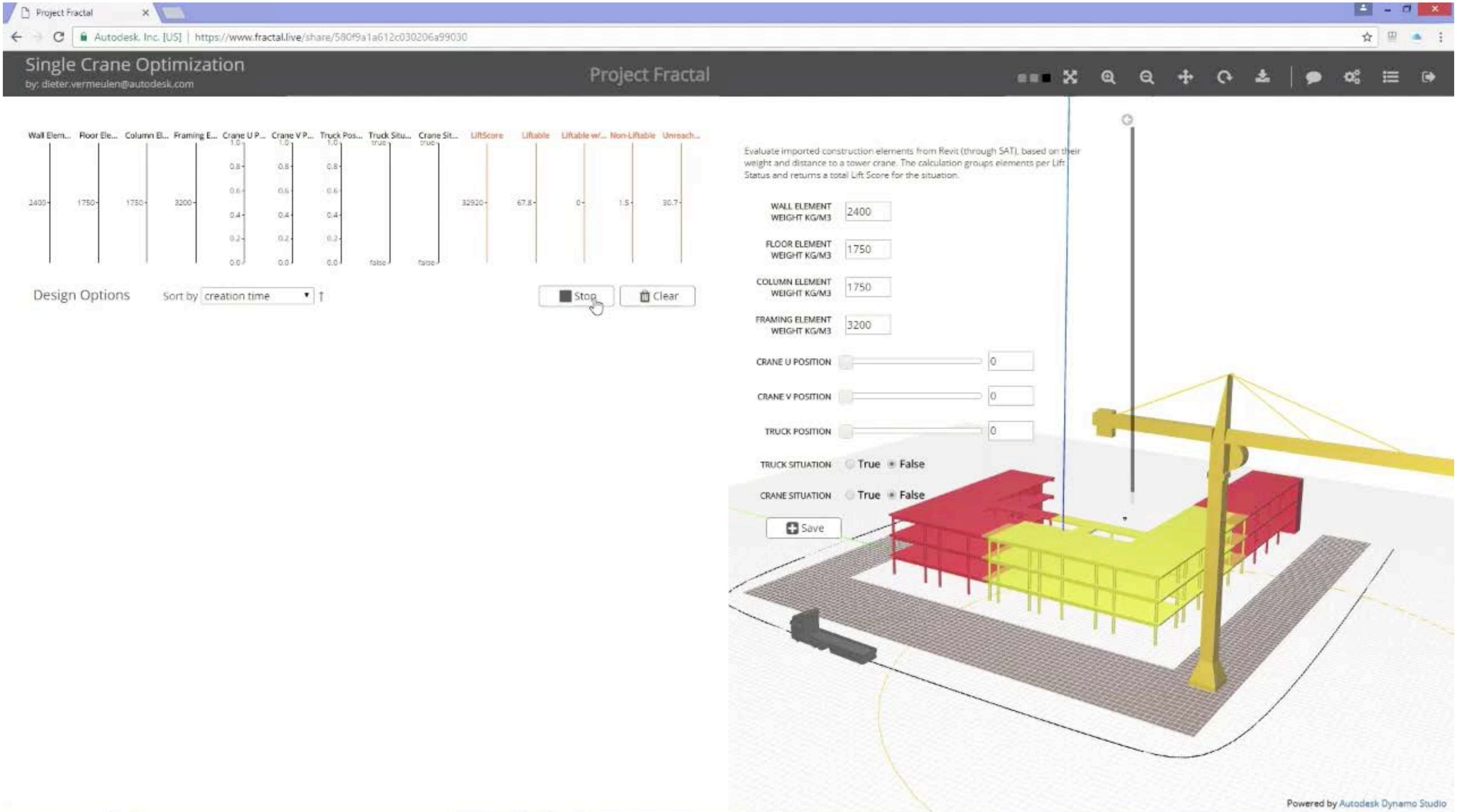
4	**Integrated lifecycle information**	***The information that is the basis for design can support improved construction process and building operation, and creates*** **a virtuous cycle of data** ***that can be used to build insight and improve results.***
5	**Intention to execution, digital making**	***Digital design information can drive*** **automated construction process and logic*****, optimize means and methods and the resulting algorithms are instructive to developing and optimizing design ideas.***

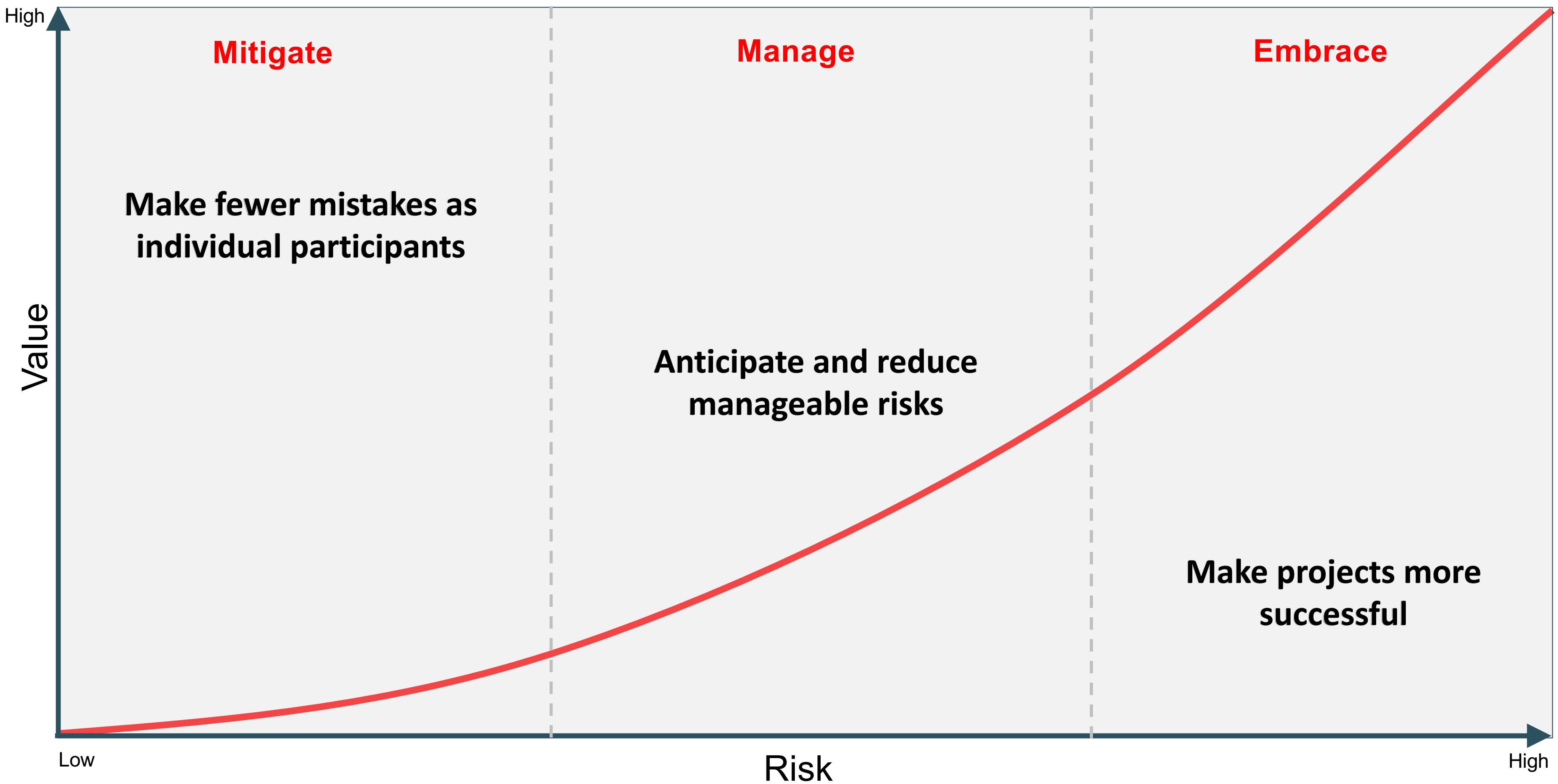
2.1.6 Technology categories and their evolution: BIM > Machine Learning

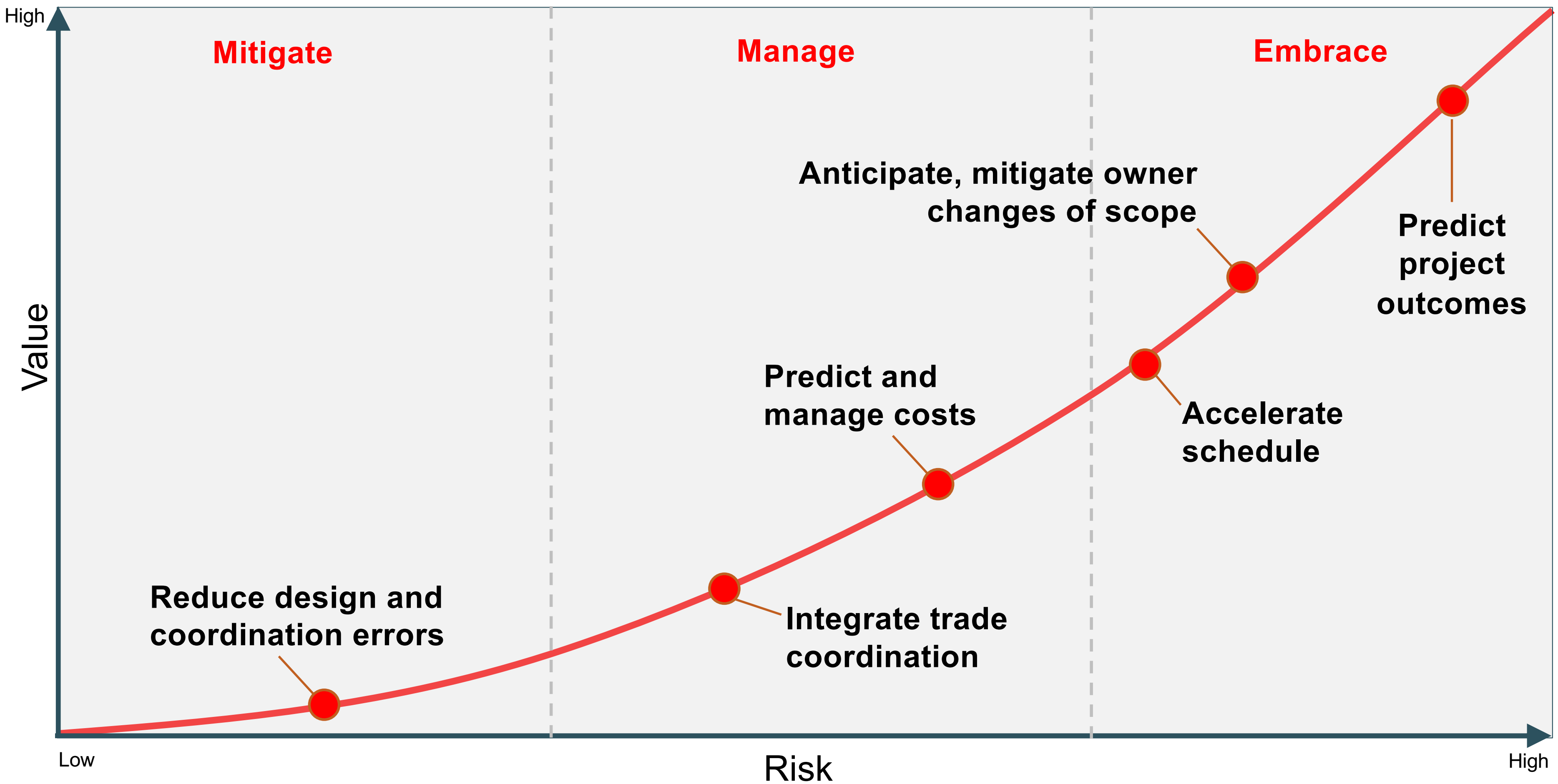
Technology Category	In the era of BIM modeling	In the era of machine learning
Representation	Parametric models of geometry and metadata	Artificial intelligence-informed design through interlinked digital models
Analysis and Simulation	Digital analytical models tied to scripts that test and choose results	Big data-based neural networks that predict complex outcomes
Realization	Model-based simulation of construction yielding build-ready data	Information originating from the design process drives self-learning automated machinery on the project site.
Collaboration	Web-based, social-media-enabled real-time connection and data exchange.	Real-time interaction enhanced by virtual and augmented reality supplemented with predictive collaboration through AI.

See also 2.1.4, p. 24



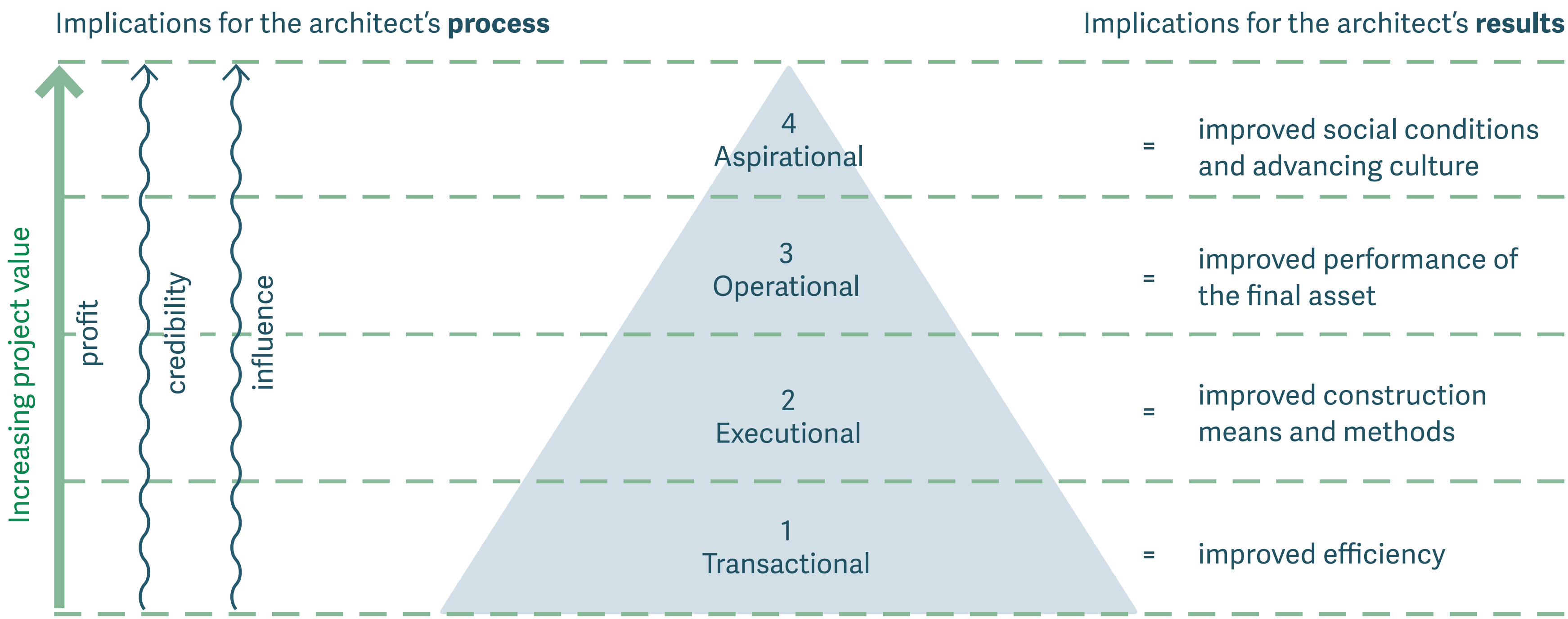
Project Fractal
Autodesk, Inc. [US] | https://www.fractal.live/share/580f9a1a612c030206a99030
Single Crane Optimization
by: dieter.vermeulen@autodesk.com
Project Fractal
Wall Elem... Floor Ele... Column El... Framing E... Crane U P... Crane V P... Truck Pos... Truck Situ... Crane Sit... LiftScore Liftable Liftable w/... Non-Liftable Unreach...
Design Options
Sort by creation time
Stop
Clear
Evaluate imported construction elements from Revit (through SAT), based on their weight and distance to a tower crane. The calculation groups elements per Lift Status and returns a total Lift Score for the situation.
WALL ELEMENT WEIGHT KG/M3 2400
FLOOR ELEMENT WEIGHT KG/M3 1750
COLUMN ELEMENT WEIGHT KG/M3 1750
FRAMING ELEMENT WEIGHT KG/M3 3200
CRANE U POSITION 0
CRANE V POSITION 0
TRUCK POSITION 0
TRUCK SITUATION True False
CRANE SITUATION True False
Save
Powered by Autodesk Dynamo Studio

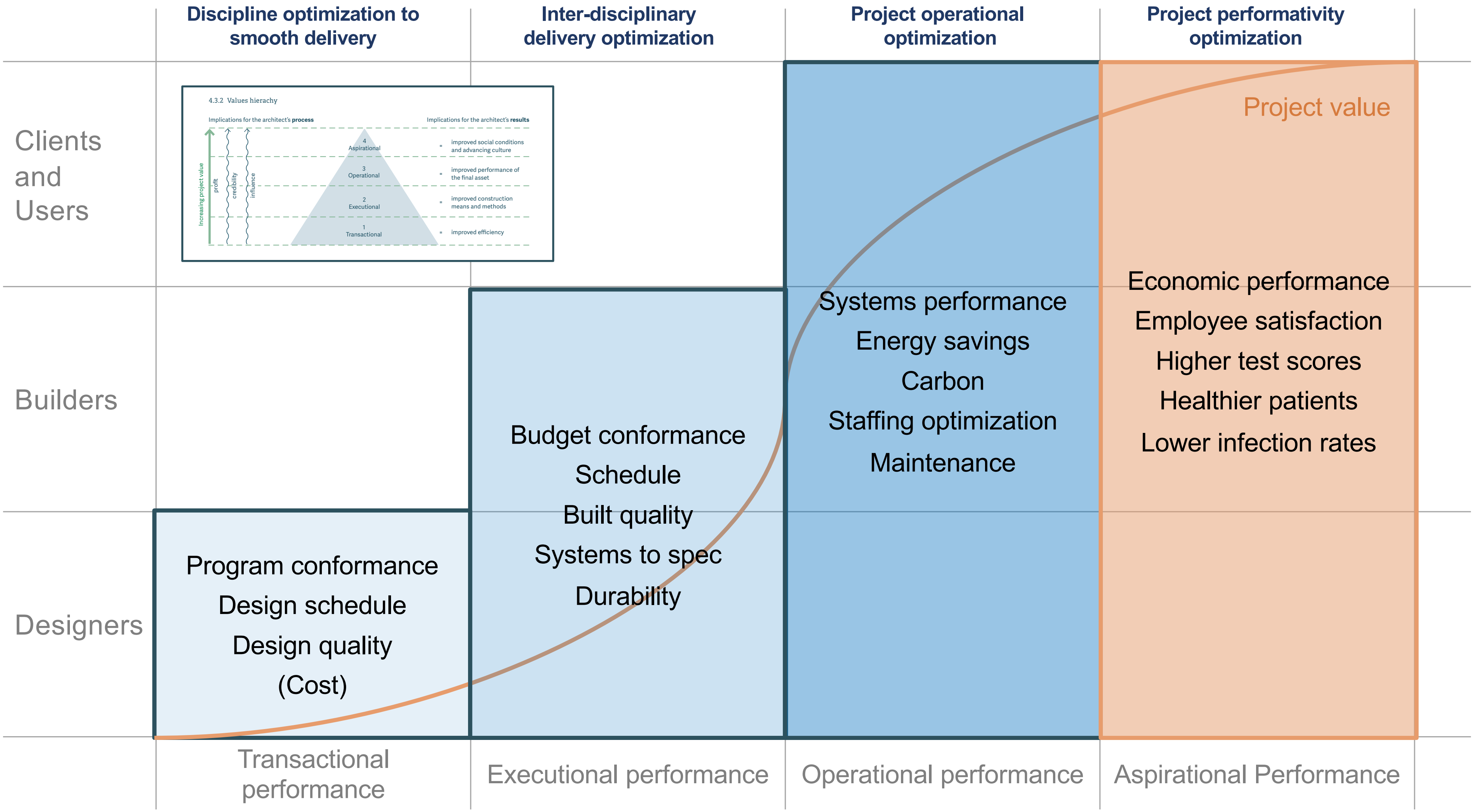

High
Value
Low
Risk
High
Mitigate
Manage
Embrace
Make fewer mistakes as individual participants
Anticipate and reduce manageable risks
Make projects more successful



High
Mitigate
Manage
Embrace
Anticipate, mitigate owner changes of scope
Predict project outcomes
Value
Predict and manage costs
Accelerate schedule
Reduce design and coordination errors
Integrate trade coordination
Low
Risk
High

4.3.2 Values hierarchy



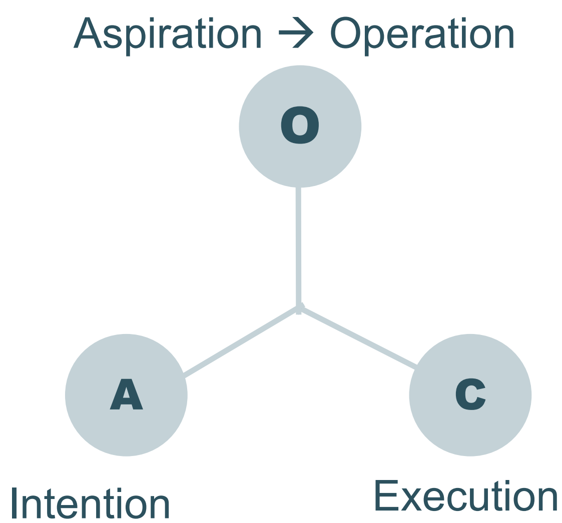


Discipline optimization to smooth delivery
Inter-disciplinary delivery optimization
Project operational optimization
Project performativity optimization
Clients and Users
Builders
Designers
4.3.2 Values hierachy
Implications for the architect's **process**
Implications for the architect's **results**
Increasing project value
profit
credibility
influence
4 Aspirational
3 Operational
2 Executional
1 Transactional
= improved social conditions and advancing culture
= improved performance of the final asset
= improved construction means and methods
= improved efficiency
Project value
Program conformance
Design schedule
Design quality
(Cost)
Budget conformance
Schedule
Built quality
Systems to spec
Durability
Systems performance
Energy savings
Carbon
Staffing optimization
Maintenance
Economic performance
Employee satisfaction
Higher test scores
Healthier patients
Lower infection rates
Transactional performance
Executional performance
Operational performance
Aspirational Performance

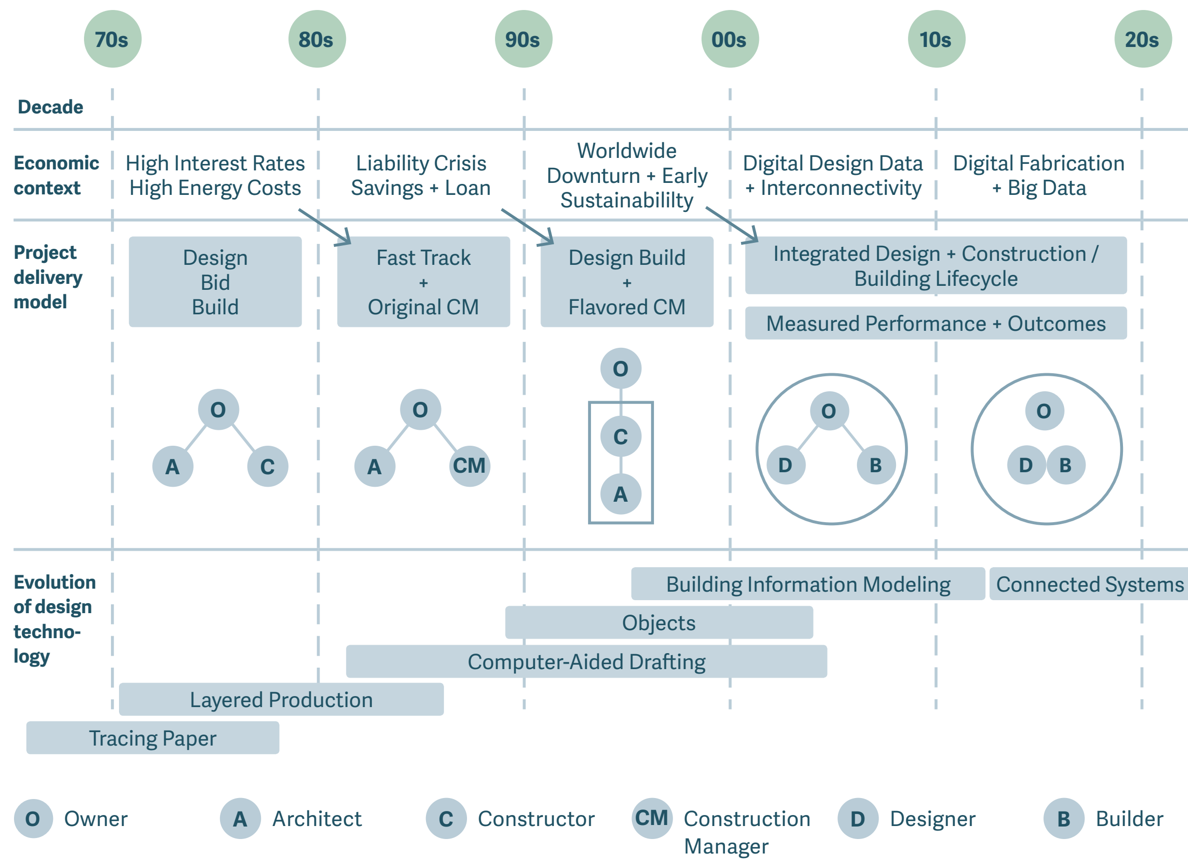
Innovation (Leslie King, Esq.)

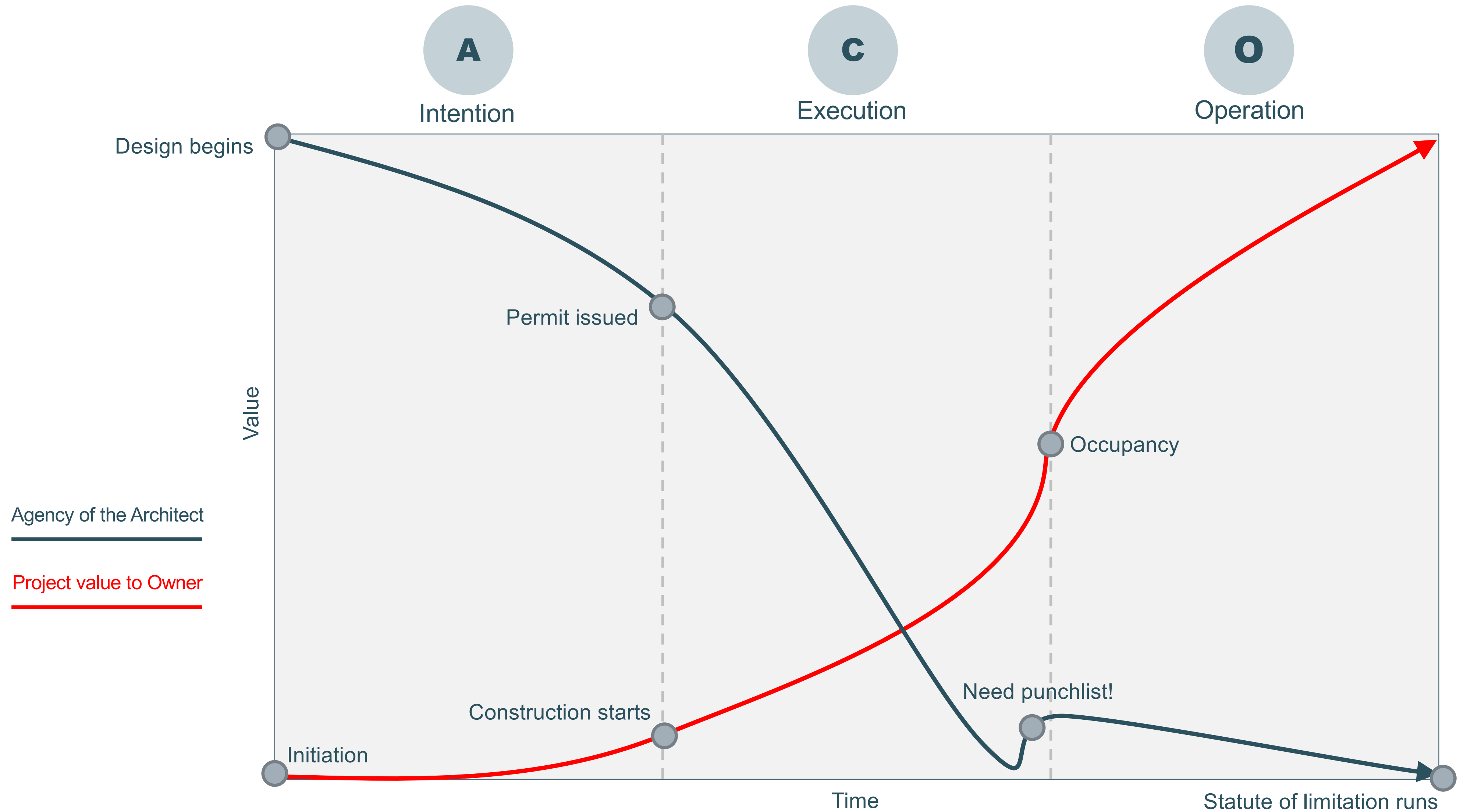
Business judgment rule? Contract for it?

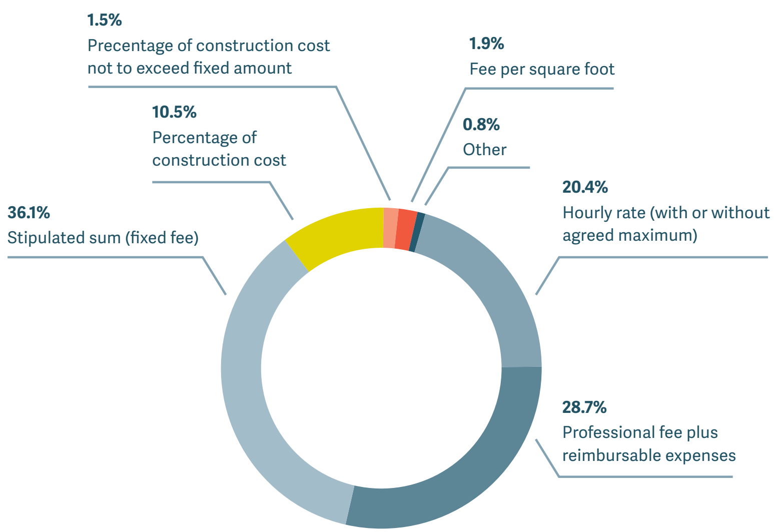
Shareholders challenging the wisdom of a business decision taken by management must overcome the business judgment rule. . . . . For efficiency reasons, corporate decision makers should be permitted to act decisively and with relative freedom from a judge's or jury's subsequent second questioning. **It is desirable to encourage directors and officers to enter new markets, develop new products, innovate, and take other business risks.**" 1 A.L.I., Principles of Corporate Governance (1994) § 4.01(c) comment, p. 174



2.1.5 The evolution of project delivery models, 1970–2020




A
Intention
C
Execution
O
Operation
Design begins
Permit issued
Value
Occupancy
Agency of the Architect
Project value to Owner
Need punchlist!
Construction starts
Initiation
Time
Statute of limitation runs

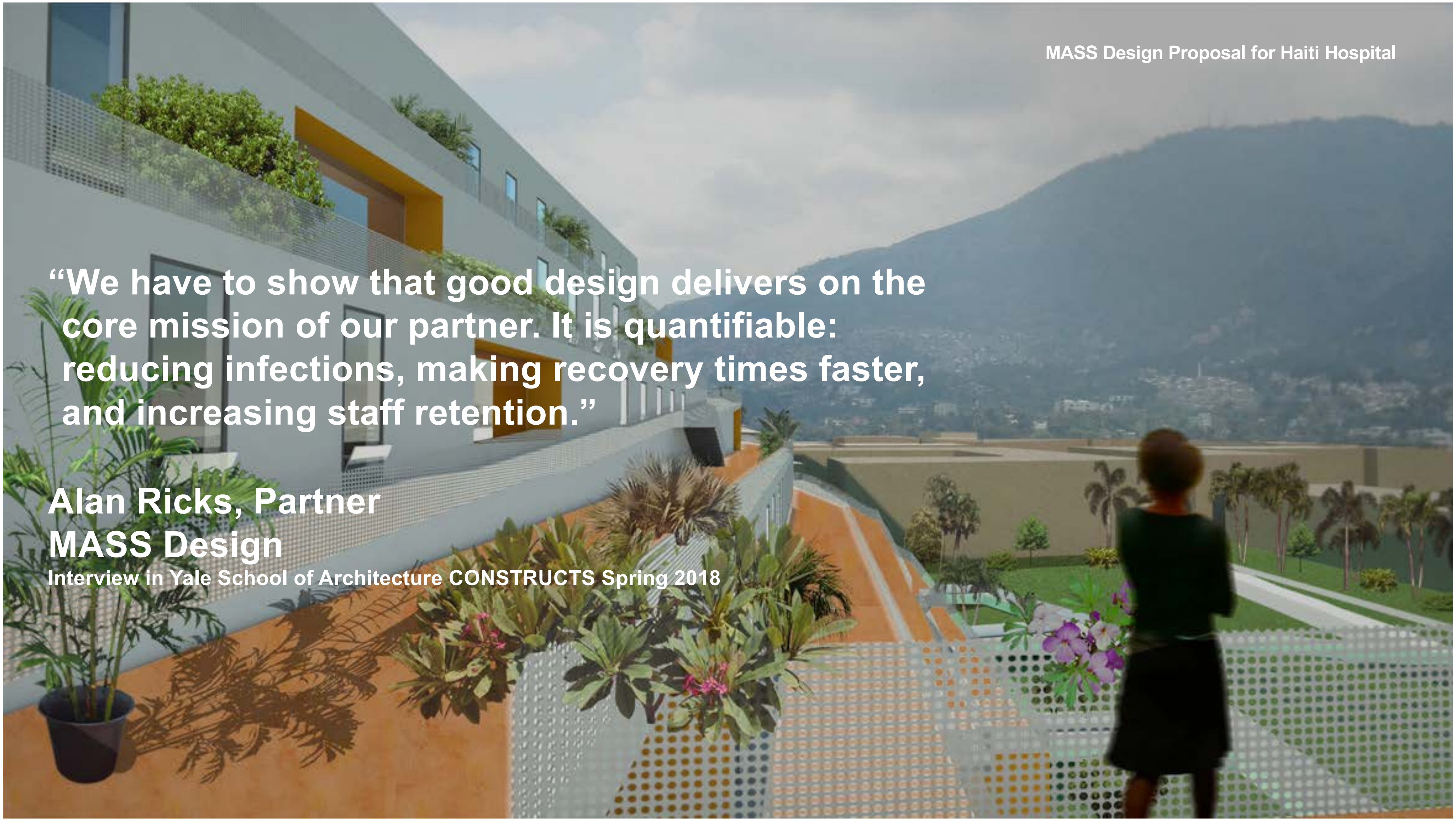


Firm profit margins, based on earnings before interest, bonus and taxes

Under 10%	Weak operating margin
10%–15%	Typical for most design firms
15%– 20%	High margin firm, above average
20–25%	Top performing firm, unusual margins
Above 25%	Very rare, extraordinary performer

Measurement →Simulation → Prediction

= Outcome-based Delivery


MASS Design Proposal for Haiti Hospital
“We have to show that good design delivers on the core mission of our partner. It is quantifiable: reducing infections, making recovery times faster, and increasing staff retention.”
Alan Ricks, Partner
MASS Design
Interview in Yale School of Architecture CONSTRUCTS Spring 2018

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