National Institute of Building Sciences

Provider Number: G168

Tomorrow's Workflows Today: Augmenting BIM, Project Delivery and Operations Workflows to Support Smart City Assets

Course Number

Joe Manganelli, AIA, LEED BC+C, PhD

Date

January 9, 2019

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

Buildings are designed, built and operated to support, enhance and optimize human and organizational performance in pursuit of human and organizational goals in order to address human and organizational needs. Yet, often the interrelationships between human and organizational performance and facility performance are underdeveloped and based on unvalidated assumptions, leading to building performance misaligned with human and organizational performance. This misalignment of human and organizational performance with building performance causes inefficiencies and nuisances. But as we transition to creating and operating facilities as smart city assets, with increasingly complex and interconnected layers of sensing, analytics, communication and self-optimization, these misalignment challenges will become unacceptable and dangerous, just as semi-autonomous vehicles with automated functions that are not aligned with the human and social dynamics of driving are useless and dangerous. To address these misalignment challenges, architecture/ engineering/ construction/ owner/ operator (AECOO) professionals must augment their workflows to model information about human and organizational performance in relation to building systems performance. This presentation will introduce constructs and methods from the aerospace, defense and automotive industries that address these challenges. Attendees will be introduced to modeling human and organizational performance, socio-technical systems, formal requirements development and multi-objective optimization as parts of enhanced building information modeling (BIM), project delivery and operations workflows.

Learning Objectives

At the end of the this course, participants will be able to:

1. Learn about modeling organizational and human performance in relation to building performance.
2. Learn about sociotechnical systems and enhancing workflows by modeling them.
3. Learn about requirements elicitation, development, and validation and enhancing workflows to incorporate it.
4. Learn about multi-objective optimization and enhancing workflows to incorporate it.

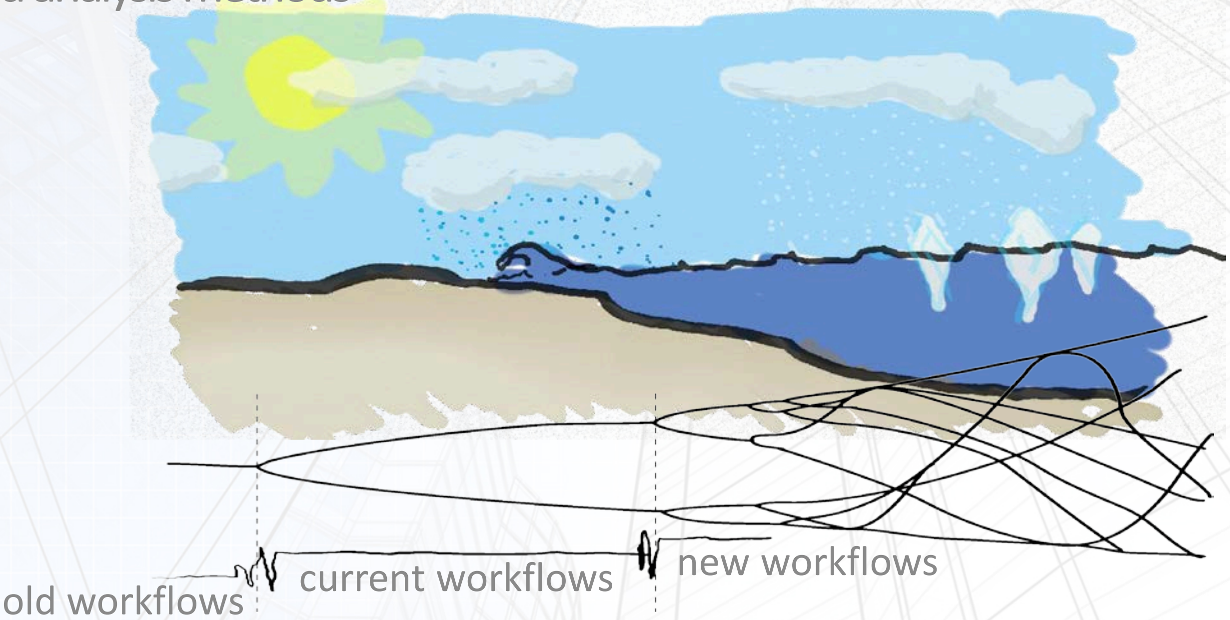
Agenda

- Introduction
- Thanks
- Motivation
- Challenge/Need & smart cities
- Paradigm shifts
- Socio-technical systems
- Requirements development
- Systems modeling
- Agent-based modeling
- Equation-based modeling
- Optimization
- Summary

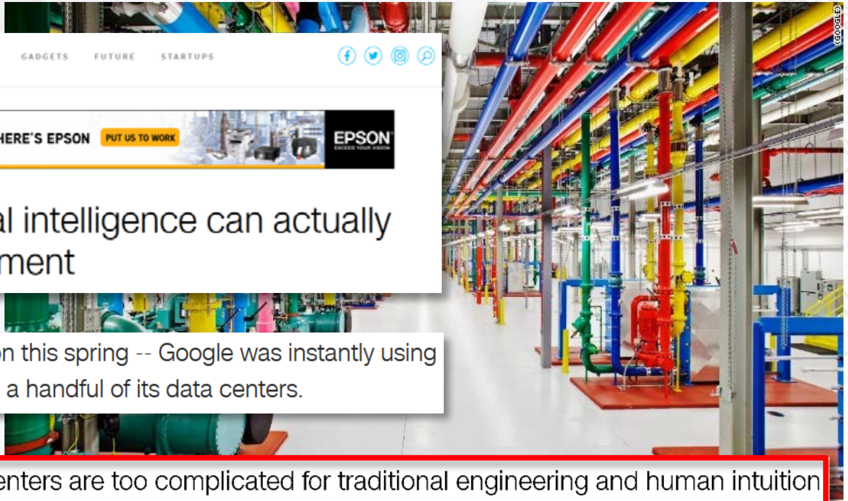
Introduction

Introduction: Phase Change in Design/Analysis Methods

Heuristic-based (& Linear) to performance-based (& at times nonlinear) design and analysis methods



Introduction: Phase Change in Design/Analysis Methods



CNN tech BUSINESS CULTURE GADGETS FUTURE STARTUPS

Innovate

Google's artificial intelligence can actually help the environment

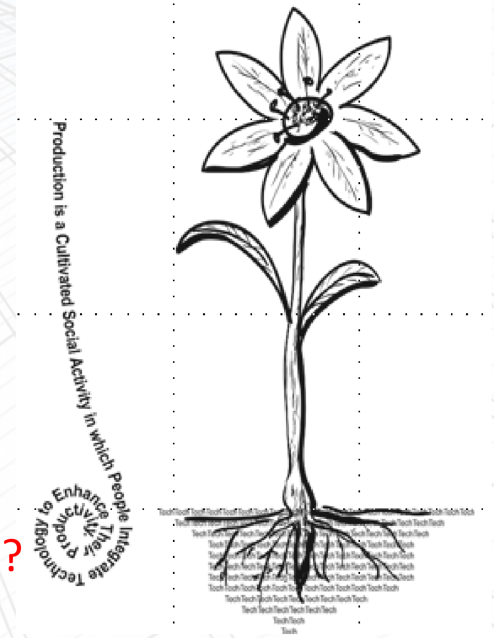
With the push of a button this spring -- Google was instantly using 40% less energy to cool a handful of its data centers.

Google said its data centers are too complicated for traditional engineering and human intuition to be able to manage as efficiently as DeepMind's algorithms.

How do we design, build, and operate facilities we can't understand?

But for now, Google isn't turning its data centers totally over to machines. Human workers in the data centers are given the DeepMind recommendations, and they sometimes reject them. This was most prevalent when the project began, as the artificial intelligence was still learning.

McFarland, M. (2016). "Google's Artificial Intelligence can Actually Help the Environment." CNN Tech News. Retrieved from: http://money.cnn.com/2016/07/20/technology/google-deepmind-data-center/index.html



Manganelli, J., Brooks, J.O. (2015). "Comparing Two Model-Based, Human-Centered Complex, Interactive Systems Modeling Methods: Lessons Learned." Presentation at the Institute for Industrial Engineers Annual Conference, May 30th, 2015, Nashville, TN. Retrieved from: https://www.xcdsystem.com/iie2015/proceedings/index.cfm?pgid=34&search=1&qtype=Session&sid=10926&submit=Go

Introduction: Phase Change in Design/Analysis Methods

Further support for the notion that smart city concepts are relevant for AECOO practitioners

ISO 37106:2018

Preview

Sustainable cities and communities -- Guidance on establishing smart city operating models for sustainable communities

This document gives guidance for leaders in smart cities and communities (from the public, private and voluntary sectors) on how to develop an open, collaborative, citizen-centric and digitally-enabled operating model for their city that puts its vision for a sustainable future into operation.

https://www.iso.org/standard/62065.html

Year of publication: 2017 | Edition: 1

Building a smart city is highly complex. Learn about how ISO standards help to make cities smarter.

Download

https://www.iso.org/publication/PUB100423.html

Introduction: Phase Change in Design/Analysis Methods

Further support for the notion that smart city concepts are relevant for AECOO practitioners

IES-City Framework   Release v1.0   September 30, 2018

A Consensus Framework for Smart City Architectures

IES-City Framework

(Internet-of-Things-Enabled Smart City Framework)   Release v1.0 20180930

This IES-City Framework is the product of an open, international public working group seeking to reduce the high cost of application integration through technical analyses of existing smart city applications and architectures. This Framework documents the findings of the authors and provides valuable tools that are based on the findings and that can lower barriers to an expanded smart city marketplace.

https://pages.nist.gov/smartcitiesarchitecture/

Aspect/Concern	
Functional	Con
physical actuation	Con
communication	Con
Syntactic Interoperability	Con
OSI-Application	Con
OSI-Presentation	Con

Thanks

Thanks

- Fluor Life Sciences & Advanced Manufacturing (LS &AM) architecture department staff for feedback on early draft:
  - Mike Brinsko
  - Jim Hambright
  - Ken Hamby
  - Jara Jones
  - Jeff Schiffer
- National Institute of Building Sciences

Motivation

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Motivation: Market Need

GRAND VIEW RESEARCH

Reports ▾ Services ▾ About Us ▾ Insights ▾ Compass

Home » Press Room » Smart Cities Market Size Worth $2.57 Trillion By 2025 | CAGR: 18.4%

Smart Cities Market Size Worth $2.57 Trillion By 2025 | CAGR: 18.4%

February 2018 | Report Format: Electronic (PDF)

The global smart cities market size is anticipated to reach USD 2.57 trillion by 2025, View Research, Inc., registering a strong CAGR of 18.4% during the forecast period. solutions is anticipated to be driven by factors such as growing urban population, ne resources, and increasing focus on environmental sustainability.

https://www.grandviewresearch.com/press-release/global-smart-cities-market

GRAND VIEW RESEARCH

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Home » Press Room » Smart Transportation Market Size Worth $285.12 Billion by 2024

Smart Transportation Market Size Worth $285.12 Billion by 2024

April 2018 | Report Format: Electronic (PDF)

The global smart transportation market size is estimated to reach USD 285.12 billion by 2024, according to a new study by Grand View Research, Inc., registering a CAGR of 22.5% during the forecast period. Rising number of on-road vehicles and ineffective existing transport infrastructure are expected to propel the need for efficient management systems. Favorable government initiatives for building better infrastructure and smooth running of existing transport systems are expected to boost industry growth.

https://www.grandviewresearch.com/press-release/global-smart-transportation-market

Motivation: Same as It Ever Was[1]

"Where is the Life we have lost in living?
Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information?"

**Where is the information lost in data? (*added, not part of poem)*

- T.S. Eliot, Choruses from the Rock

http://www.westminster.edu/staff/brennie/wisdoms/eliot1.htm

"Scientists & designers must be brought in as advisers, to decide why we build & what to build. This is a much more difficult & controversial question than how to build." [2, p. 3].

- Sir Ove Arup, Engineer

M. Prins, "Architectural value," in Architectural Management: International Research and Practice, S. Emmitt, M. Prins and A. den Otter, Eds., Oxford, Wiley-Blackwell, 2009, pp. 3-16.

"Essentially, all models are wrong, but some are useful."

- George Box, Statistician

Box, G. E. P. (1979), "Robustness in the strategy of scientific model building", in Launer, R. L.; Wilkinson, G. N., Robustness in Statistics, Academic Press, pp. 201–236.

[1] Byrne, D., Eno, B., Frantz, C., Harrison, J., Weymouth, T. (1980). Once in a lifetime [Recorded by Talking Heads]. On Remain in the Light [LP]. Bahamas; New York City, New York; Los Angeles, CA: Sire Records.

Motivation: Same as It Ever Was[1]

1. Keep It Simple Stupid (KISS Principle)
2. Bound complexity
3. "Things should be as simple as possible, but no simpler." (Einstein Principle)
4. Minimize Degrees of Freedom of systems
5. Tend to low-energy / low-information states.
6. Occam's Razor (the answer with least/simplest assumptions is usually correct)
7. "All models are wrong, but some are useful." (George Box)
   Box, G. E. P. (1979), "Robustness in the strategy of scientific model building", in Launer, R. L.; Wilkinson, G. N., Robustness in Statistics, Academic Press, pp. 201–236.
8. Our technological systems are inextricable from our social systems.

[1] Byrne, D., Eno, B., Frantz, C., Harrison, J., Weymouth, T. (1980). Once in a lifetime [Recorded by Talking Heads]. On Remain in the Light [LP]. Bahamas; New York City, New York; Los Angeles, CA: Sire Records.

Challenge/Need & Smart Cities

Challenge/Need: Smart Cities
(Connect & Optimize Performance of Larger System of Systems)

Present Needs & Challenges

- Reduce risk
- Manage risk
- Manage change
- Reduce cost

Future Needs & Challenges

- Scale, Complexity, Integrated-ness
- Real-time data sensing/processing
- Trust/verification of data
- Decentralization of data storage, processing, & ownership

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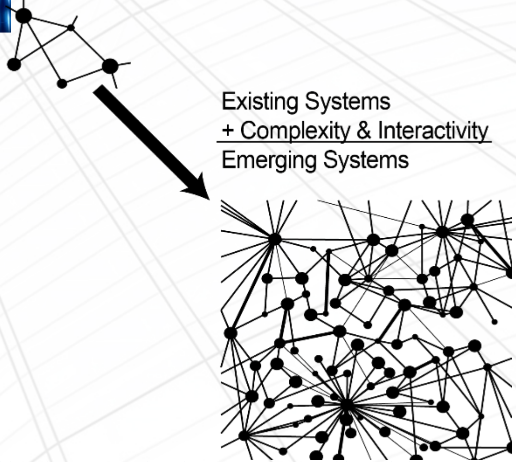

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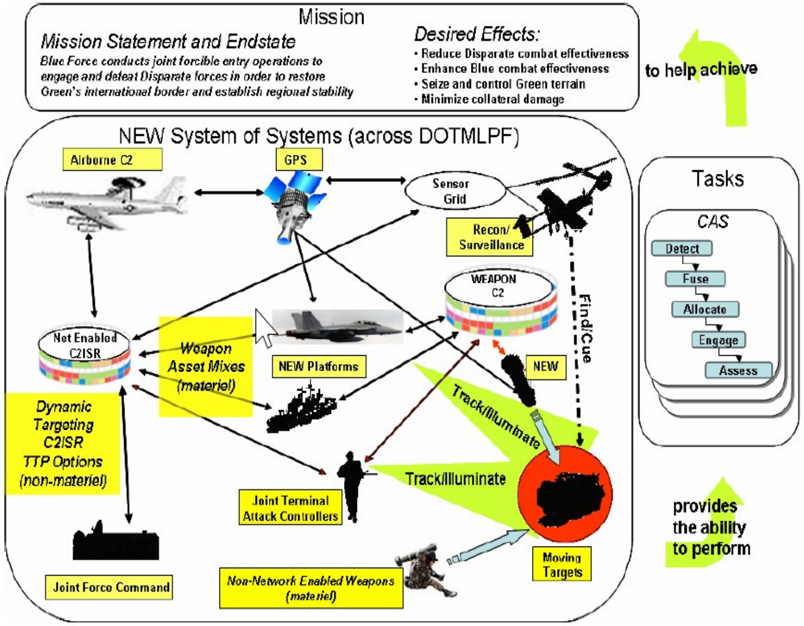


Precedence: Military: Theaters of War

Manganelli, J. (2018). "BIM+Blockchain in the Smart City: Concepts, Early Work, and Potential Usefulness, National Institute of Building Sciences Annual Conference, Washington, D.C., January 8-11, 2018

https://commons.wikimedia.org/wiki/File:Joint_Network_Enabled_Weapon_(NEW)_Capability_Operational_Concept_Graphic_(OV-1).jpg

Introduction
Thanks
Motivation
Challenge/ Need & smart cities
Paradigm shifts
Socio-technical systems
Systems modeling
Agent-based modeling
Equation-based modeling
Requirements development
Optimization
Summary

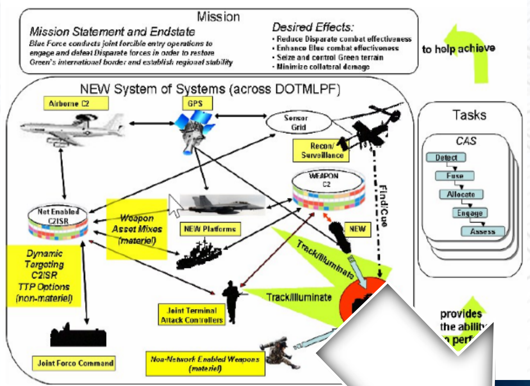
Challenge/Need: Smart Cities
(Connect & Optimize Performance of Larger System of Systems)

1. human / software / hardware / organization systems of systems so complex that they require, "…billions of lines of code…"

   Northrop, L., Feiler, P., Gabriel, R., Goodenough, J., Linger, R., Longstaff, T., . . . Wallnau, K. (2006). Ultra-large-scale systems: The software challenge of the future. Software Engineering Institute. Pittsburgh, PA: Software Engineering Institute. Retrieved from https://resources.sei.cmu.edu/asset_files/Book/2006_014_001_30542.pdf

2. aerospace and defense industries have been dealing with this issue directly for almost two decades

3. similar complexity is now manifesting in evolving smart city infrastructure



https://commons.wikimedia.org/wiki/File:Joint_Network_Enabled_Weapon_(NEW)_Capability_Operational_Concept_Graphic_(OV-1).jpg

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Challenge/Need: Smart Cities
(Connect & Optimize Performance of Larger System of Systems)

Present Needs & Challenges

- Reduce risk
- Manage risk
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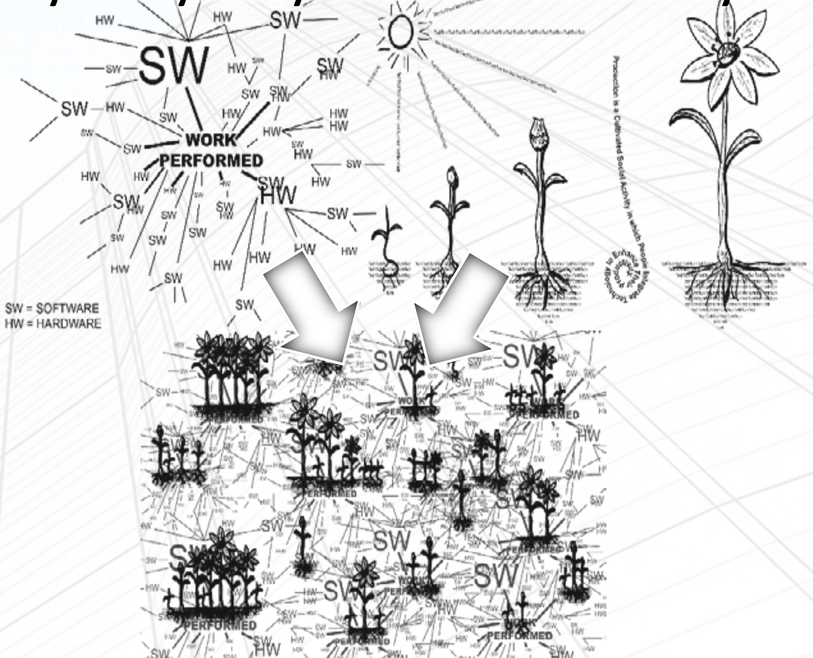
Cyber-Physical Systems **Socio-Technical Systems**



Ultra-Large-Scale Systems

Manganelli, J. (2018). "BIM+Blockchain in the Smart City: Concepts, Early Work, and Potential Usefulness, National Institute of Building Sciences Annual Conference, Washington, D.C., January 8-11, 2018

Manganelli, J., Brooks, J.O. (2015). "Comparing Two Model-Based, Human-Centered Complex, Interactive Systems Modeling Methods: Lessons Learned." Presentation at the Institute for Industrial Engineers Annual Conference, May 30th, 2015, Nashville, TN. Retrieved from: https://www.xcdsystem.com/iie2015/proceedings/index.cfm?pgid=34&search=1&qtype=Session&sid=10926&submit=Go

Challenge/Need: Smart Cities
(Connect & Optimize Performance of Larger System of Systems)

1. Cyber-physical systems (CPS)
   - Globally virtual and locally physical
   - "…engineered systems…depend upon the synergy of computational and physical components…"

F. Xie, "Component-based cyber-physical systems," in *NSF Workshop on Cyber-Physical Systmes*, Austin, TX, 2006.

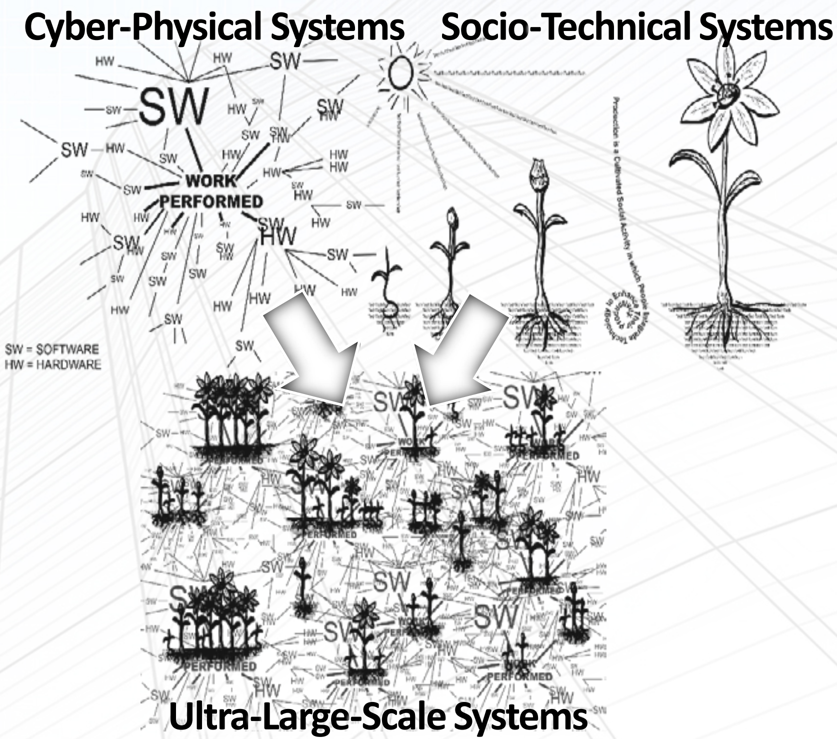
National Science Foundation, "Cyber-physical systems," National Science Foundation, [Online]. Available: https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503286. [Accessed 25 10 2013]

2. Socio-technical systems (STS)
   - Social dynamics key to successful operation
   - Finalize systems development in use
   - Cultivate systems like living things

G. Fischer and T. Hermann, "Socio-technical systems: A meta-design perspective," *International Journal for Socio-technology and Knowledge Development*, vol. 3, no. 1, pp. 1-33, 2011.

3. Ultra-large-scale systems (ULS)
   - Integration of CPS & STS…..and much more
   - "…interdependent webs of software-intensive systems, people, policies, cultures, & economics…"

Northrop, L., Feiler, P., Gabriel, R., Goodenough, J., Linger, R., Longstaff, T., . . . Wallnau, K. (2006). Ultra-large-scale systems: The software challenge of the future. Software Engineering Institute. Pittsburgh, PA: Software Engineering Institute. Retrieved from https://resources.sei.cmu.edu/asset_files/Book/2006_014_001_30542.pdf



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Challenge/Need: Smart Cities
(Connect & Optimize Performance of Larger System of Systems)

These emerging project types entail many design challenges, that may be broadly distilled into three complex systems characteristics for **complex, interactive, architectural systems**:

1. A component of a larger complex/interactive systems of systems while being composed of systems of systems;
2. Real-time hardware/software interactions amongst and between internal and external systems to function successfully; and
3. Real-time human-machine-software interactions are essential to meeting user goals and expectations.

J. Manganelli. *Designing complex, interactive, architectural systems with CIAS-DM: A model-based, human-centered, design & analysis methodology.* Retrieved on April 9, 2015 from: https://tigerprints.clemson.edu/cgi/viewcontent.cgi?article=2250&context=all_dissertations

Challenge/Need: Smart Cities
(Connect & Optimize Performance of Larger System of Systems)

Given the tight integration of human and organizational performance with the functioning of technical systems, it is necessary to adapt the way we model environmental systems to account for ---

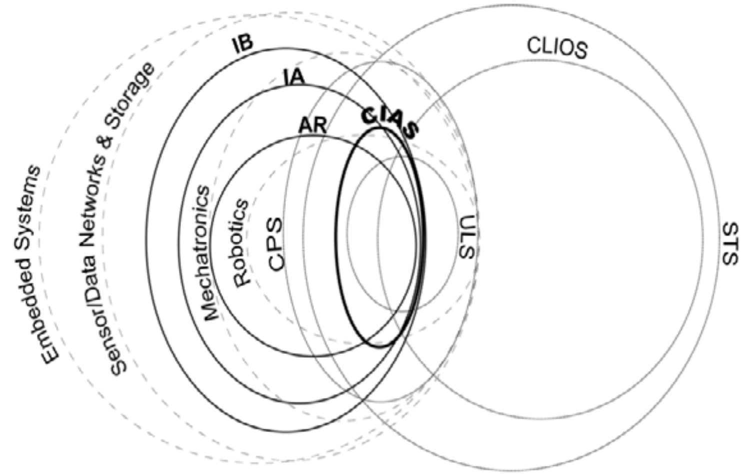
human-organization-software-hardware integrations and symbiosis.

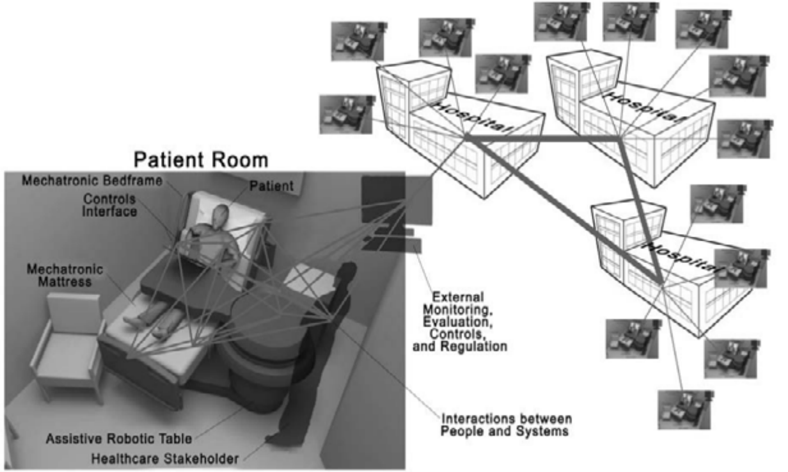
Paradigm Shifts

Paradigm Shifts: Origins

Origins of constructs, measures, methods, and tools presented here

(2003-present – systems science, cognitive science, computer science, neuroscience, evolutionary biology, systems engineering, human factors, architecture)





Literature Review

Case Studies

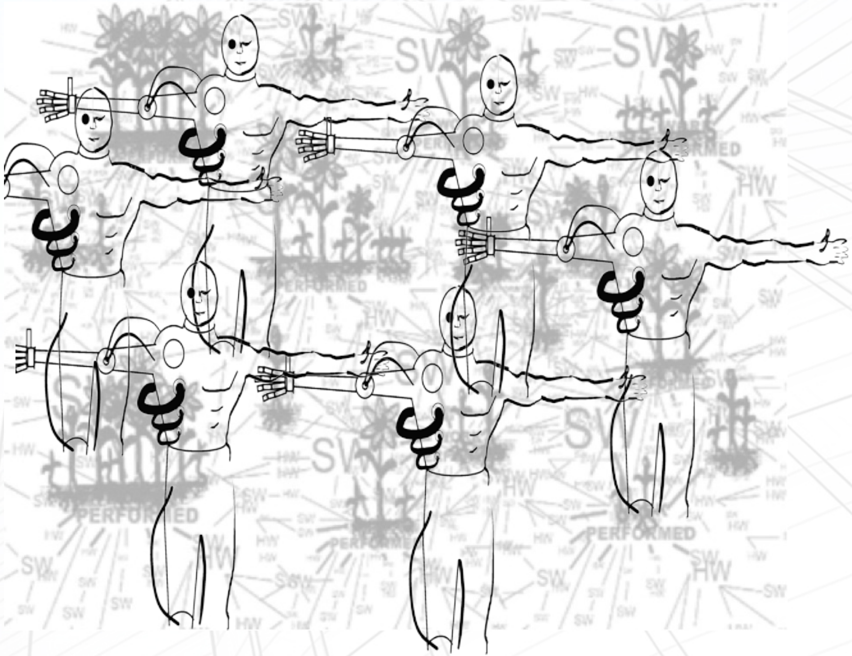
J. Manganelli. *Designing complex, interactive, architectural systems with CIAS-DM: A model-based, human-centered, design & analysis methodology.* Retrieved on April 9, 2015 from: https://tigerprints.clemson.edu/cgi/viewcontent.cgi?article=2250&context=all_dissertations

J. Manganelli, J. (2015, 10 04). Tending the Artifact Ecology: Cultivating Architectural Ecosystems. Retrieved from data:structure:form:design: http://datastructureformdesign.com/2015/10/04/tending-the-artifact-ecology-cultivating-architectural-ecosystems/

Paradigm Shifts: Human-Organization-Systems Integration

Big-Picture Concepts

Performance-oriented system of systems optimization through continuous modeling and simulation requires firstly that we place humans, organizations, software, and hardware in a shared representational framework



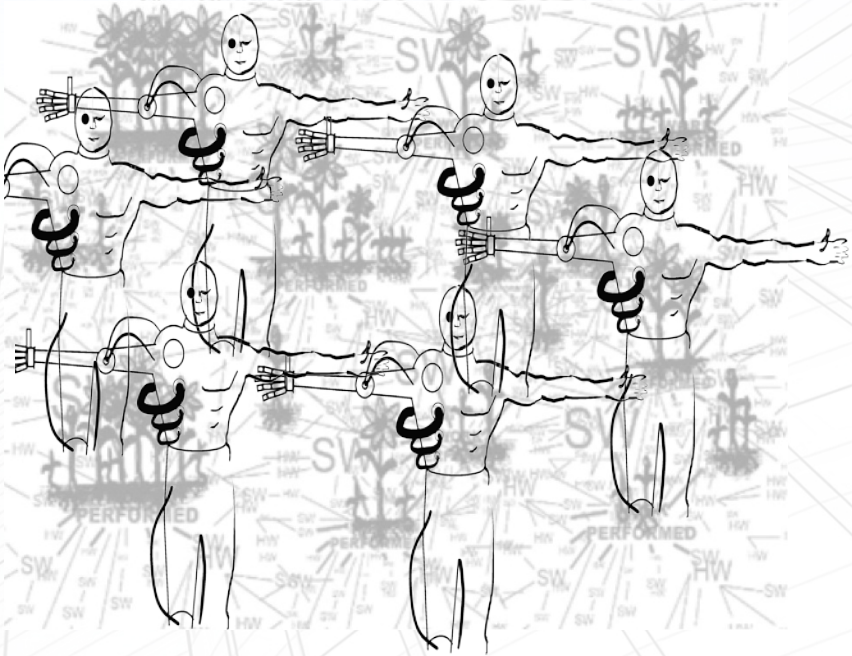
Paradigm Shifts: Human-Organization-Systems Integration

Big-Picture Concepts

1. logical physical and non-physical constructs apply equally to biological systems as to non-biological systems

2. human-machine is not a dichotomy, it is a continuum

3. human-organization is not a dichotomy, it is a continuum

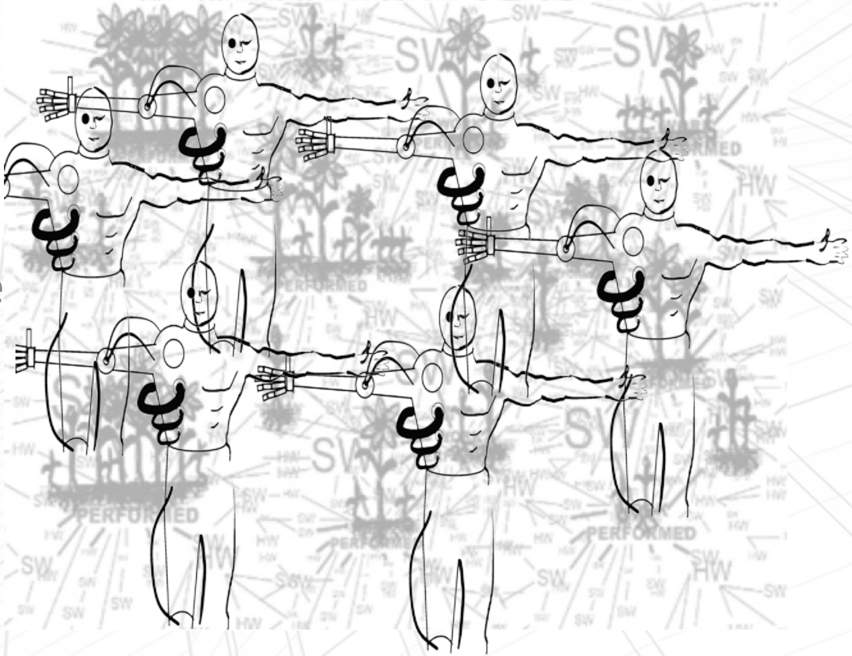


Paradigm Shifts: Human-Organization-Systems Integration

Big-Picture Concepts

With all systems of systems, two of the most critical and difficult tasks for successful analysis, design, and management are to:

1. determine where to draw the boundaries for systems and sub-systems
2. Determine which systems of systems to integrate versus which to modularize



Paradigm Shifts: Themes

1. Human-Focused
2. Organization-Focused
3. Systems-Focused

Paradigm Shifts: Sub-Themes

1. Construct:
   1. Operationalizable concept
   2. Can be used to identify, categorize, or measure
2. Measure:
   1. Detectable and identifiable physical or behavioral characteristic of a phenomenon
   2. Triangulation of measures is a way to validate data by sampling many of any one type of measure of a phenomenon
3. Method:
   1. Systematic, procedural means of inquiry, analysis, or synthesis
   2. Triangulation of methods is a way to validate data by using multiple methods with multipe types of measures of a phenomenon
4. Tool:
   1. Logical physical or non-physical device used to execute a method of inquiry, analysis, or synthesis

Introduction

Thanks

Motivation

Challenge/Need & smart cities

Paradigm shifts

Socio-technical systems

Systems modeling

Agent-based modeling

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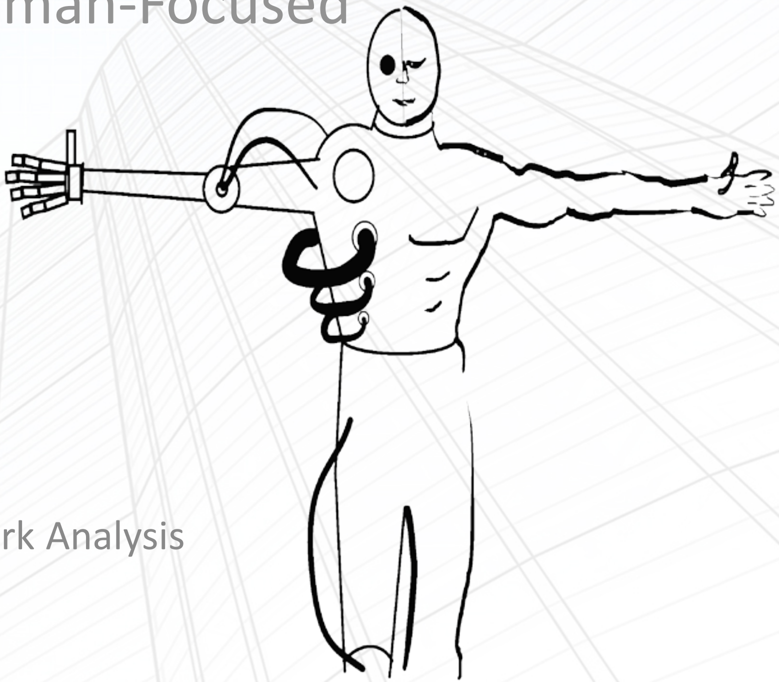
Paradigm Shifts: Human-Organization-Systems Integration

Concepts and Constructs: Human-Focused



Some useful search terms:

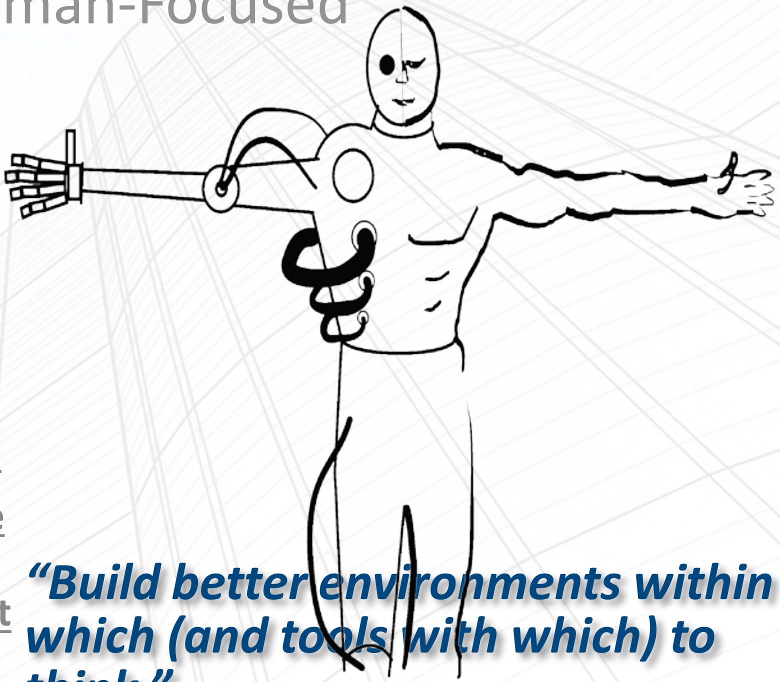
1. Cognitive scaffolding
2. Affordances
3. Embodied cognition
4. Embedded cognition
5. Augmented cognition
6. Extended mind
7. Direct & Indirect Perception
8. Neuroergonomics
9. Ecological Niche Construction
10. Work Domain Analysis & Cognitive Work Analysis
11. Abstract Decomposition Space
12. Skills, Rules, Knowledge Assessment
13. Hierarchical Task Analysis
14. Epistemic versus Pragmatic Knowledge

Paradigm Shifts: Human-Organization-Systems Integration

Concepts and Constructs: Human-Focused

Extended mind & cognitive scaffolding:

"In all this we discern two distinct, but deeply interanimated, ways in which biological cognition leans on cultural and environmental structures. One way involves a developmental loop, in which exposure to external symbols adds something to the brain's own inner toolkit. The other involves a persisting loop, in which ongoing neural activity becomes geared to the presence of specific external tools and media**…..the true power and beauty of the brain's role was that it acted as a mediating factor in a wide variety of complex and iterated processes, which continually looped between brain, body and technological environment, and it is this larger system that solved the problem**."



"Build better environments within which (and tools with which) to think."

Clark, A. (2003). Natural-Born Cyborgs: Minds, Technologies, and the Future of Human Intelligence. New York, New York: Oxford University Press.

Paradigm Shifts: Human-Organization-Systems Integration

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Concepts and Constructs: Human-Focused

Cognitive Work Analysis

1. Method for analyzing human use of complex software and hardware systems
2. Five components:
    1. Abstract Decomposition Space
    2. Decision Ladder
    3. Information Flow Maps
    4. Socio-Organizational Structures
    5. Skills, Rules, & Knowledge Models

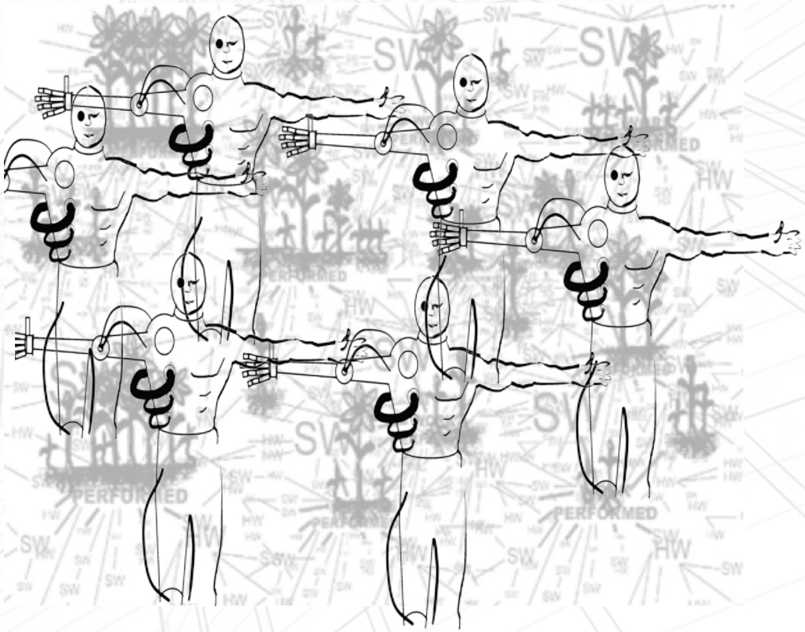
J. Manganelli. *Designing complex, interactive, architectural systems with CIAS-DM: A model-based, human-centered, design & analysis methodology.* Retrieved on April 9, 2015 from: https://tigerprints.clemson.edu/cgi/viewcontent.cgi?article=2250&context=all_dissertations
C. Miller and K. J. Vicente, "Comparison of display requirements generated via hierarchical task and abstraction-decomposition space analysis techniques," International Journal of Cognitive Ergonomics, vol. 5, no. 3, pp. 335-355, 2001.
N. Naikar, A. Moylan and B. Pearce, "Analysing activity in complex systems with cognitive work analysis: Concepts, guidelines and case study for control task analysis," Theoretical Issues in Ergonomics Science, vol. 7, no. 4, pp. 371-394, 2006.
W. Preiser and E. Ostroff, Universal Design Handbook, W. Preiser and E. Ostroff, Eds., New York, NY: McGraw-Hill, 2001.

Paradigm Shifts: Human-Organization-Systems Integration

Concepts and Constructs: Organization-Focused

Some useful search terms:

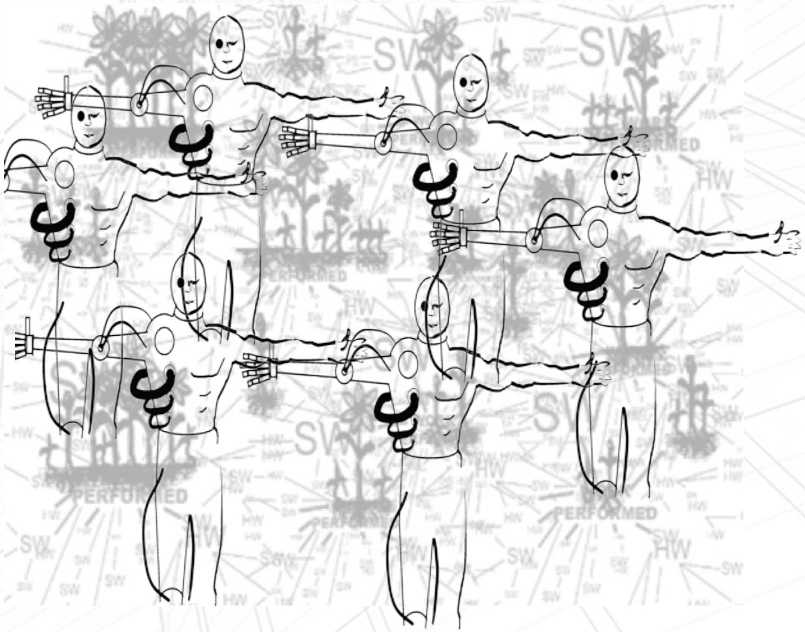
1. T-shaped professional/SME
2. Crew resource management
3. Human-machine teaming
4. Industrial & organizational psychology
5. Human-systems integration
6. Neuroergonomics
7. Ecological Niche Construction
8. Business Process Modeling
9. Socio-technical systems
10. Psychofortology
11. Expert performance
12. Learning organization
13. Agent-based modeling
14. Delphi-Method, Kano Method, MoSCoW Method



Paradigm Shifts: Human-Organization-Systems Integration

Concepts and Constructs: Organization-Focused

Cultivating socio-technical systems requires fundamental shifts in thinking, work processes, and management because the limits of the usefulness of rational thought and engineering methods are encountered. Given this, the boundary between CapEx and OpEx is less useful. Socio-technical systems are in states of continuous evolution.

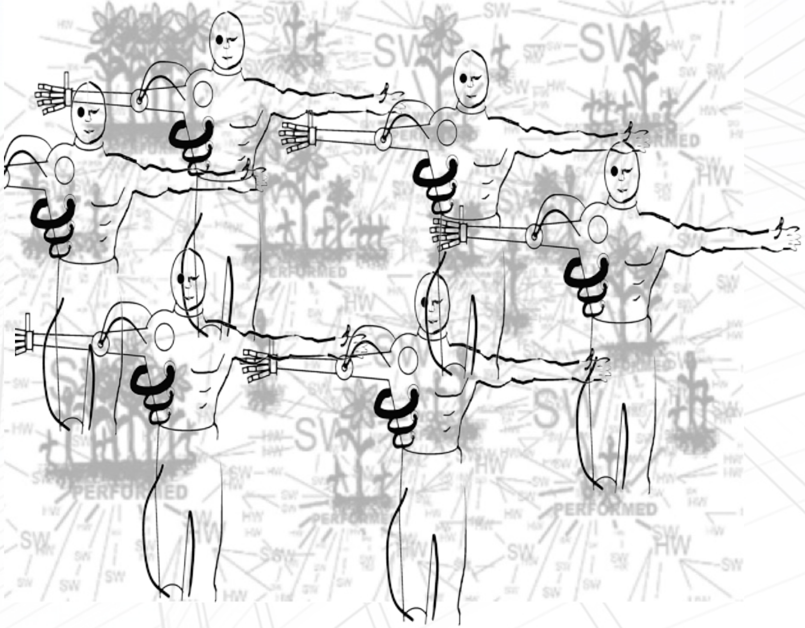


Paradigm Shifts: Human-Organization-Systems Integration

Concepts and Constructs: Organization-Focused

Agent-based modeling is useful when:

1. system state and performance vary over time
2. systems are complex and not deterministically analyzable
3. Agent performance entails rule-based actions



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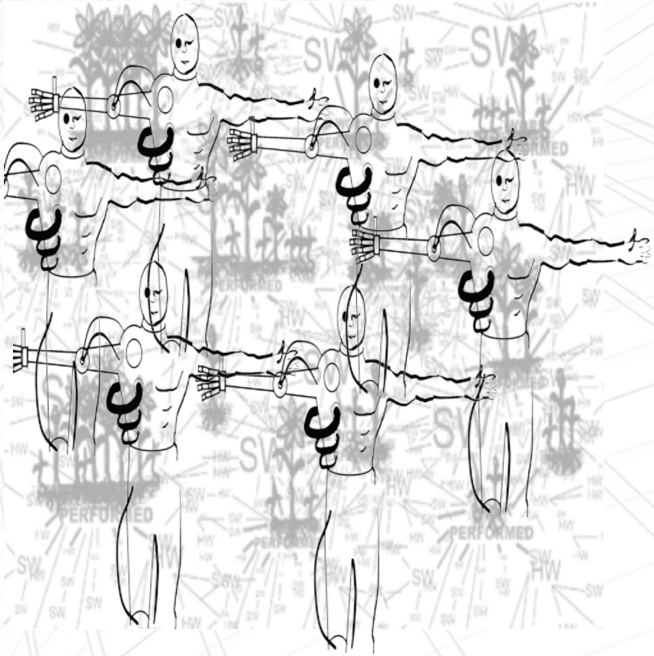
Paradigm Shifts: Human-Organization-Systems Integration

Concepts and Constructs: System-Focused

Some useful search terms:

1. Complex systems
2. Chaotic systems
3. Dynamical systems
4. Positive & negative feedback
5. Complexity analysis & risk management
6. Emergent architectures & behaviors
7. Architecture vs behavior
8. Deterministic vs stochastic modeling/simulation
9. Agent-based modeling
10. Information content/gain/entropy
11. Network structures
12. Graph theory
13. Data streams/rivers, lakes, & oceans
14. Multi-objective optimization



Paradigm Shifts: Human-Organization-Systems Integration

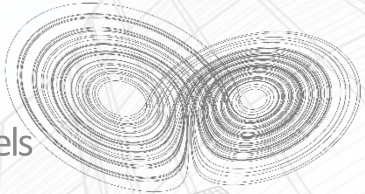
Concepts and Constructs: Systems-Focused

- What is the difference between a complex versus a chaotic system?
  - Complex system: Many components and/or complicated rules/relationships producing simple, orderly behavior. (e.g., a factory)
  - Chaotic system: Few components and/or simple rules/relationships producing highly variable, disorderly and/or complex behavior. (e.g., a problem)

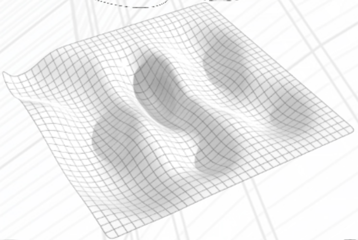
Paradigm Shifts: Human-Organization-Systems Integration

Concepts and Constructs: Systems-Focused

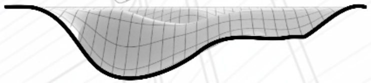
- any phenomena that entail chaotic behavior are difficult or impossible to model deterministically, and must be approximated with stochastic models
- complexity can entail emergent interactions that drive **emergent system behavior** and are also difficult or impossible to deterministically model, and must be stochastically modeled
- complex, chaotic, and dynamical systems can display long periods of stable, deterministic-like behavior as long as manipulations fall well within attractor basin norms, but can enter inflection points or tipping points suddenly and with great impact



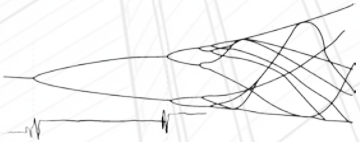
Chaotic attractor



System attractor basin *(linear & nonlinear dynamics)*



System attractor basin



Phase change

Introduction

Thanks

Motivation

Challenge/Need & smart cities

Paradigm shifts

Socio-technical systems

Systems modeling

Agent-based modeling

Equation-based modeling

Requirements development

Optimization

Summary

Paradigm Shifts: Human-Organization-Systems Integration

Concepts and Constructs: Systems-Focused

How can we model/predict the performance of a factory if we cannot predict the performance of a billiard ball?

"If you know a set of basic parameters concerning the ball at rest, can compute the resistance of the table (quite elementary), and can gauge the strength of the impact, then it is rather easy to predict what would happen at the first hit. The second impact becomes more complicated, but possible; and more precision is called for. ***The problem is that to correctly computer the ninth impact, you need to take account of the gravitational pull of someone standing next to the table (modestly, Berry's computations use a weight of less than 150 pounds). And to compute the fifty-sixth impact, every single elementary particle in the universe needs to be present in your assumptions!*** An electron at the edge of the universe, separated from us by 10 billion light-years, must figure in the calculations, since it exerts a meaningful effect on the outcome. (p. 178)

Taleb, N. N. (2010). *The black swan: the impact of the highly improbable.* 2nd ed., Random trade pbk. ed. New York: Random House Trade Paperbacks

Paradigm Shifts: Human-Organization-Systems Integration

Concepts and Constructs: Systems-Focused

1. Information content: measure of how much unique information is required to convey something
2. Closely related in concept but distinct in formalism is the mathematics of symmetry breaking

$$H(x) = -\sum_{i=0}^{N-1} p_i \log_2 p_i$$

Shannon Entropy

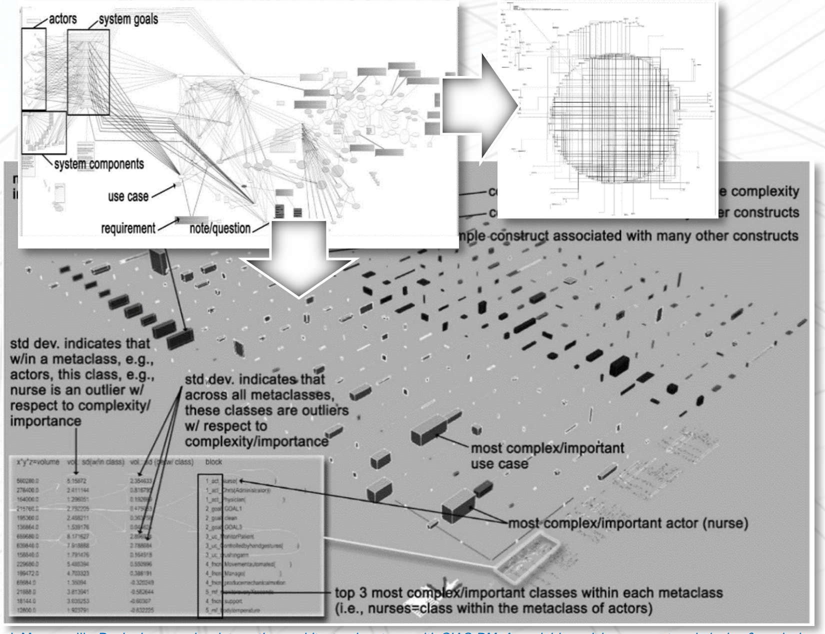
Paradigm Shifts: Human-Organization-Systems Integration

Concepts and Constructs: Systems-Focused

1. Bound complexity/limit degrees of freedom (limit risk)
2. Understand the relationships between agents: Complexity measures (find criticality, find risk)

- Number of nodes
- Number of edges
- Number of connections
- Centrality
- Average edge length
- Maximum edge length
- Number of operators
- Sparsity/density of network
- Coincidence of nodes
- Coincidence of edges
- Directionality of edges
- Node density
- Network type
- Many, many, many others

https://en.wikipedia.org/wiki/Complexity_measure



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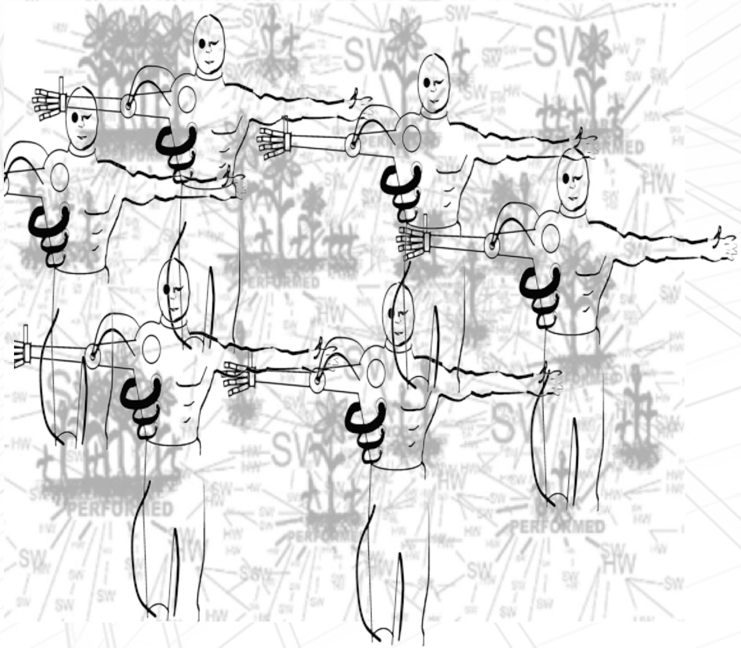
Socio-Technical Systems

Socio-Technical Systems

Concepts and Constructs

1. assumes one or more technical components & social components to how organizations conduct business
2. assumes the technical component is an organizational armature structuring how work is done
3. its use will be adapted in field, integrating the social structure and organizational dynamics
4. the social component cannot be specified and must be incrementally evolved
5. symbiosis between the technical and the social components is the goal



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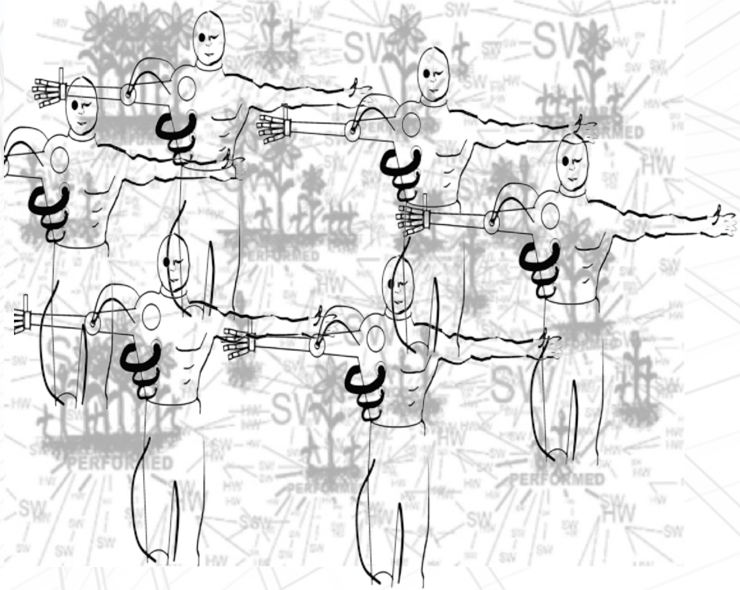
Socio-Technical Systems

Measures, Methods, & Tools

1. developing a culture of participation that includes an established ecology of roles
2. empowering staff and users to tailor procedures and adapt tools and procedures over time
3. **under-designing the work culture** and technological interventions and **cultivating the STS**
4. identifying and establishing infrastructure to be implemented without participatory design
5. semi-structured modeling and walk-through-oriented facilitation



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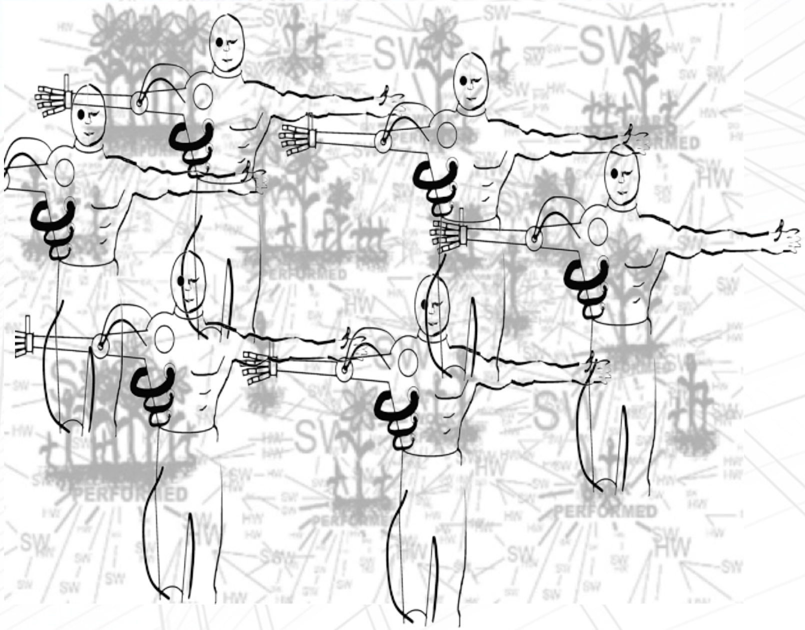
Socio-Technical Systems

BIM & Project Delivery Integration

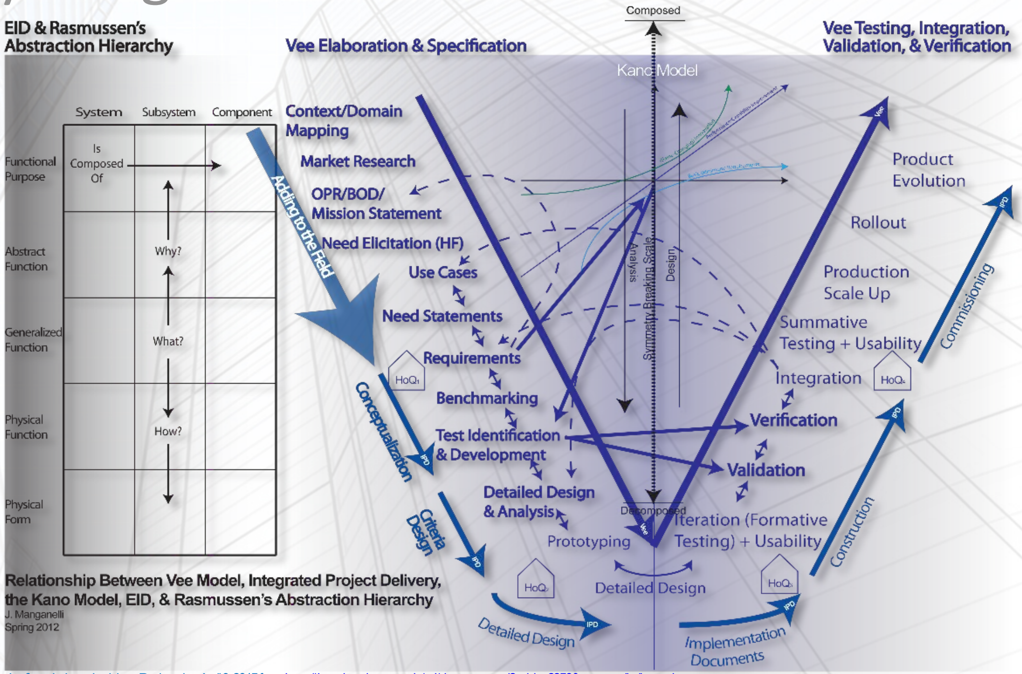
1. Boundary between capex and opex is no longer meaningful
2. business process modeling is useful
3. Ongoing requirements validation is useful (how to we validate that we're designing the right thing)
4. Identifying platform technologies and their constraints early in planning is essential
5. Team cohesion and participation from early conceptual design is essential



Socio-Technical Systems

BIM & Project Delivery Integration

1. AECOO's Integrated Project Delivery aligns well with the V-Model of project delivery, the current best practice for model-based systems engineering, as well as Rasmussen's Abstraction Hierarchy, a best practice from human factors.



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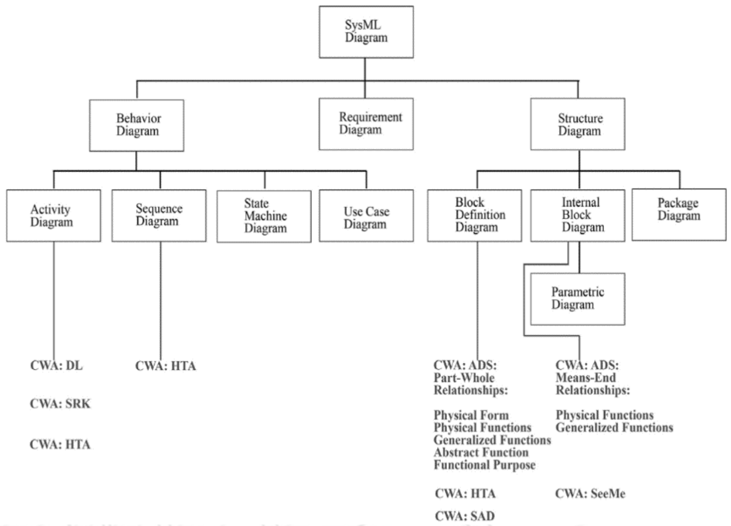
Systems Modeling

Systems Modeling

Concepts and Constructs

1. Object-oriented systems engineering method (OOSEM) is a current best practice
2. OOSEM is a type of model-based systems engineering (MBSE), also current best practice
3. Unified Modeling Language (UML) describes the interactions of logical assets and is widely used in software development
4. Systems Modeling Language (SysML) is a specialized profile of UML that can represent logical non-physical and physical assets and perform parametric simulations



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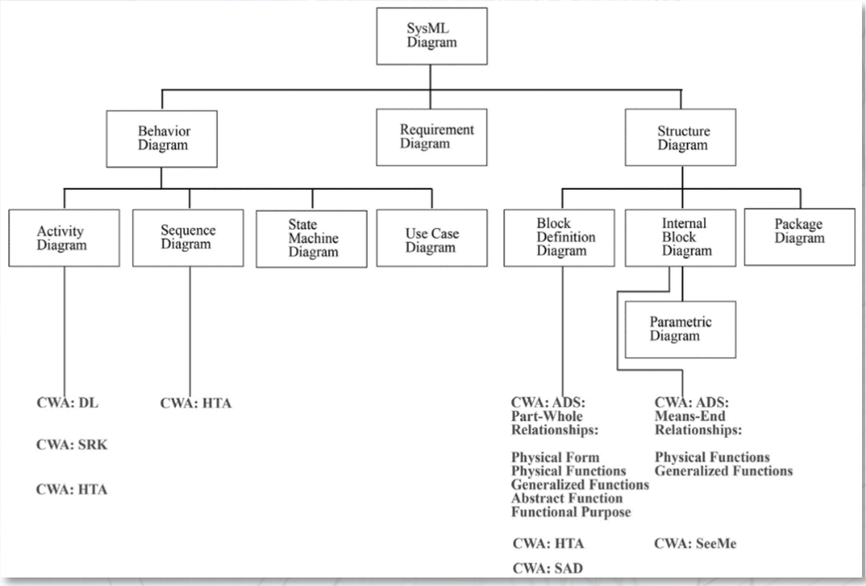
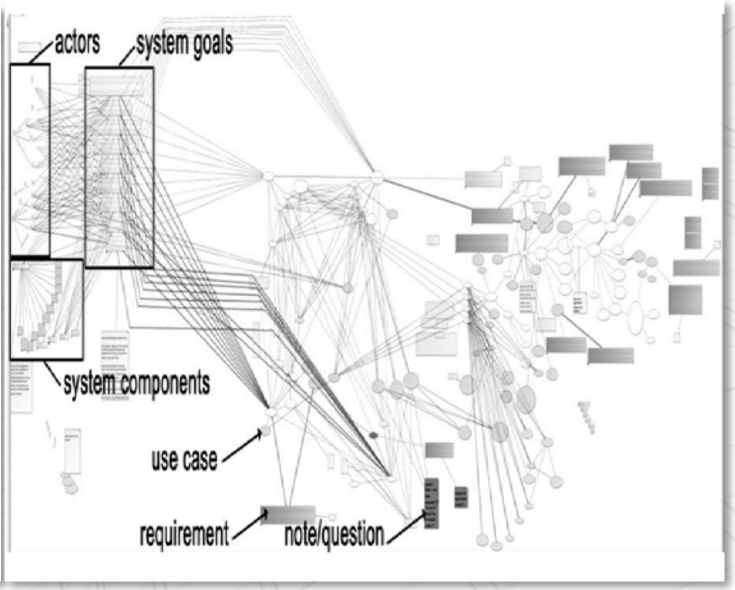
Systems Modeling

Measures, Methods, & Tools





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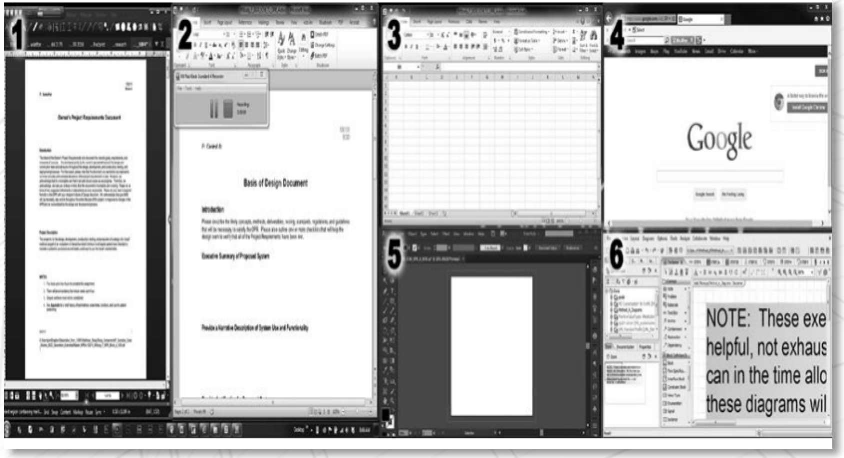
Systems Modeling

BIM & Project Delivery Integration

1. Boundary between capex and opex is no longer meaningful
2. business process modeling is useful
3. Ongoing requirements validation is useful (how to we validate that we're designing the right thing)
4. Integrating with ASHRAE Guideline 0 OPR/BOD works well
5. Team cohesion and participation from early conceptual design is essential



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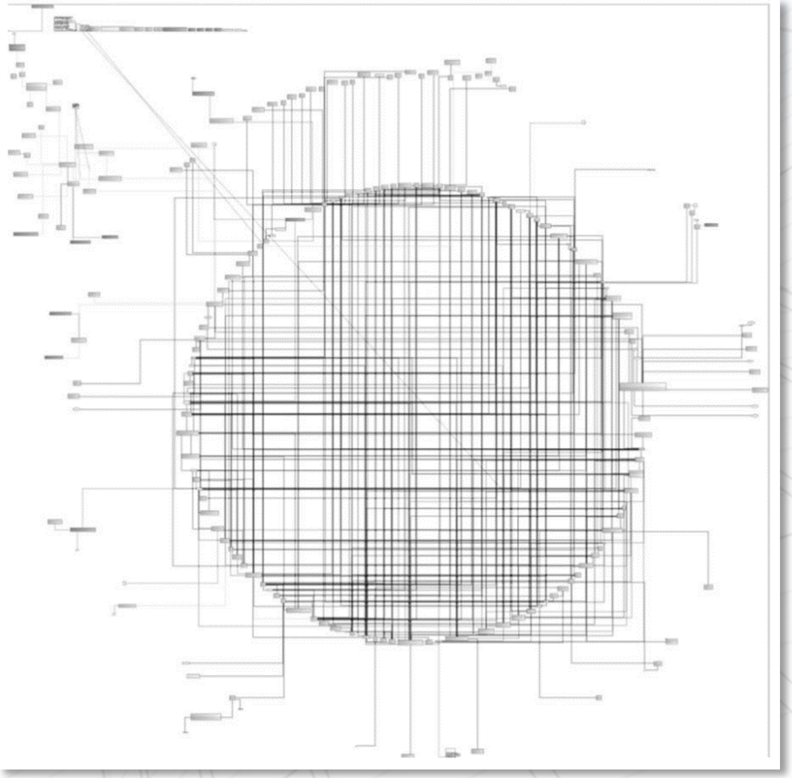
Systems Modeling

BIM & Project Delivery Integration

1. Useful for finding platform technologies
2. Useful for finding risk
3. Useful for prioritizing requirements
4. Useful as a communication facilitation tool with stakeholders
5. Useful at a glance or with rigorous quantitative analytic methods
6. Some CAD/BIM integration



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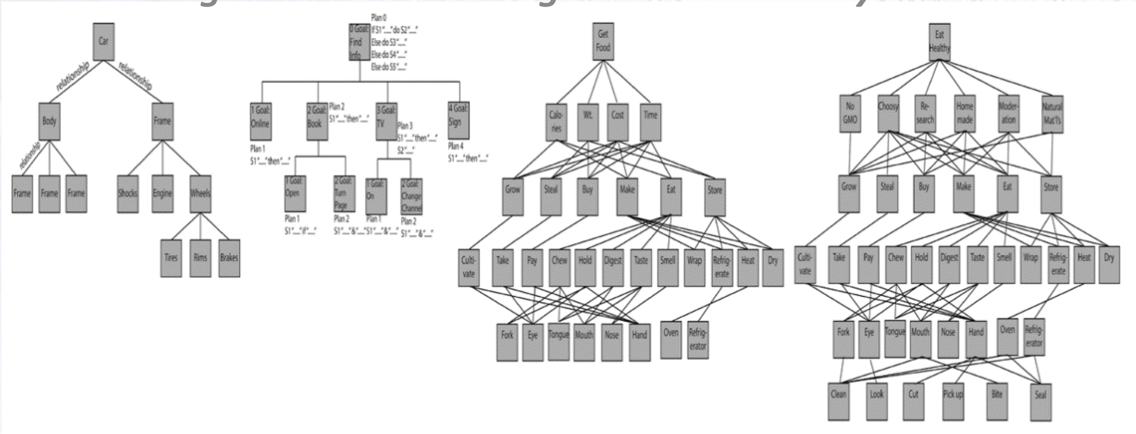
Systems Modeling

BIM & Project Delivery Integration

1. Integrates well with Cognitive Work Analysis

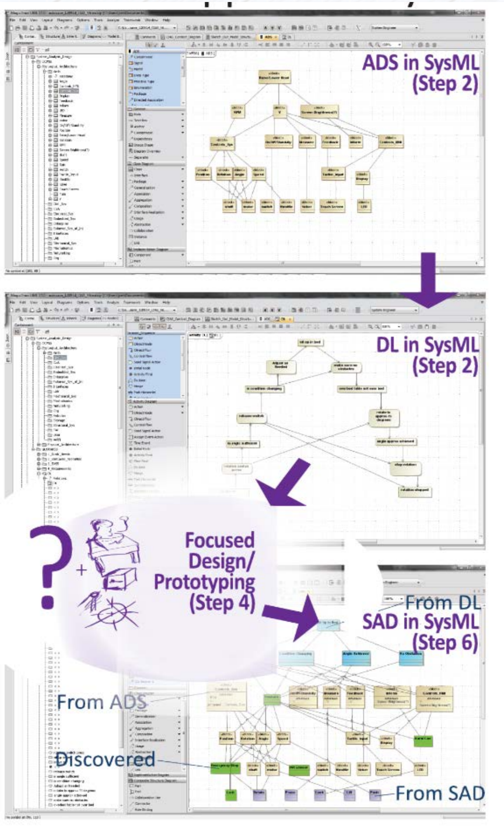


Block Definition Diagram (relationships between things)

Hierarchical Task Analysis (relationships between goals and plans)

Abstract Decomposition Space (ADS) (relationships between goals, flows, functions, features)

Strategies Analysis Diagram (SAD) (relationships between goals, strategies, actions, users, and system)



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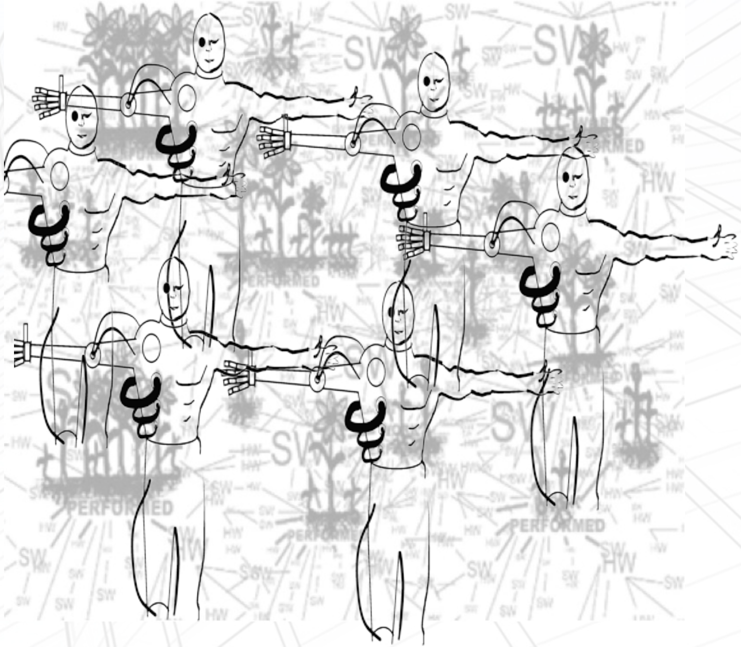
Agent-Based Modeling

Agent-Based Modeling

Concepts and Constructs

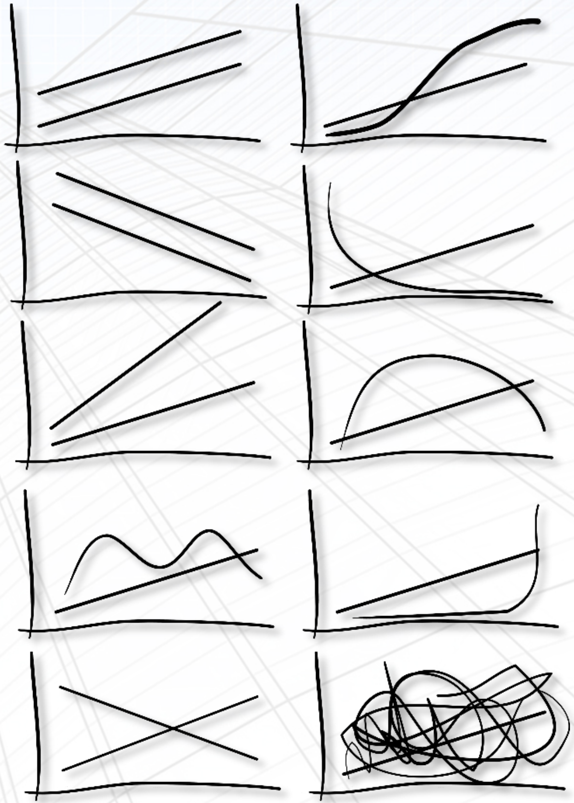
1. Represent ***agents*** (human, organizational, software, hardware, environmental) as ***collections of rule-based behaviors***
2. Useful when outcomes always vary through time
3. Useful when experiments not feasible (too many variables/interactions or too costly or time-consuming)
4. Useful when deterministic model is not possible (too many variables, interaction effects, chaotic/complex behaviors)
5. Appropriate for urban design, building envelopes, building performance, organizational, human, and systems performance



Agent-Based Modeling

Measures, Methods, & Tools

1. Run many iterations so that sample of results has sufficiently high power for statistical analysis
2. Vary input parameters and seek optimization of effects
3. Continuously refine model if/as possible
4. Develop confidence interval or credible interval for results
5. Use descriptive statistics, chi-squared, linear nonlinear regressions, multi-variate analyses, and possibly structural equation modeling and Bayesian analysis to assess results (Is there a significant difference between baseline condition and design model outcomes?)



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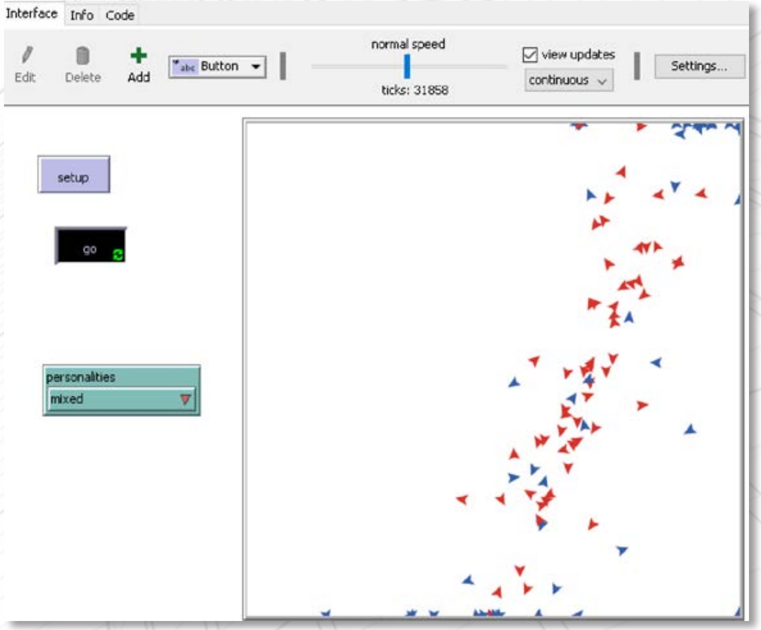
Agent-Based Modeling

BIM & Project Delivery Integration

1. Model early and often and throughout
2. Modeling activity is a useful mechanism for engaging client about its personnel roles, tasks, tools, and organizational dynamics
3. Boundary between capex and opex is no longer meaningful
4. Business process model may provide useful starting point for agent-based models

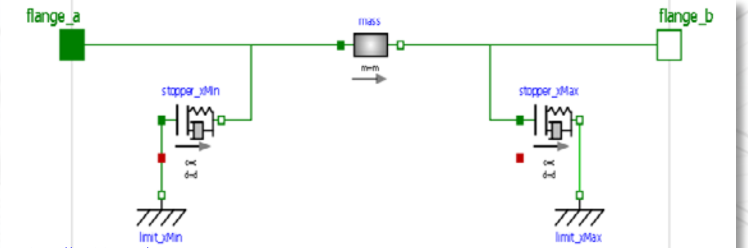


Equation-Based Modeling

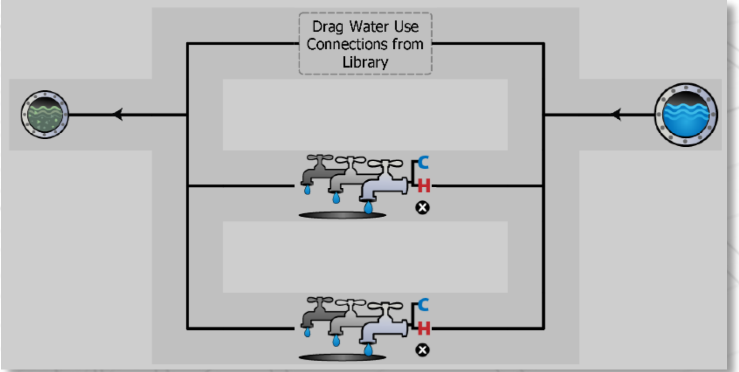
Equation-Based Modeling

Concepts and Constructs

1. Represent physical and organizational functions as mathematical equations
2. Use object-oriented (component/node/block and link/connector/relationship)
3. Simulate logical non-physical and physical information flows



https://modelica.org/



https://www.openstudio.net/

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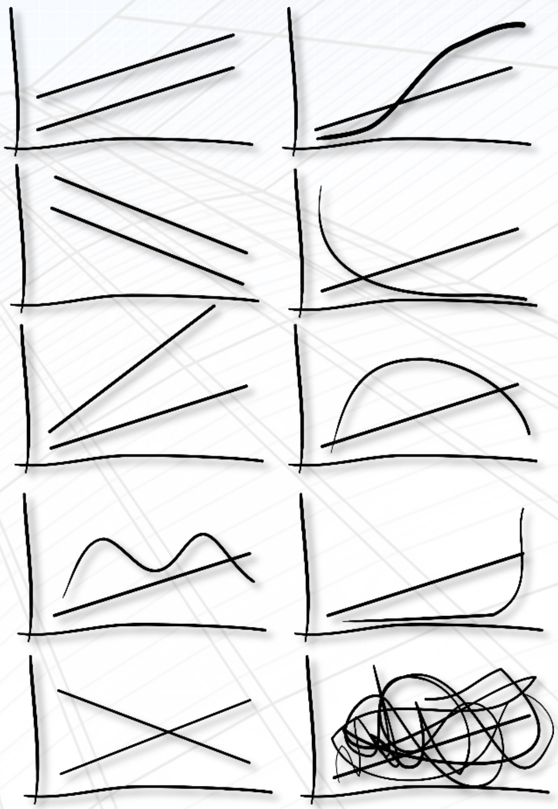
Equation-Based Modeling

Measures, Methods, & Tools

1. Run many iterations so that sample of results has sufficiently high power for statistical analysis
2. Vary input parameters and seek optimization of effects
3. Continuously refine model if/as possible
4. Develop confidence interval or credible interval for results
5. Use descriptive statistics, chi-squared, linear nonlinear regressions, multi-variate analyses, and possibly structural equation modeling and Bayesian analysis to assess results (Is there a significant difference between baseline condition and design model outcomes?)
6. Use tools like evolutionary algorithms to optimize parameters



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Equation-Based Modeling

BIM & Project Delivery Integration

1. Model early and often and throughout
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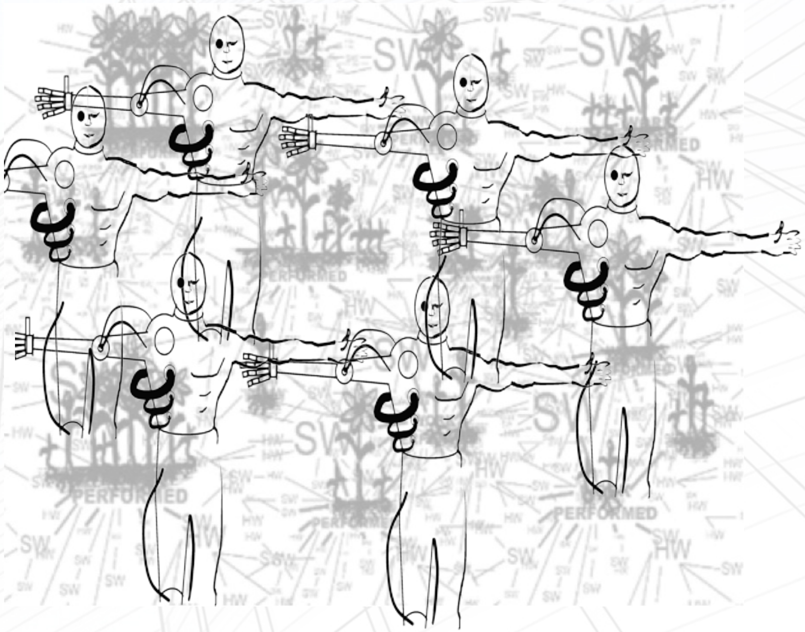
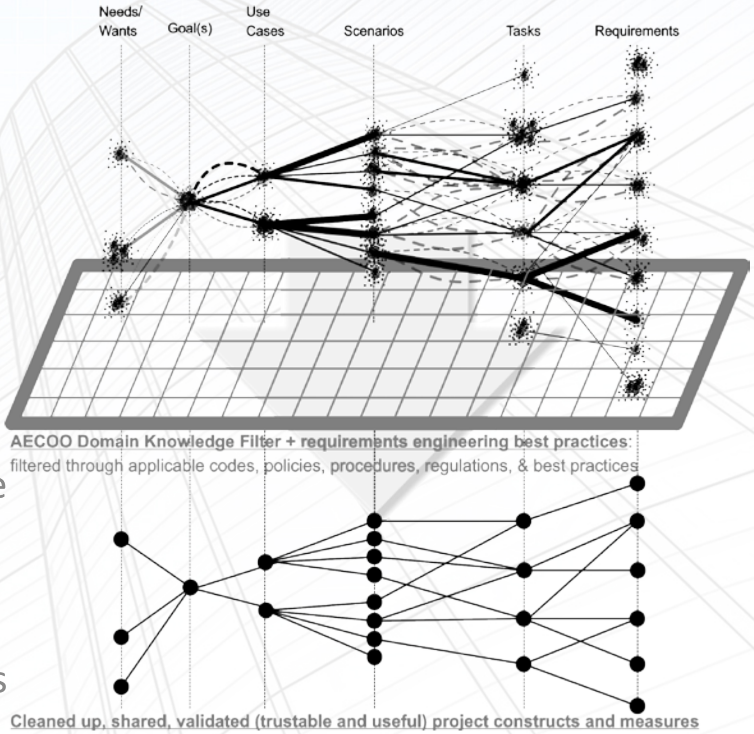


Requirements Development

Requirements Development

Concepts and Constructs

1. Validation (are we building the right thing) vs Verification (are we building the thing the right way)
    1. building systems commissioning is the latter, not the former
    2. ASHRAE Guideline 0 OPR/BOD are AECOO tools to structure and manage Validation process
2. Need to adopt more systematic approaches to requirements elicitation, definition, and validation and be more correct, consistent, and complete)
3. Need to stabilize requirements
4. Need to maintain traceability of requirements if possible
5. Need to link requirements to BIM/BEM/Systems models



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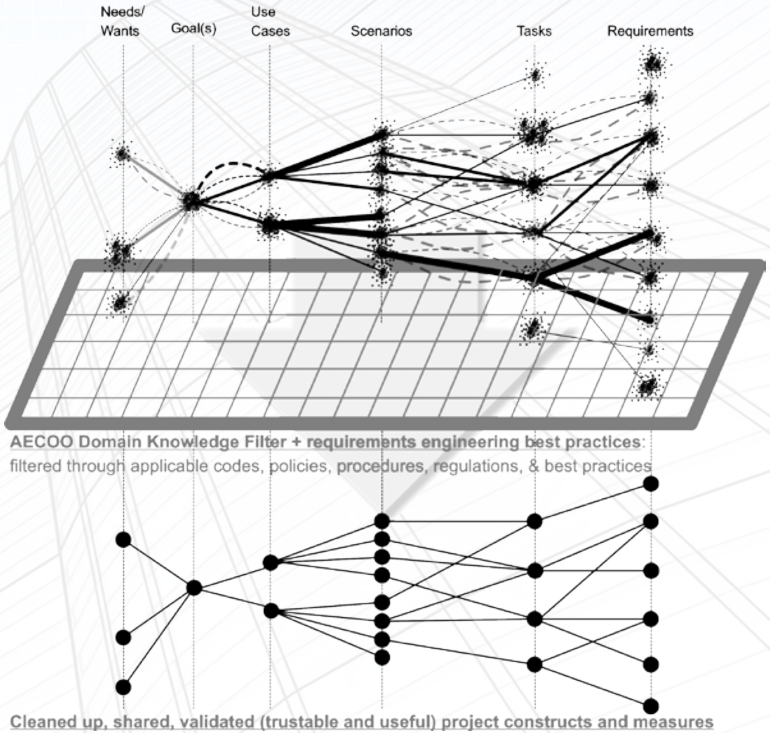
Manganelli, J. (2018). AECNEXT BIMSTORM: Standards and Risk Presentation, Anaheim, CA, USA, June 5, 2018

Concepts and Constructs

1. Compose requirements traceability tree of the following:
   - Needs
     - Goals
       - Use cases
         - Scenarios
           - Tasks
             - Requirements
               - Stated
               - Derived
               - Functional
               - Non-functional



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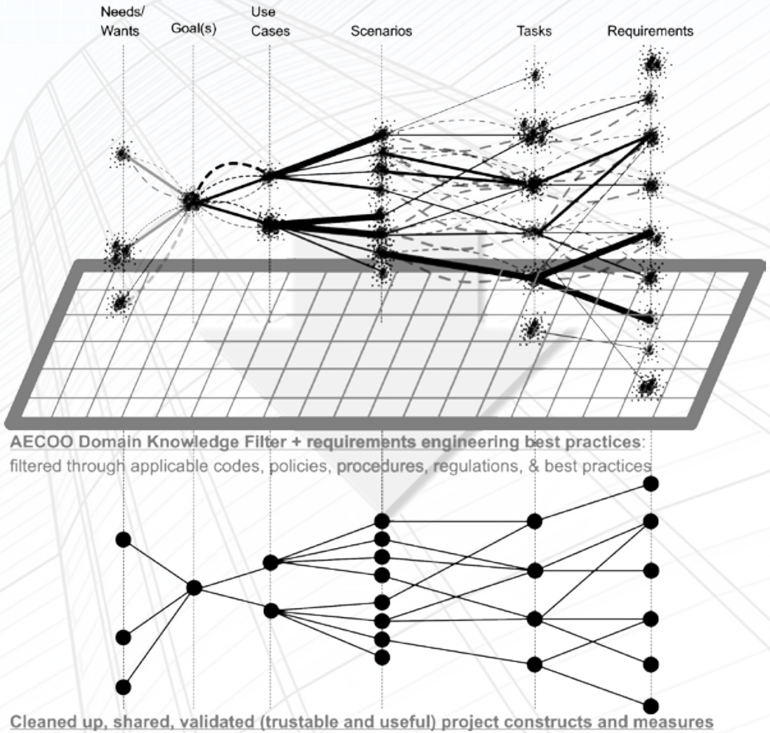
Requirements Development

Measures, Methods, & Tools

1. Complex, Interactive Architectural Systems Design Method (CIAS-DM) can be used to elicit, validate, and prioritize requirements
2. Continuous Early Validation (CEaVa)
   1. A method for requirements elicitation, definition, and validation
   2. Logically rigorous such that formal measures and analysis can be mapped onto it
   3. Stakeholder needs validated against:
      1. Concept validity
      2. Policy validity
      3. Requirements validity
      4. Design validity



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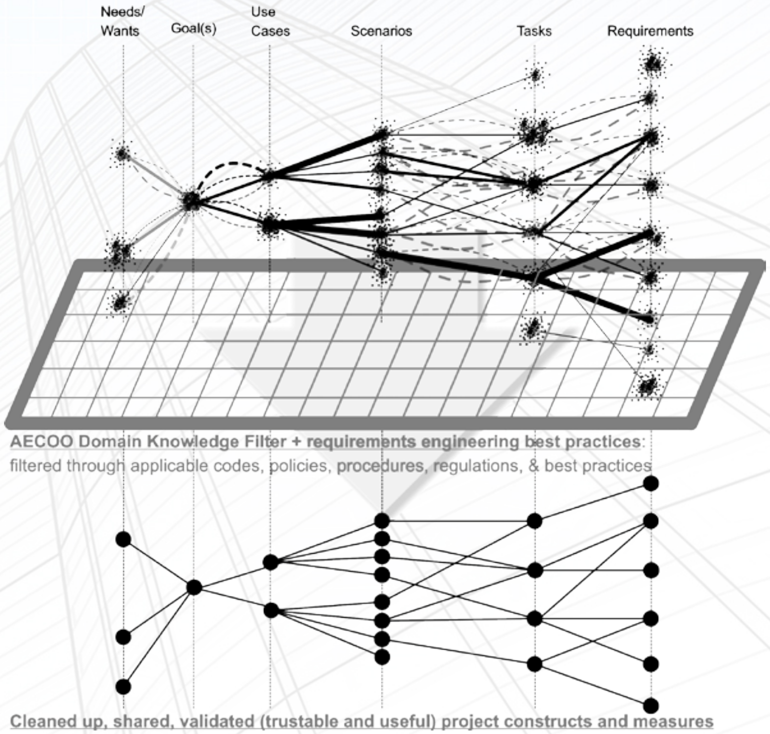
Requirements Development

Measures, Methods, & Tools

Case study that shows the military used CEaVa and realized $200 million in savings by stabilizing requirements/goals/use cases, etc.



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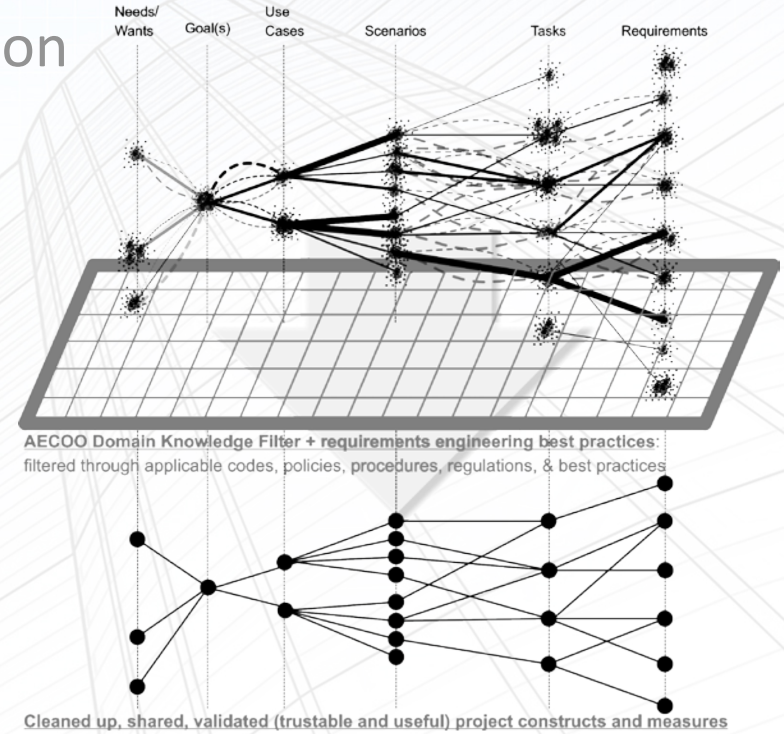
Requirements Development

BIM & Project Delivery Integration

1. Requirements stabilization and CEaVA and/or CIAS-DM dovetail very nicely with the Integrated Project Delivery framework, as well as the V-Model of project delivery
2. Structured requirements elicitation and ASHRAE Guideline 0’s OPR/BOD can form a sound basis for beginning the CEaVa method
3. Process can be documented via SysML to integrate with OOSEM and simulation of performance of system of systems



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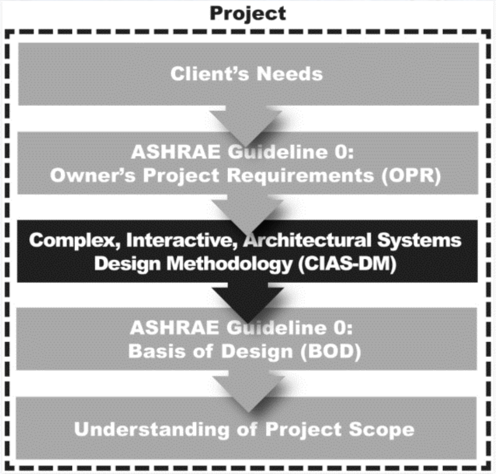
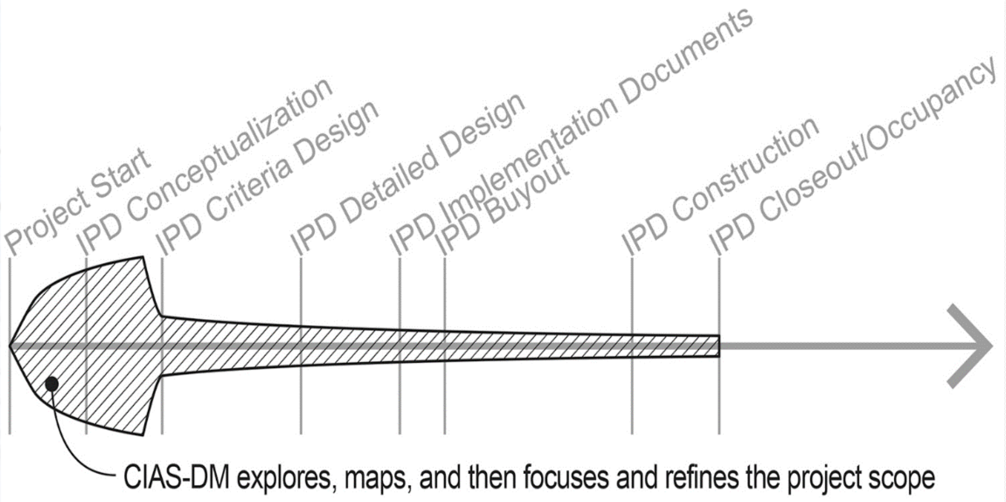
Requirements Development

BIM & Project Delivery Integration

1. Complex, Interactive Architectural Systems Design Method (CIAS-DM) is a version of this developed as a research project that integrates with Integrated Project Delivery (IPD) framework





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Requirements Development

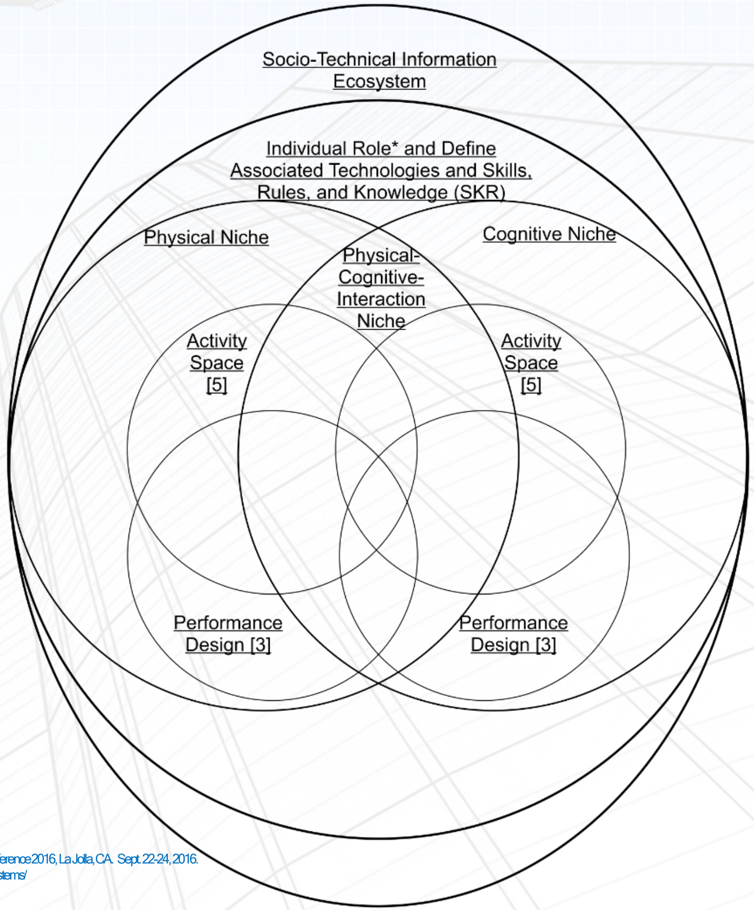
BIM & Project Delivery Integration

Design Project Ecological Niche Construction Checklist

Physical-Cognitive-Interaction Niche Checklist

Activity Space Checklist [5]
- problem constraints (subgoal structure implicit in a task)
- physical space of task
- actions agent can perform in space
- concepts, plans, other intellectual or representational resources avaialable in the environment
- concepts, plans, other intellectual or representational resources avaialable in agents

Performance Design Checklist [3]
- right people
- right “artifact ecology”
- simplicity (right stuff, right form)
- locality (right place, right time)
- tempo (right pace, right duration)
- right information to make spatial
- how to make right information spatial?



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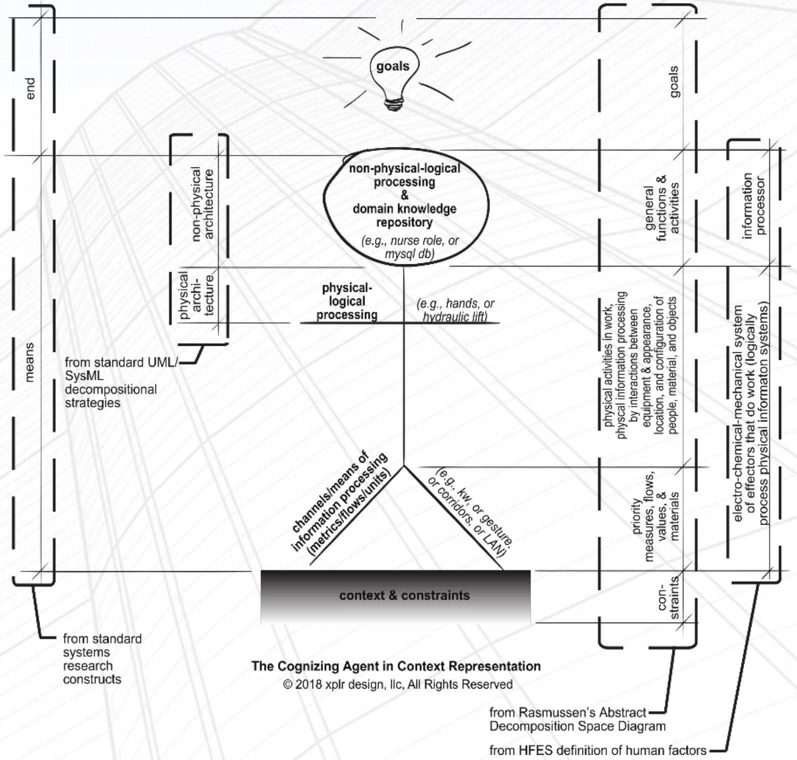
Requirements Development

BIM & Project Delivery Integration

Agent Architecture Interaction Assessment Framework



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Optimization

BUILDING INNOVATION 2019
National Institute of BUILDING SCIENCES
CONFERENCE & EXPO

Optimization

Concepts and Constructs

1. Information/knowledge classification/development
    1. Apple role, implementation, look/feel analysis
    2. under design
    3. Semi-structured modeling
    4. Walk-through-oriented facilitation
2. Information/knowledge prioritization
    1. Skills, rules, knowledge analysis
    2. Kano Method
    3. MoSCoW Method
    4. Operational View 1 (OV-1)
3. Multi-objective optimization

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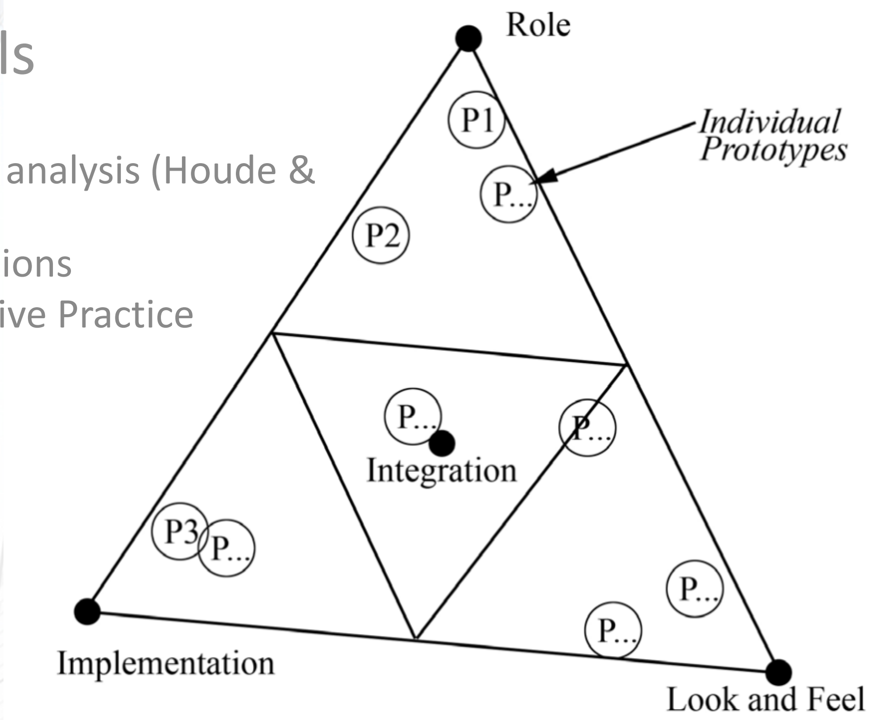
S. Houde and C. Hill, "What do prototypes prototype?," in Handbook of Human-Computer Interaction, Second ed., M. Helander, T. Landauer and P. Prabhu, Eds., Amsterdam, Elsevier Science BV, 1997, pp. 1-16.

Optimization

Measures, Methods, & Tools

1. Apple role, implementation, look/feel analysis (Houde & Hill, 1997)
2. Using prototypes as tools to ask questions
3. Aligns with Schon’s concept of Reflective Practice



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D. Schon, The Reflective Practitioner: How Professionals Think in Action, New York, NY: Basic Books, 1984.

Optimization

Measures, Methods, & Tools

1. Under design
    1. Establish/identify the ecology of roles of the stakeholders
    2. Work culture & have stakeholders take ownership and optimize it
    3. Technological interventions guided by stakeholders in use
    4. Technological interventions are catalysts for stakeholders' socio-technical systems optimization
2. Semi-structured modeling
    1. Technical systems diagrammatic abstractions for analysis with stakeholders
3. Walk-through-oriented facilitation
    1. Method of semi-structured interviews / contextual inquiries using semi-structured models with stakeholders to help them reflect on and develop/enhance their socio-technical system

J. Manganelli. *Designing complex, interactive, architectural systems with CIAS-DM: A model-based, human-centered, design & analysis methodology.* Retrieved on April 9, 2015 from: https://tigerprints.clemson.edu/cgi/viewcontent.cgi?article=2250&context=all_dissertations
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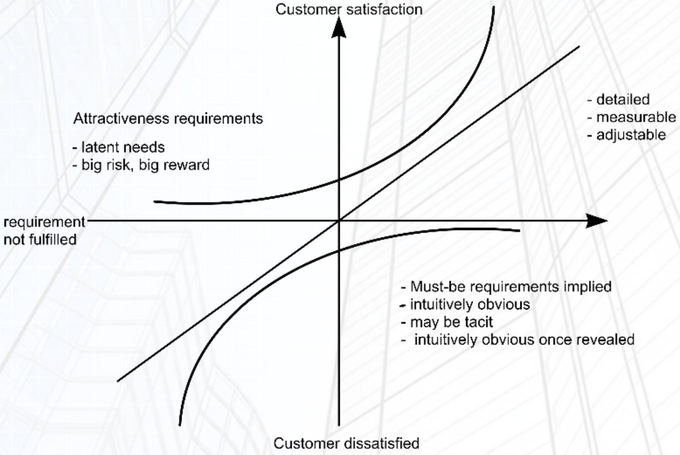
Optimization

Measures, Methods, & Tools

1. Skills, Rules, Knowledge framework, Kano Method, MoSCoW Method for prioritizing needs, goals, use cases, scenarios, tasks, requirements

- **Skills** – automatized behavior (shoveling, keystrokes)
    - Lowest cognitive load
- **Rules** – automatized behavior (skill) that requires integral learned branching logic (left-click, right-click, middle mouse button click, framing a roof)
- **Knowledge** – deliberate cogitating on a partially or wholly unique challenge that requires access to and use of abstract knowledge (design, management)
    - Highest cognitive load



- **Must** (address requirement or project fails)
- **Should** (best practice, will do if feasible, but not required)
- **Could** (may have some clear value, but either logistically infeasible or not in budget, so unlikely to be included in scope)
- **Would** (may be valuable in an ideal world and therefore team would do if no constraints, but given existing constraints it is not at all feasible nor will anyone care if it is not part of scope)

Rasmussen, J. (1983). Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models. IEEE transactions on systems, man, and cybernetics, (3), 257-266.
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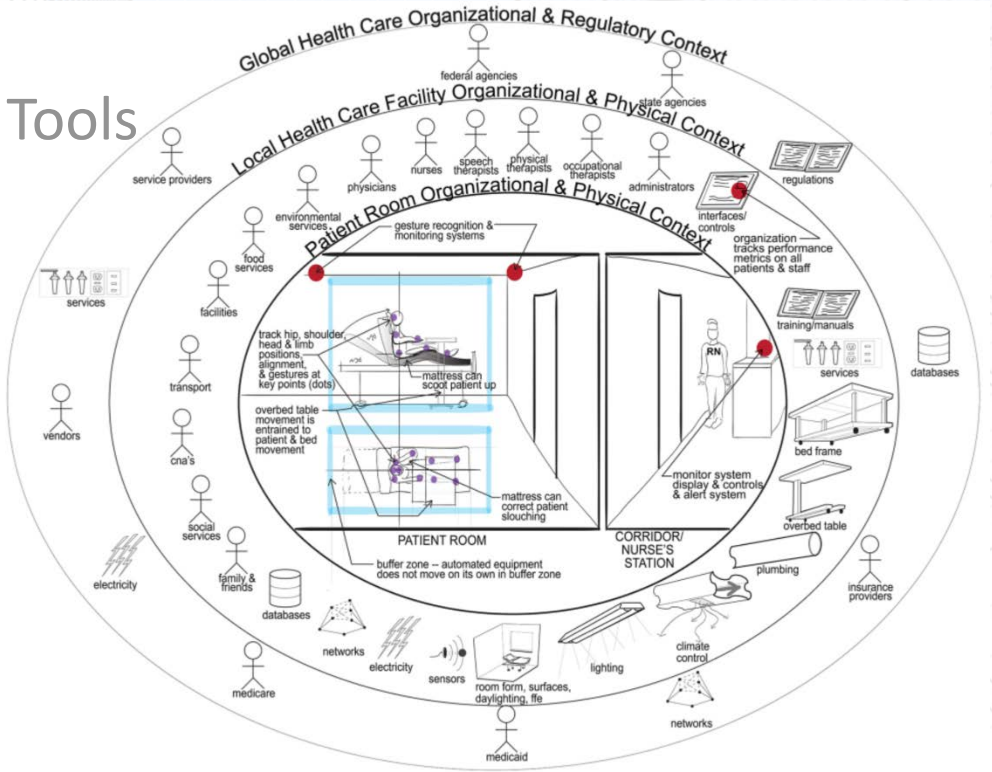
https://en.wikipedia.org/wiki/MoSCoW_method

Optimization

Measures, Methods, & Tools

Department of Defense
Architecture Framework (DoDAF)
Operational View 1 (OV-1) Diagram



Department of Defense, "Department of Defense architecture framework version 202," Department of Defense, Arlington, VA, 2013.

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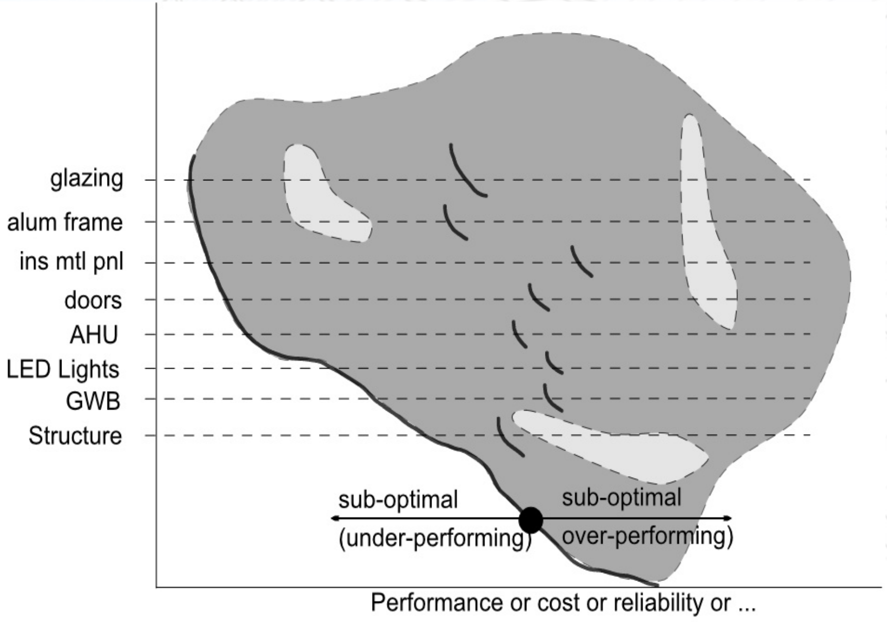
Optimization

Measures, Methods, & Tools

1. Multi-objective optimization:
    1. Optimize the overall system of systems, which typically entails that all sub-systems are sub-optimal
    2. Makes intuitive sense --- making any one sub-system or component the best it can be usually involves trade-offs with other sub-systems or components
    3. Useful as a management assessment of risk management and design/cost optimization



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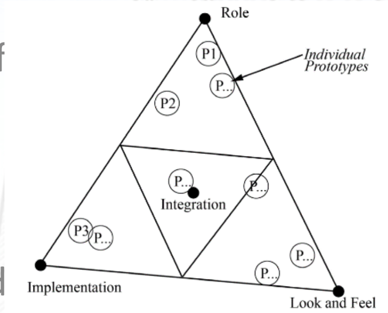
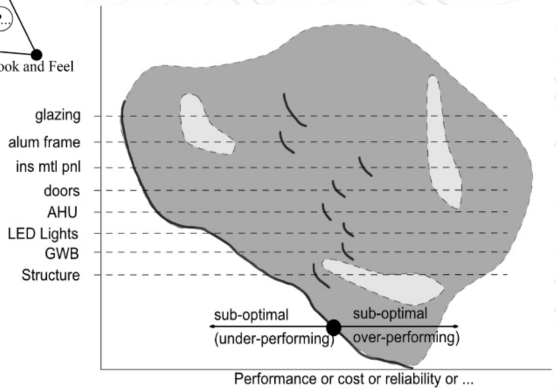
Optimization

BIM & Project Delivery Integration

1. Useful for focusing/narrowing scope of design services
2. Useful for determining underlying platform technologies, where to focus early design, and how much risk due to insufficient information is embodied in design challenge
3. Useful for managing risk and project performance





Summary

- Scale, complexity, and degree of integratedness of emerging smart infrastructure and smart buildings require fundamentally new workflows for facility design, construction, and operations
- Non-intuitive behaviors of complex systems must be accounted for because scale, complexity, and degree of integratedness exposes the limitations of deterministic models
- Constructs, measures, methods, and tools from aerospace, defense, automotive, and software industries provide guidance on how to innovate AECOO project delivery methods

This concludes The American Institute of Architects Continuing Education Systems Course

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