VDC and BIM

The use of Building Information Modeling in Virtual Design and Construction

Presented by Rex Tate

Technology adoption and VDC

Part 3

Presented by ***Rex Tate***

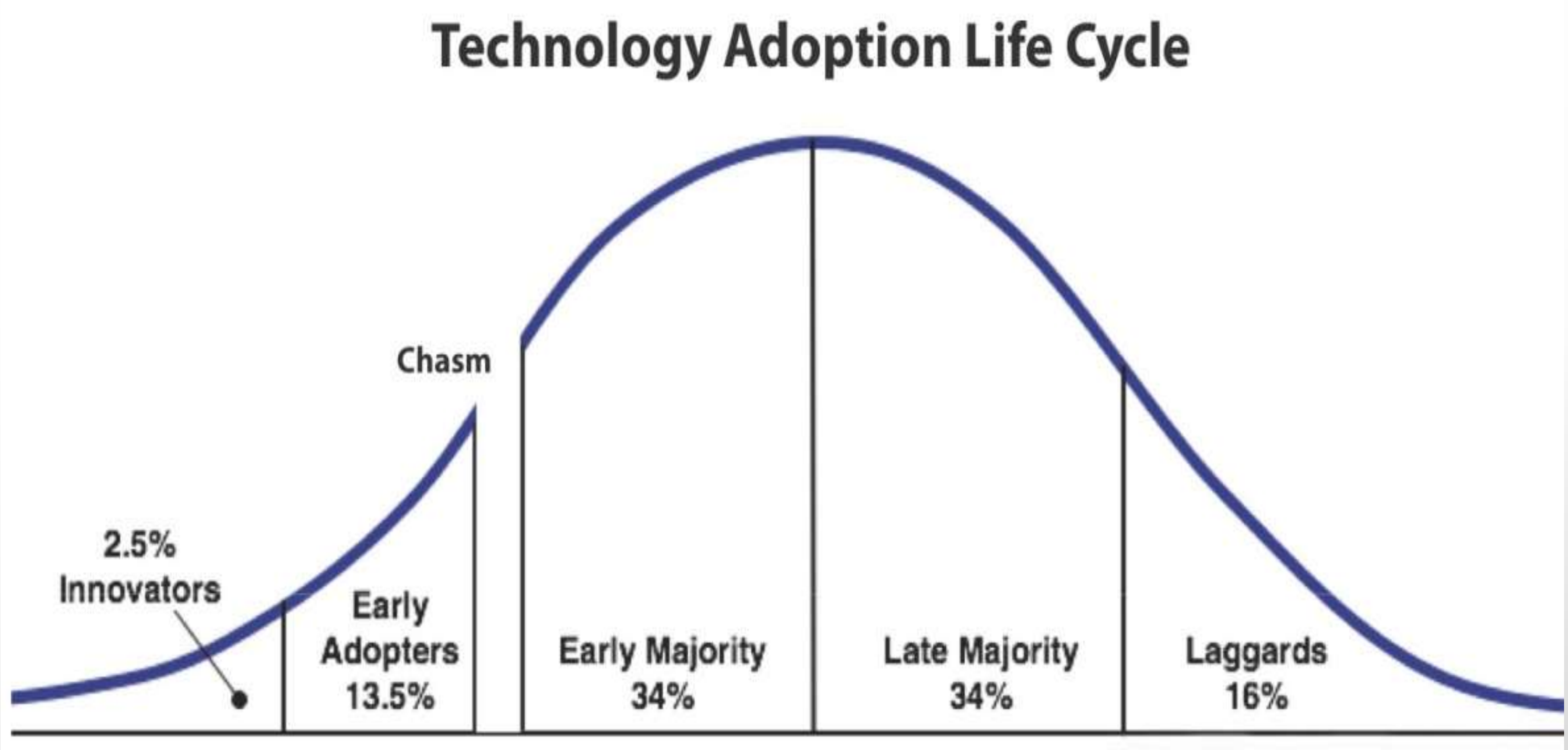
Session 3 subjects

- Early technology adoption and crossing the chasm
- The cowboys and the farmers
- The Gartner hype cycle
- Constructability scores and buildability standards
- The Pareto principle of uneven distribution of outcomes and Pareto frontiers
- VDC components, processes and i-rooms
- Disruptive technology

A review of session 2 subjects

- Model management and the AIA G202 BIM protocol
- The concept of "parts" as one tool in the fight against waste in construction
- Model dimensions from 2d to 7d
- Clash detection
- The right of reliance
- Change management and parametric modeling

Technology adoption groups over time



Source: Crossing the Chasm
Geoffrey Moore, 3rd edition 2014

The cowboys and the farmers

- The **cowboys versus farmers phenomenon** distinguishes those individuals and companies that are innovative and mobile (the cowboys) and those that are systematic and are not mobile and less innovative (the farmers). A cowboy rides a horse and is not tied to a specific geographical spot and so is mobile both physically and in thought (innovative). A farmer must remain in place on his farm to carry out his work and so is not mobile and so is not exposed to distant places and the different ideas that may exist in these locations and so is less innovative in his thoughts than a cowboy that is able to travel widely.
- The early adopters and the innovators are pure cowboys. But, as you move toward the end of the adoption cycle (the **Laggards** group), you observe an increase in the characteristics of **farmers** and an elimination of the **cowboy** traits.

Inside the minds of technology adopters

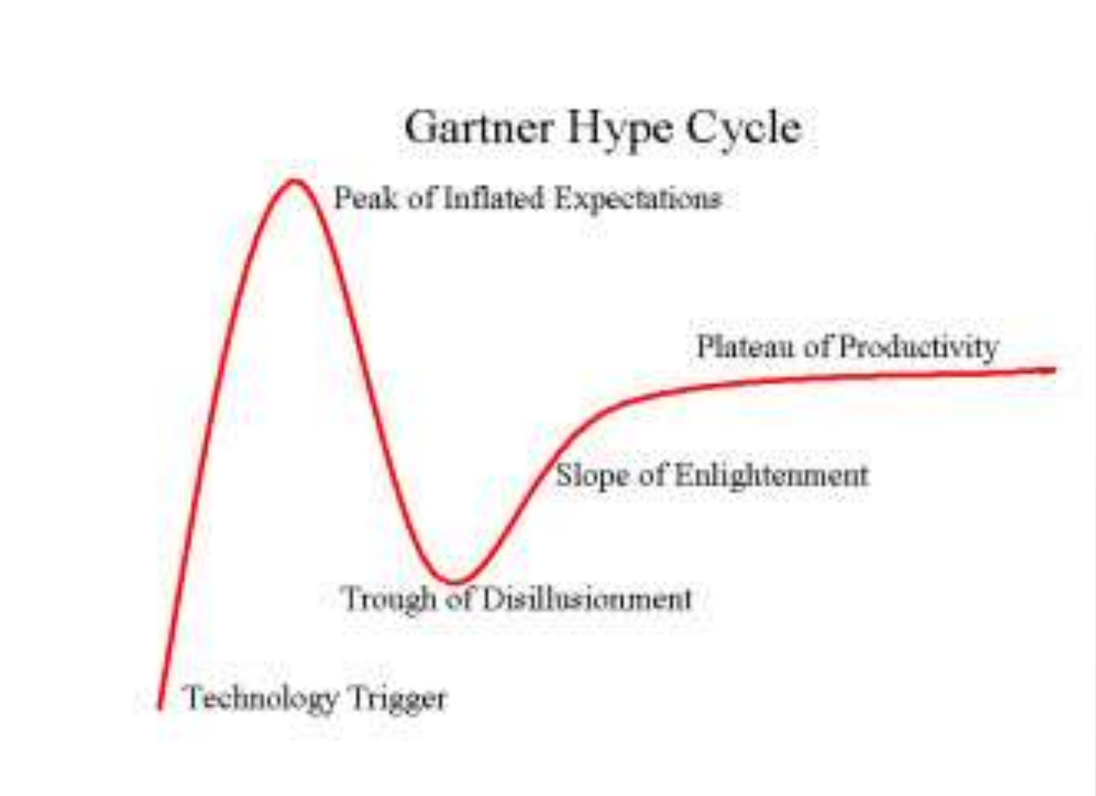
There are levels of expectations during the technology adoption cycle

- Before ‘crossing the chasm’, the population of adopters is small and only 16% of the potential users have acquired and applied the technology to any degree
- As the population enters the early and late majority, it moves up the slope and onto the plateau
- Only then do the last 16%, the least innovative of the laggard farmers acquire and apply
- At this time, the innovators and early adopters are far ahead in the uses, knowledge and applications

Inside the minds of technology adopters

Where are BIM users currently on the hype cycle?
Where are we right now?

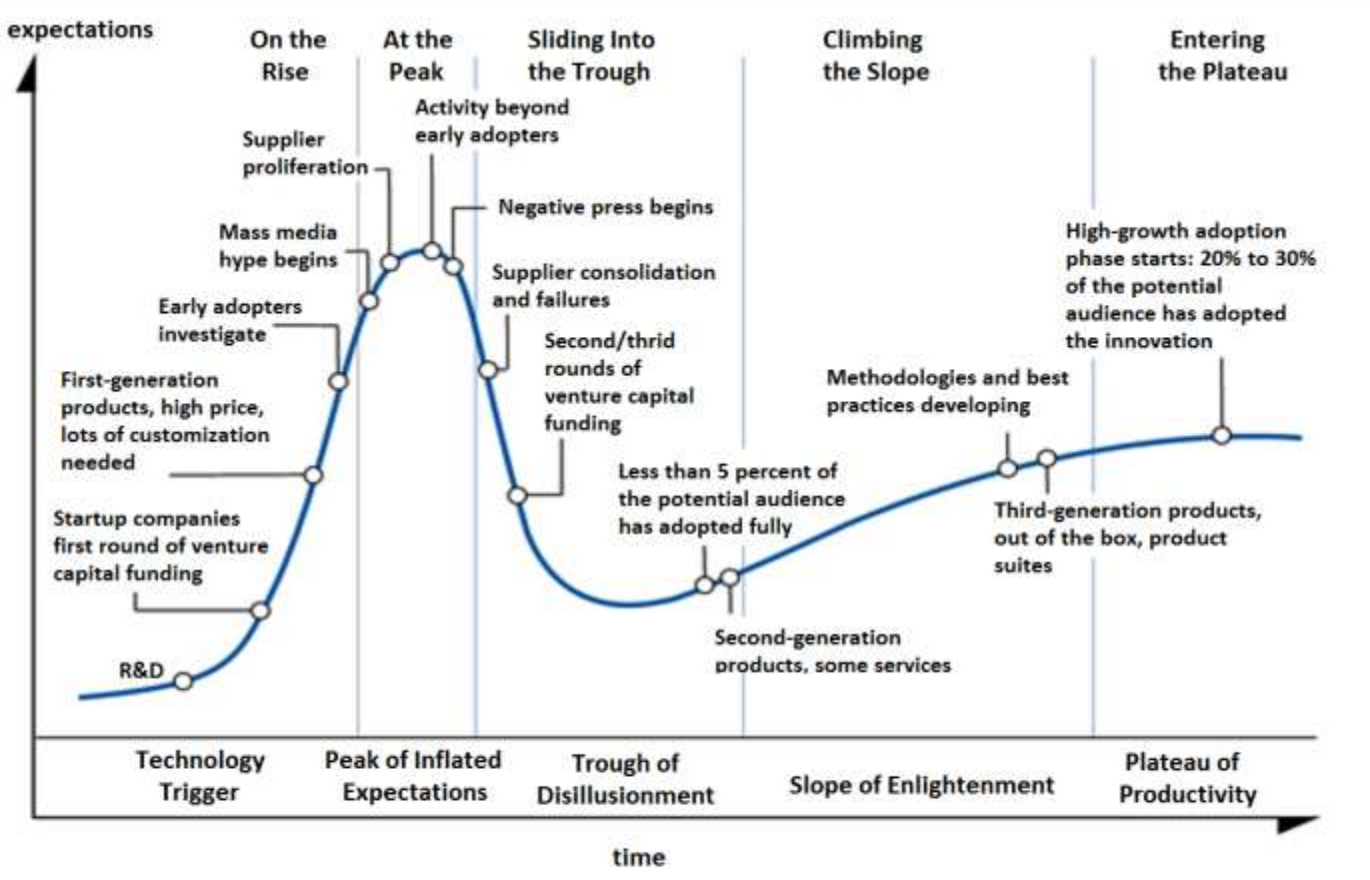
The 5 phases of the cycle



Source: Gartner, Inc.
20th cycle 2014

The path of the use and development of technologies

Cycle activities within the five phases



Source: Gartner, Inc.
20th annual edition
2014

Some barriers to the adoption and use of 3d models by contractors and subcontractors

- The 3d model approach to projects is viewed as too great a change from how work is currently performed
- Remember that it was the contractors that immediately understood the power of models and this triggered the growth of the use of BIM
- The use of 3d models is not required by the project and so they choose not to do it
- The belief that new, expensive computers and other hardware must be purchased
- The misconception that model builders must be hired
- Too busy with current work to learn and adopt new project methods
- The false belief that building usable models is very time consuming and extremely difficult
- They do not think that the benefits outweigh the costs and efforts of the investment in the ‘new’
- Non-adopters believe that their current methods are the best and cannot be improved
- Tradition-bound and detest the idea of new and different things

Constructability versus Buildability

- Buildability

  A project's <u>design</u> determines its buildability

  Buildability is the degree of ease of constructing the building

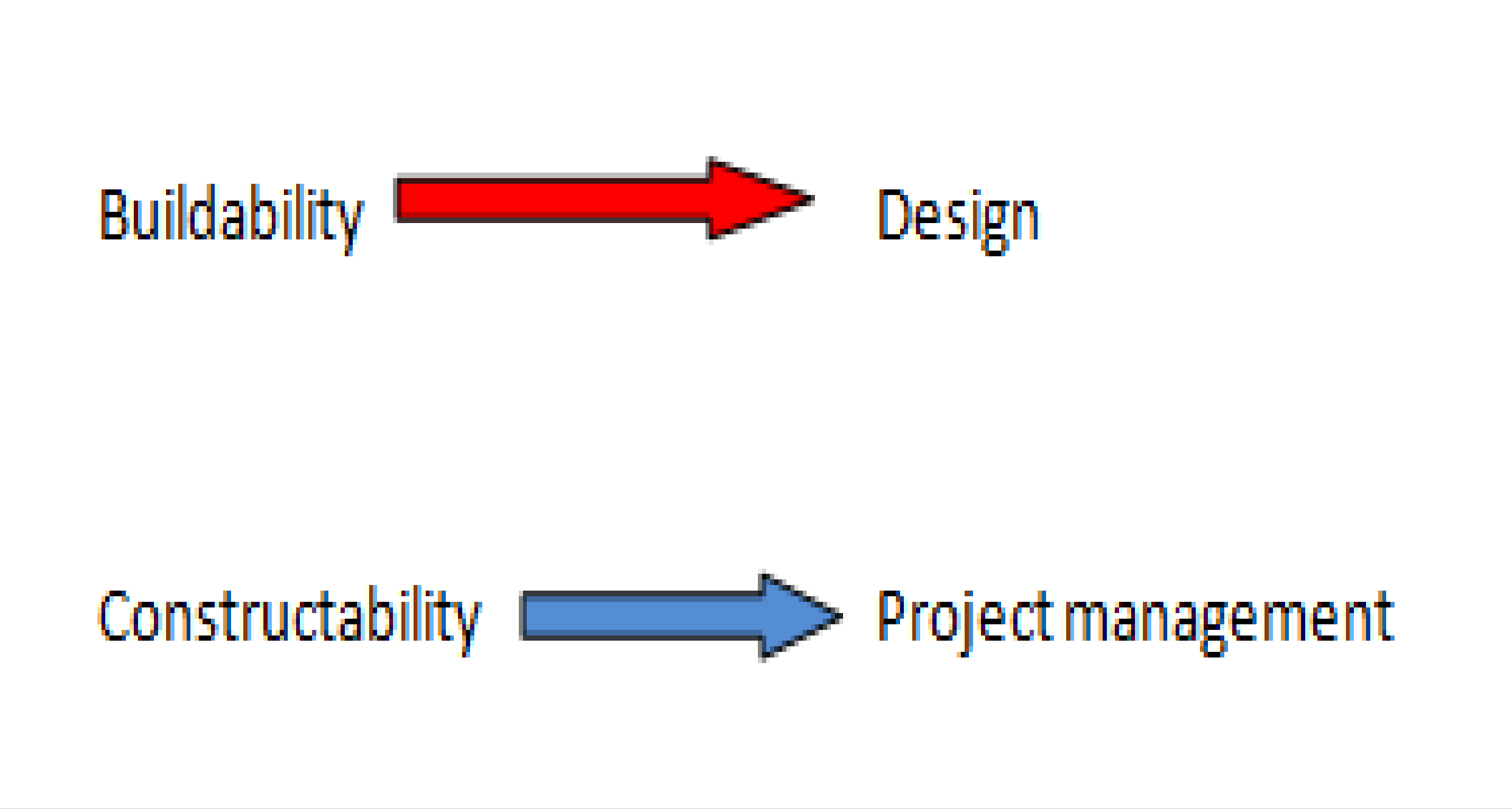
  Lower manpower requirements is a mark of buildability

- Constructability

  The <u>project management methods</u> determine the constructability

  Improvements in crew productivity equals increased constructability

Design and construction management tactics



Constructability and constructability factors
Using BIM to assess a project's constructability

RIB running together

- Design attributes
  - 1 What is the amount of use of precast and prefabricated items?
  - 2 How standardized and how complex is the grid layout?
  - 3 How standardized are the dimensions for partitions, doors, windows, gypsum board, tiles?
  - 4 How flexible is the repositioning of interior components?
  - 5 What is the availability of equipment?
  - 6 How available is skilled labor?
- Construction attributes
  - 7 How complex is the construction sequence?
  - 8 What is the percent of the duration of underground construction?
  - 9 What is the percent of the duration of the building envelope?
  - 10 What is the climate and weather conditions of the site?
  - 11 What is the impact of safety needs on the sequence?
  - 12 How is material storage and transportation on site arranged?
  - 13 What is the degree of accessibility to equipment and tools in different site locations?
  - 14 What is the ease of personnel access in different construction locations as the project proceeds?
- External impacts
  - 15 How available are utilities?
  - 16 How available is transportation and the use of roads?
  - 17 How does any adjacent construction affect the project?

Quantifying the constructability assessment

Building and Construction Authority

BLOCK DETAILS

BLOCK NO. / NAME ____________ Please indicate other typical blocks (if any) : ____________

CALCULATIONS OF OVERALL CONSTRUCTABLILTY SCORE (CScore)

Construction Technologies/Methods	Maximum Allocated Points (a)	Computation Method			CScore (a) x (b) or Direct pts
A. STRUCTURAL SYSTEMS (max 60pts)					
1. EXTERNAL ACCESS SYSTEM (max 15pts) (for carrying out both structural and architectural works)		Computation Method	Building Perimeter (m)	% of Length (b)	
(a) No external scaffold	15	ΣLength with external access system / Total Building Perimeter Length X (a)			0.00
(b) Self-climbing perimeter scaffold	15				0.00
(c) Crane-lifted perimeter scaffold/ fly cage	14				0.00
(d) Traditional external scaffold	1				0.00
		Sub Total for A1	0.00	0.00	0.00
2. FORMWORK SYSTEM (max 30pts)					
(a) Vertical Contact Area (at least one of the fields in this section should be completed)		Computation Method	Vertical Contact Area (m2)	% of Contact (b)	
(i) No formwork (precast construction)	15	Σ(Vertical Formwork Contact Area / Total Vertical Formwork Contact Area X (a)			0.00
(ii) Traditional timber/metal formwork	1				0.00
Vertical Formwork					
(i) System Formwork (Band 1) description:	15	Σ(Vertical Formwork Contact Area / Total Vertical Formwork Contact Area X (a)			0.00
(ii) System Formwork (Band 2) description:	14	Σ(Vertical Formwork Contact Area / Total Vertical Formwork Contact Area X (a)			0.00
(iii) System Formwork (Band 3) description:	13	Σ(Vertical Formwork Contact Area / Total Vertical Formwork Contact Area X (a)			0.00
(iv) System Formwork (Band 4) description:	11	Σ(Vertical Formwork Contact Area / Total Vertical Formwork Contact Area X (a)			0.00
(v) System Formwork (Band 5) description:	8	Σ(Vertical Formwork Contact Area / Total Vertical Formwork Contact Area X (a)			0.00
		Sub Total for A2a	0.00	0.00	0.00
(b) Floor Area (at least one of the fields in this section should be completed)		Computation Method	Floor Area (m2)	% of Floor (b)	
(i) No formwork (precast construction)	15	Σ(Floor Area) / Total Floor Area X (a)			0.00
(ii) Traditional timber/metal formwork	1				0.00
Horizontal Formwork					
(i) System Formwork (Band 1) description:	15	Σ(Floor Area) / Total Floor Area X (a)			0.00
(ii) System Formwork (Band 2) description:	14	Σ(Floor Area) / Total Floor Area X (a)			0.00
(iii) System Formwork (Band 3) description:	13	Σ(Floor Area) / Total Floor Area X (a)			0.00
(iv) System Formwork (Band 4) description:	11	Σ(Floor Area) / Total Floor Area X (a)			0.00
(v) System Formwork (Band 5) description:	8	Σ(Floor Area) / Total Floor Area X (a)			0.00
		Sub Total for A2b	0.00	0.00	0.00
				Sub Total for A2	0.00
3. STRUCTURAL INNOVATIVE METHODS, SYSTEMS, PROCESSES, PLANT AND EQUIPMENT (max 15pts)				usage %	
(a) Use of self compacting concrete	2	If usage is ≥ 5% of total superstructure concrete volume			0.00
(b) Use of hydraulic stationary placing boom for concreting	2	Points will be given once used		☐ YES	

Constructability scores and buildability standards

A building project can be assessed and a constructability score determined

The score is a value from 0 to 120

The higher the number, the more constructible the building

- A constructability score consists of 3 parts:

Structural system	60 points
AMEP (Architecture Mechanical Electrical Plumbing)	50 points
Innovation and productivity	10 points

- The score provides a buildable design appraisal and is used to determine the impact of the design on the efficiencies of the crews' work on site
- Some countries have buildability standards and require that designs have a <u>minimum constructability score</u>

Pareto / non-Pareto

The Pareto principle and the observation of uneven distribution

- The Pareto principle is an observation that most things are not distributed evenly

There is an unequal relationship between inputs and outputs

- 12% of the investments are responsible for 86% of the gains
- 91% of the consequences arise from 4% of the causes
- 64% of your output at work comes from 23% of your time there
- 18% of the customers provide 79% of the revenue
- 36% of the workmen perform 88% of the work
- 7% of the CPM activities are the causes of 96% of the delayed items

Pareto / non-Pareto

The Pareto principle and the observation of uneven distribution

- The Pareto principle shows that the majority of the results come from a smaller fraction of inputs
- When you know this, concentrate on those identified inputs
- Focus effort and resources on those items that make large differences and not on those that don't

Italian economist Vilfredo Pareto's 1906 observation

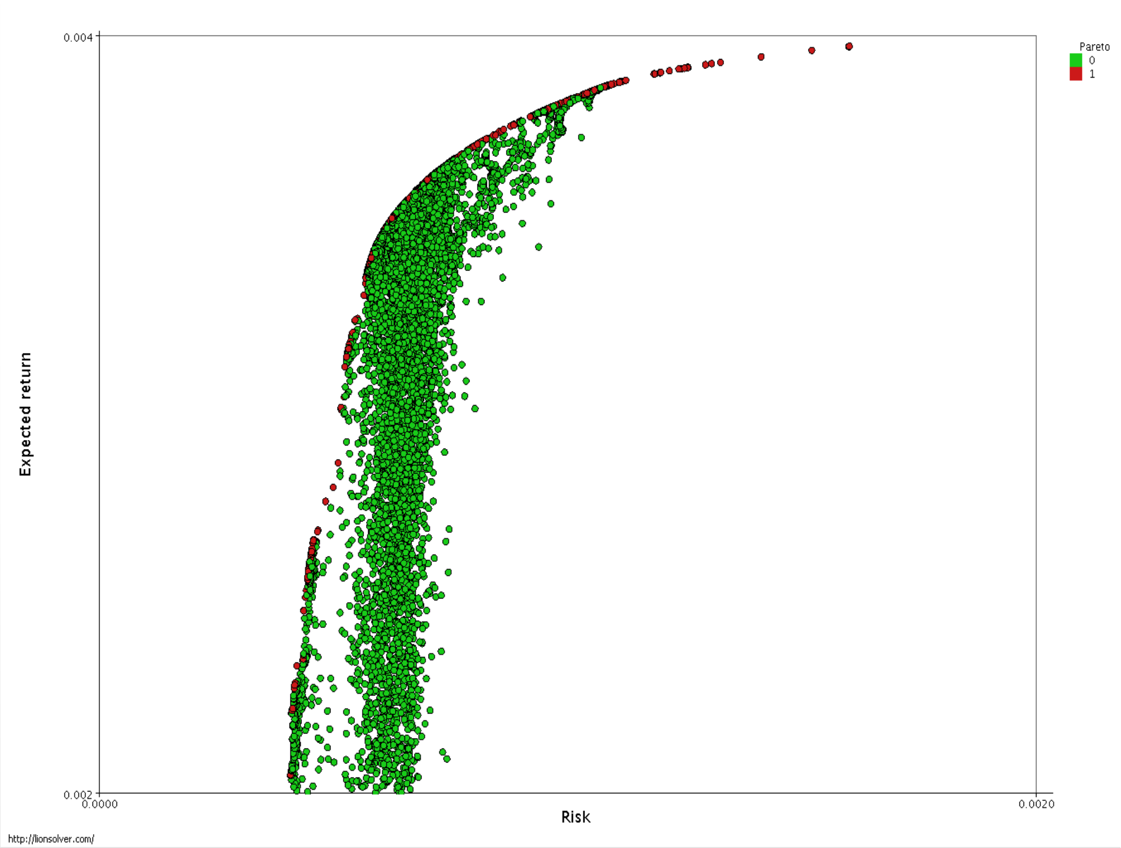
(20% of his garden's pea plants produced 80% of the garden's peas)

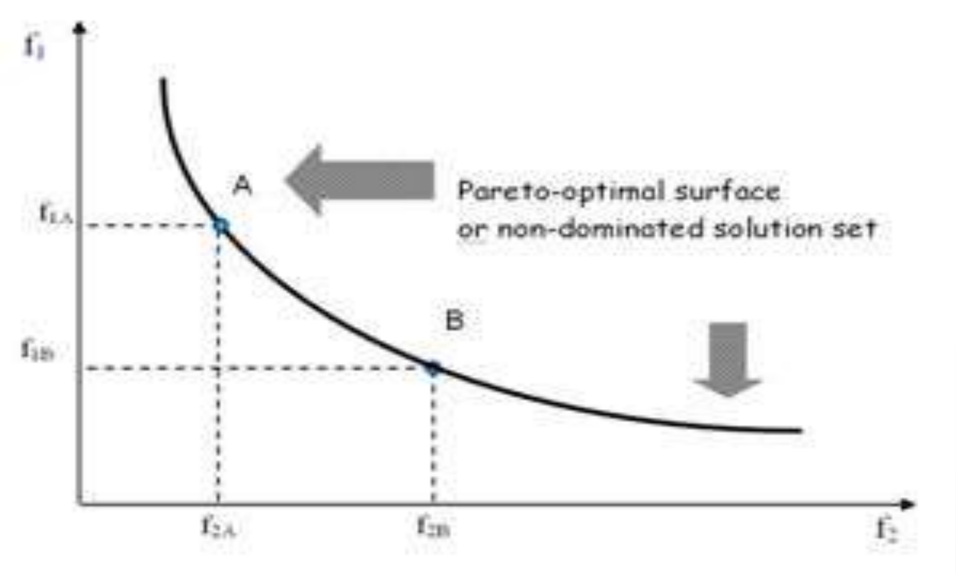
Pareto efficiency

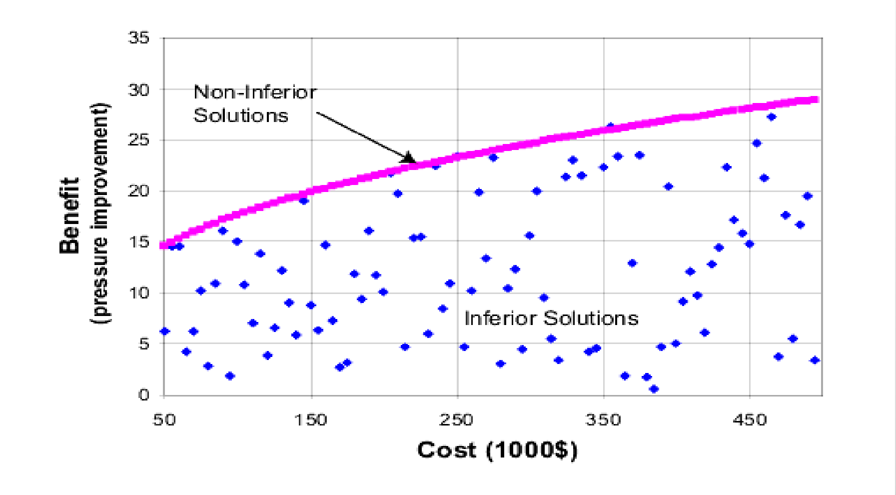
- The Pareto principle provides applications of determining distributions based on positive allocations of resources on a minimal notion of efficiency
- This application lets AEC narrow down choices in design and construction processes to a set that is Pareto efficient so that an entire range of considerations do not have to be reviewed
- This allows us to produce graphs that illustrate which choices are in the efficient set and which are not

Pareto frontiers

The efficient sets in 2 dimensions







Pareto frontiers

History of design optimization methods

1700's
Numerical optimization methods

→

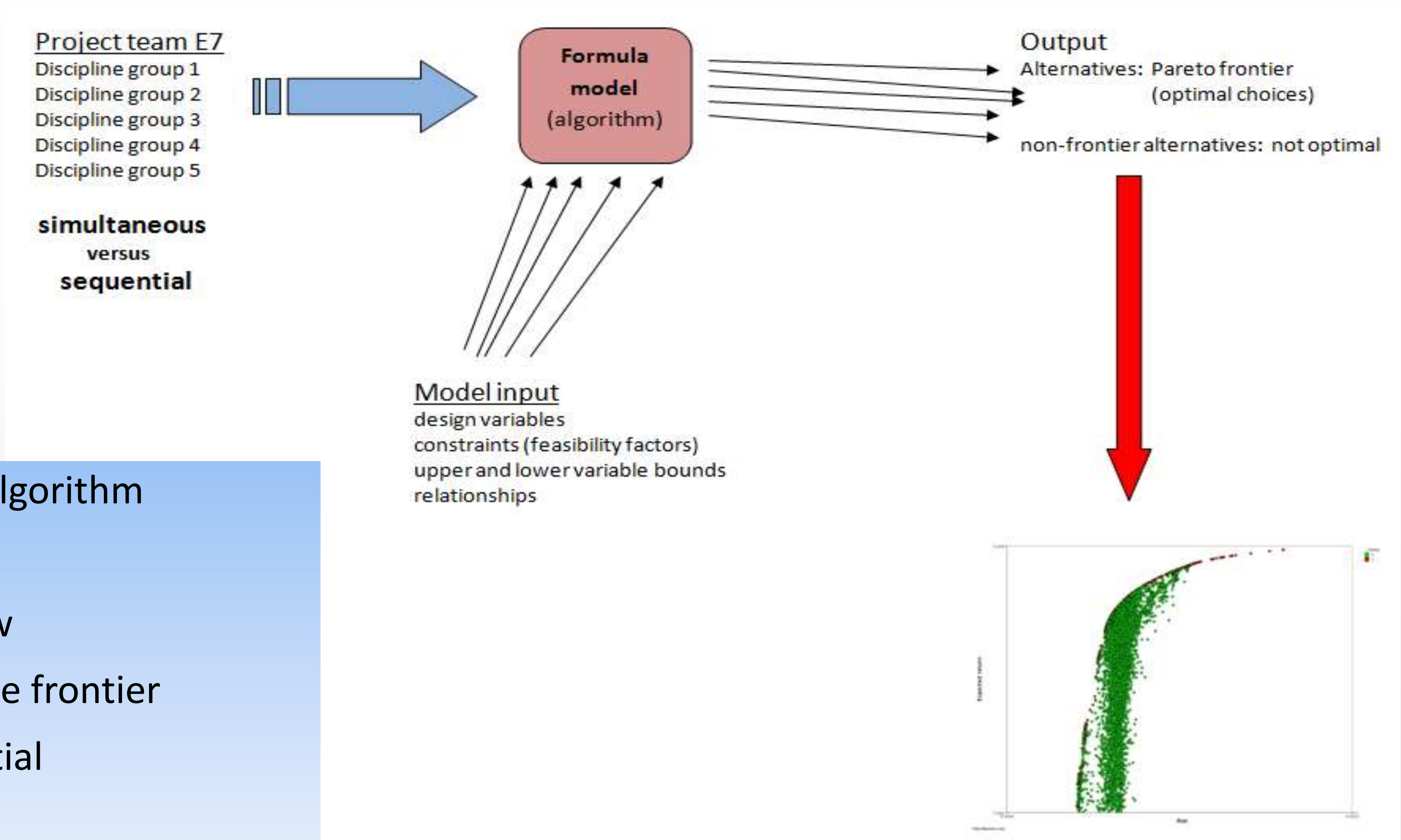
1970's
CAD based optimization by gradient based methods

→

1980's to present
MDO

1. Gradient and non-gradient based methods
2. Population methods
3. Search methods

MDO algorithm and Pareto frontier output



- The iterative power of the algorithm
- Velocity of analysis
- Many alternatives for review
- Set of optimal choices on the frontier
- Simultaneous versus Sequential

Examples of multiple disciplines within teams during MDO processes

1 HVAC team
Determine the optimal ductwork sizes

Groups:
HVAC engineers
Ductwork manufacturer
HVAC equipment manufacturer
Structural designers
Finishing subcontractor

2 Structural frame team
Determine quantities, types and sizes of structural frame members: I-shapes, built up girders, joists, joist girders

Groups:
Structural designers
Erector
Rolling mill
Transportation group

3 Foundation team
Determine the type of foundation: caissons vs. mat foundation vs. barrettes vs. piling and caps

Groups:
Concrete subcontractor
Structural designers
Reinforcing bar subcontractor
Concrete supplier
Equipment supplier

4 Earthwork team
Determine the best choices of excavation equipment

Groups:
Equipment supplier
Equipment maintenance
Earthmoving/excavation subcontractor
Hauling contractor
Excavation sequencer
Working space allowance group

The standard form of an MDO model

MDO formula model

Model's contents

- Objective (maximum/minimum)
- Design variables
- Constraints (feasibility factors)

The standard model form:

Find a value of X that maximizes/minimizes the function $j(x)$

subject to:

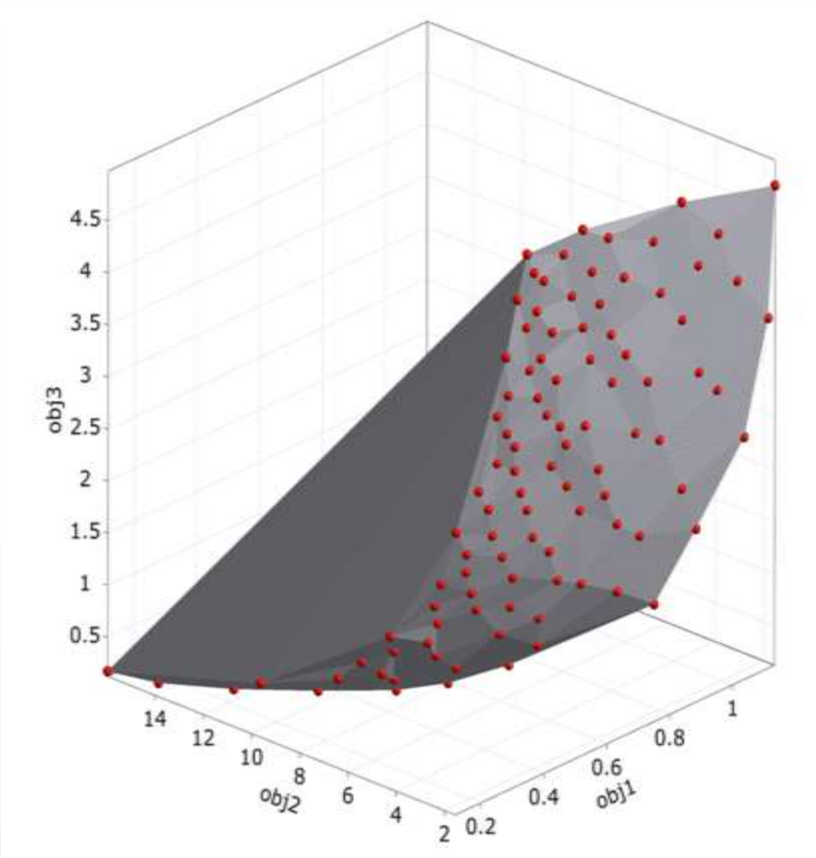
$$g(x) \leq 0$$
$$h(x) = 0$$
$$x_a \leq X \leq x_b$$

where:

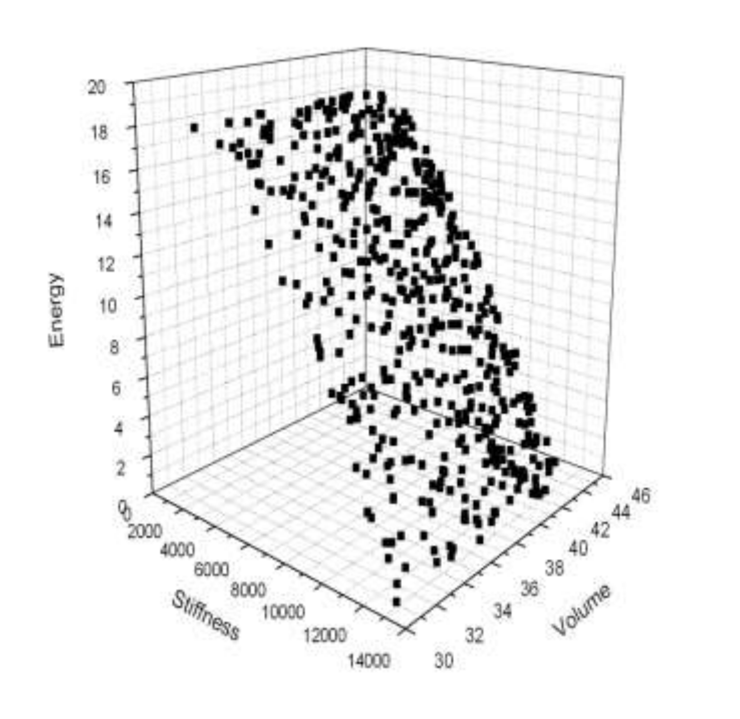
j = the objective
x = the vector of the design variable
g = the vector of the inequality constraints
h = the vector of the equality constraints
x_a = the vector of the design variable's lower bounds
x_b = the vector of the design variable's upper bounds

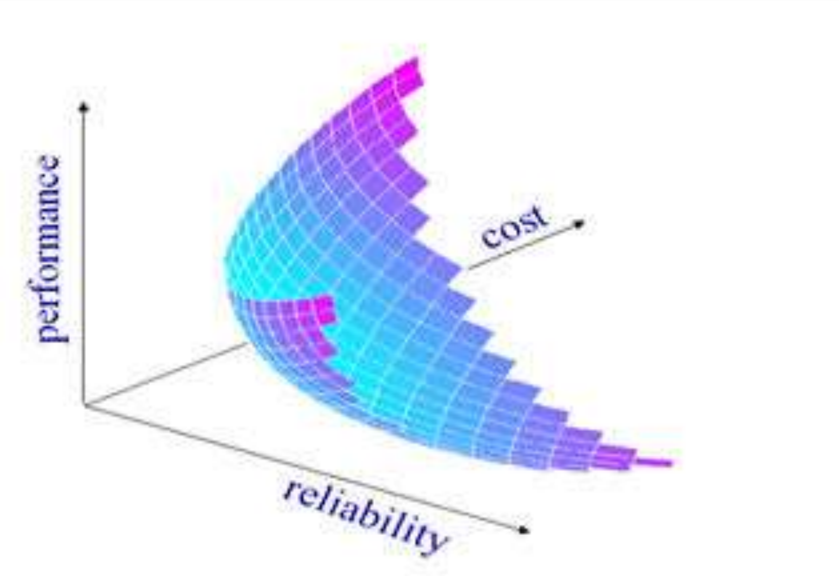
- An MDO model can contain multiple design variables resulting in multi-dimensional frontiers

3d examples of Pareto frontiers



- A 3d frontier is a surface
- A 2d frontier is a curve





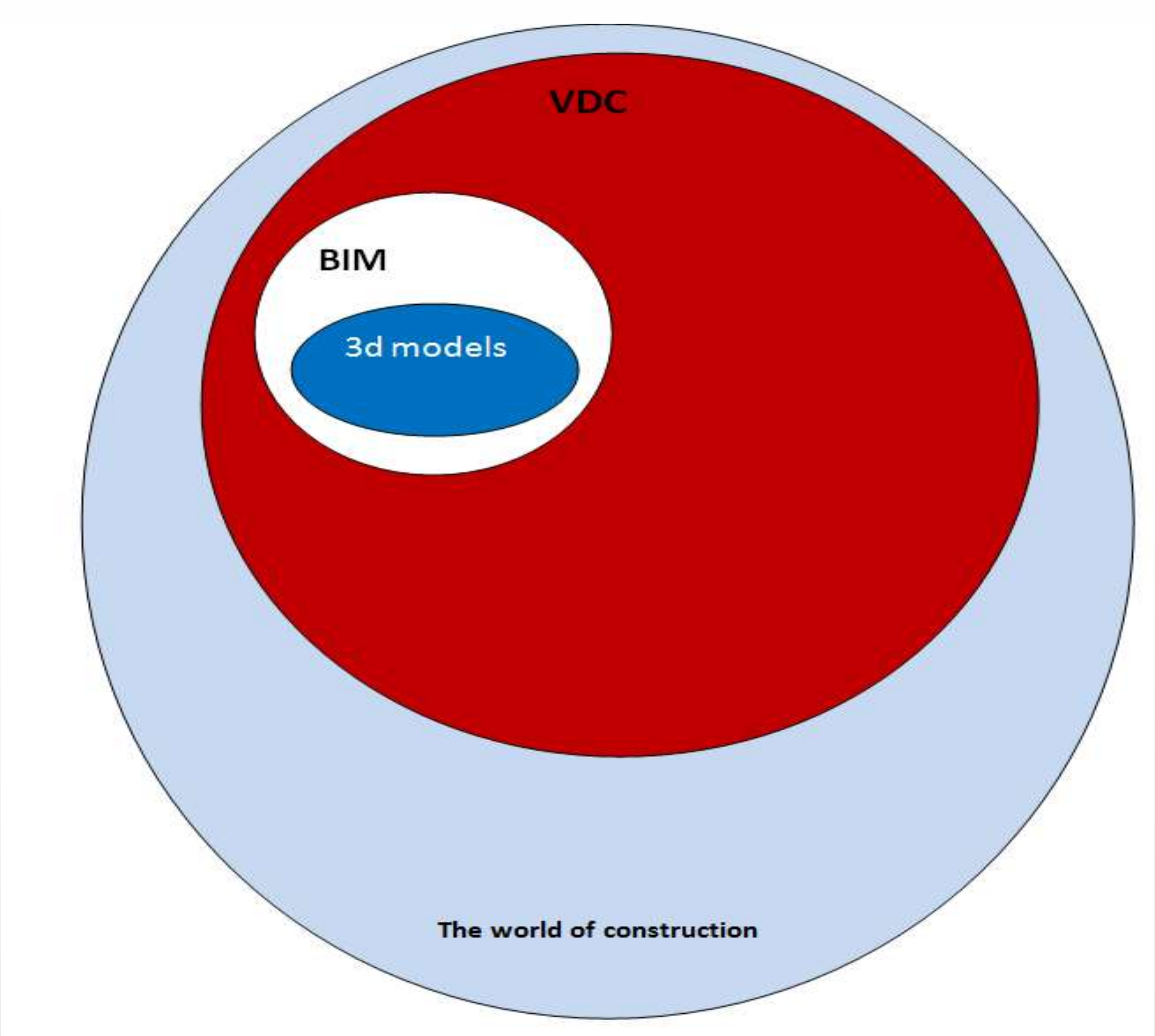
- An MDO model with more than three design variables cannot be visualized as an image but can generate upper power numeric results as multi-dimensional frontiers

Remember that VDC is a way of doing things to perform construction projects and the design

VDC methods can be separated into four broad areas:

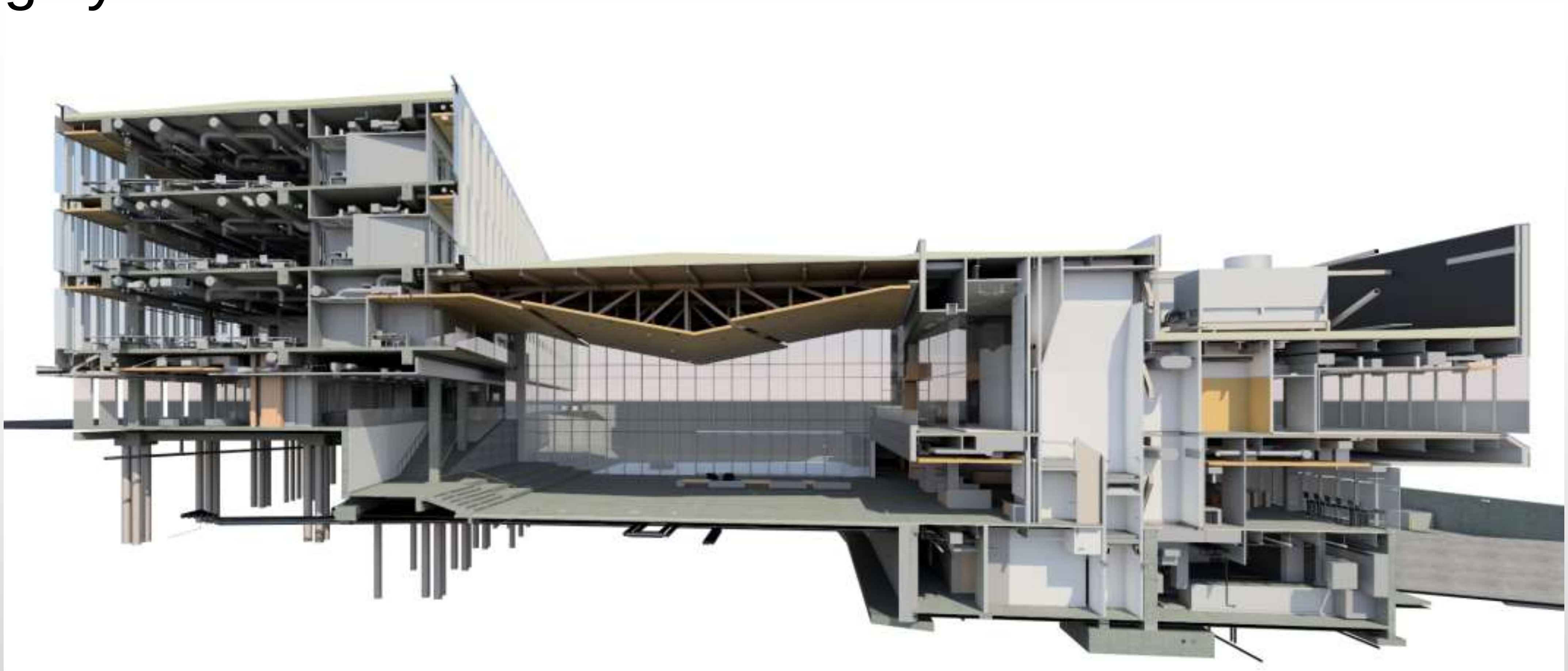
- Process management
- BIM
- ICE sessions
- Metrics

VDC contains BIM and 3d models are within BIM



BIM model

Highly rendered



Key VDC aspects

- ICE sessions
  Intense, specialized sessions where project team member work together exchanging information, making decisions quickly and moving the project towards milestones and ultimate completion more quickly than can be done by conventional construction management methods. ICE is Integrated Concurrent Engineering. ICE sessions are **nothing** like typical meetings.
- Co-located team members
  Co-location is when members of the team from different disciplines are working together, usually physically but can be virtually, in organized groups such as ICE sessions. VDC requires co-location and collaboration as opposed to working in isolation (siloed).
- POP models
  A POP model is a matrix used as a tool to organize objectives and information for determining decisions in the VDC process. POP models can be of different complexities and have various content for differing purposes in the project but all have a standard matrix format. These models let you operate at a very organized level by summarizing all types of construction project information in a standard form.
- Latency reduction
  Latency is the time required for a function to occur. In VDC, there are two classes of latency. *Response* latency (for receiving information and decisions) and construction *activity* latency (on a CPM schedule).

POP model

A VDC organizing / analysis tool developed at Stanford University

P **Product**

Construction materials, on site equipment, BIM models and model objects, management office supplies, any type of ‘output’ or ‘stuff’

O **Organization**

Subcontractors, engineers, rebar crews, welding crews, material suppliers, consultants, owners’ representatives, designers, political regulatory entities, any group of humans and its structure that deals with the project

P **Process**

Activities and actions that carry out operations and procedures in the project

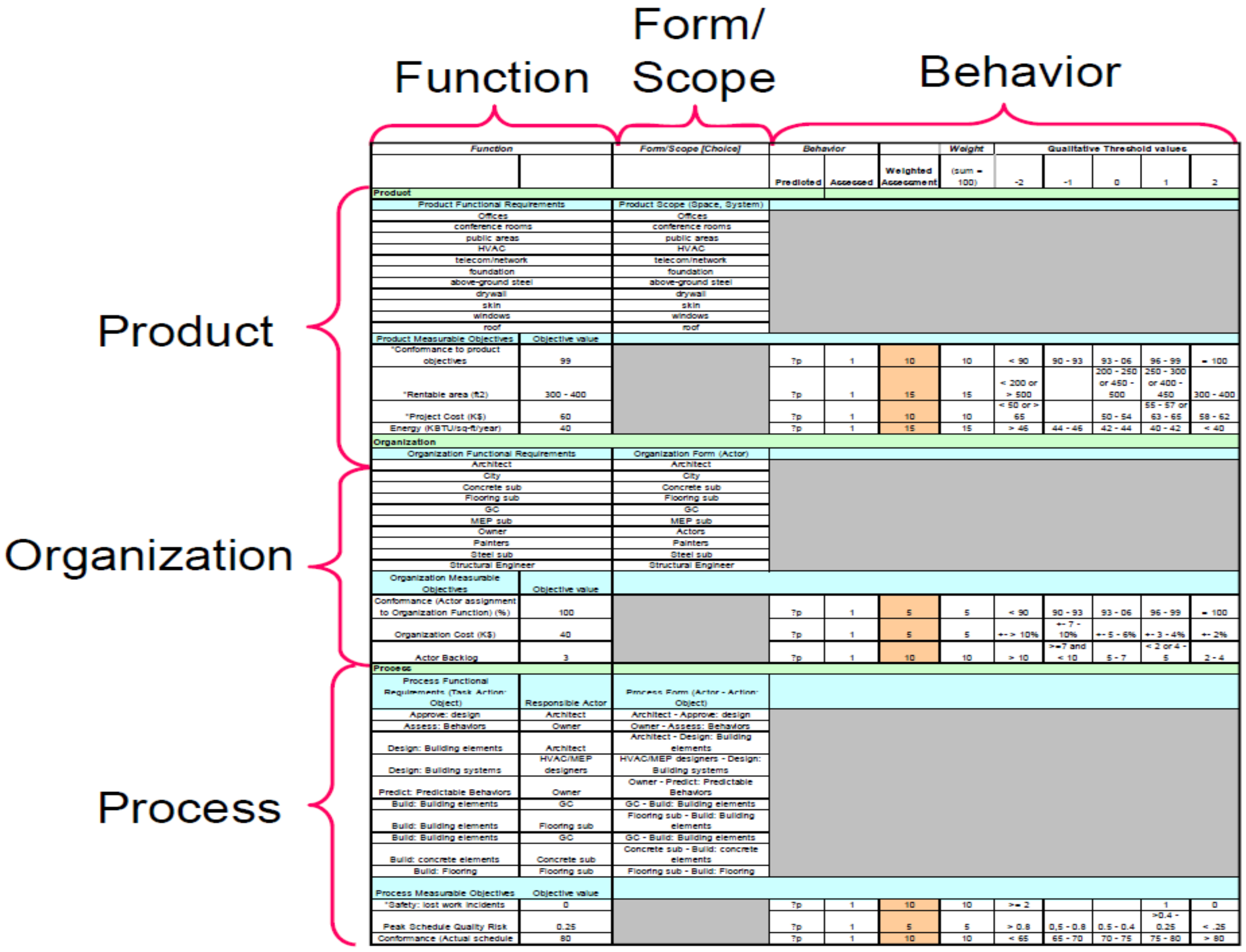
A POP model layout

	Function: Objectives	Form/Scope: Design choices	Behavior: predictions
Product	spaces, elements and systems	Designed spaces, elements and systems	Predicted cost ($)
	Measurable Objectives	Values	Predictions; Assessed values
Organization	Actors	Selected actors	Predicted cost (hours or $)
	Measurable Objectives	Values	Predictions; Assessed values
Process	Tasks	Designed tasks	Predicted cost (days or $)
	Measurable Objectives	Values	Predictions; Assessed values

Note how the matrix let's you organize and summarize all kinds of functions, choices, results, costs and behaviors in the construction project

Use these summarizations to observe and assess outcomes to improve management decisions and perform the project at higher levels of quality and achievement

POP model structure



Function		Form/Scope [Choice]	Behavior Predicted	Assessed	Weighted Assessment	Weight (sum = 100)	Qualitative Threshold values -2	-1	0	1	2
Product											
Product Functional Requirements		Product Scope (Space, System)									
Offices		Offices									
conference rooms		conference rooms									
public areas		public areas									
HVAC		HVAC									
telecom/network		telecom/network									
foundation		foundation									
above-ground steel		above-ground steel									
drywall		drywall									
skin		skin									
windows		windows									
roof		roof									
Product Measurable Objectives	Objective value										
*Conformance to product objectives	99		?p	1	10	10	< 90	90 - 93	93 - 06	96 - 99	= 100
*Rentable area (ft2)	300 - 400		?p	1	15	15	< 200 or > 500		200 - 250 or 450 - 500	250 - 300 or 400 - 450	300 - 400
*Project Cost (K$)	60		?p	1	10	10	< 50 or > 65		50 - 54	55 - 57 or 63 - 65	58 - 62
Energy (KBTU/sq-ft/year)	40		?p	1	15	15	> 46	44 - 46	42 - 44	40 - 42	< 40
Organization											
Organization Functional Requirements		Organization Form (Actor)									
Architect		Architect									
City		City									
Concrete sub		Concrete sub									
Flooring sub		Flooring sub									
GC		GC									
MEP sub		MEP sub									
Owner		Actors									
Painters		Painters									
Steel sub		Steel sub									
Structural Engineer		Structural Engineer									
Organization Measurable Objectives	Objective value										
Conformance (Actor assignment to Organization Function) (%)	100		?p	1	5	5	< 90	90 - 93	93 - 06	96 - 99	= 100
Organization Cost (K$)	40		?p	1	5	5	+- > 10%	+- 7 - 10%	+- 5 - 6%	+- 3 - 4%	+- 2%
Actor Backlog	3		?p	1	10	10	> 10	>=7 and < 10	5 - 7	< 2 or 4 - 5	2 - 4
Process											
Process Functional Requirements (Task Action: Object)	Responsible Actor	Process Form (Actor - Action: Object)									
Approve: design	Architect	Architect - Approve: design									
Assess: Behaviors	Owner	Owner - Assess: Behaviors									
Design: Building elements	Architect	Architect - Design: Building elements									
Design: Building systems	HVAC/MEP designers	HVAC/MEP designers - Design: Building systems									
Predict: Predictable Behaviors	Owner	Owner - Predict: Predictable Behaviors									
Build: Building elements	GC	GC - Build: Building elements									
Build: Building elements	Flooring sub	Flooring sub - Build: Building elements									
Build: Building elements	GC	GC - Build: Building elements									
Build: concrete elements	Concrete sub	Concrete sub - Build: concrete elements									
Build: Flooring	Flooring sub	Flooring sub - Build: Flooring									
Process Measurable Objectives	Objective value										
*Safety: lost work incidents	0		?p	1	10	10	>= 2			1	0
Peak Schedule Quality Risk	0.25		?p	1	5	5	> 0.8	0,5 - 0.8	0.5 - 0.4	>0.4 - 0.25	< .25
Conformance (Actual schedule	80		?p	1	10	10	< 65	65 - 70	70 - 75	75 - 80	> 80

i-Rooms and ICE sessions

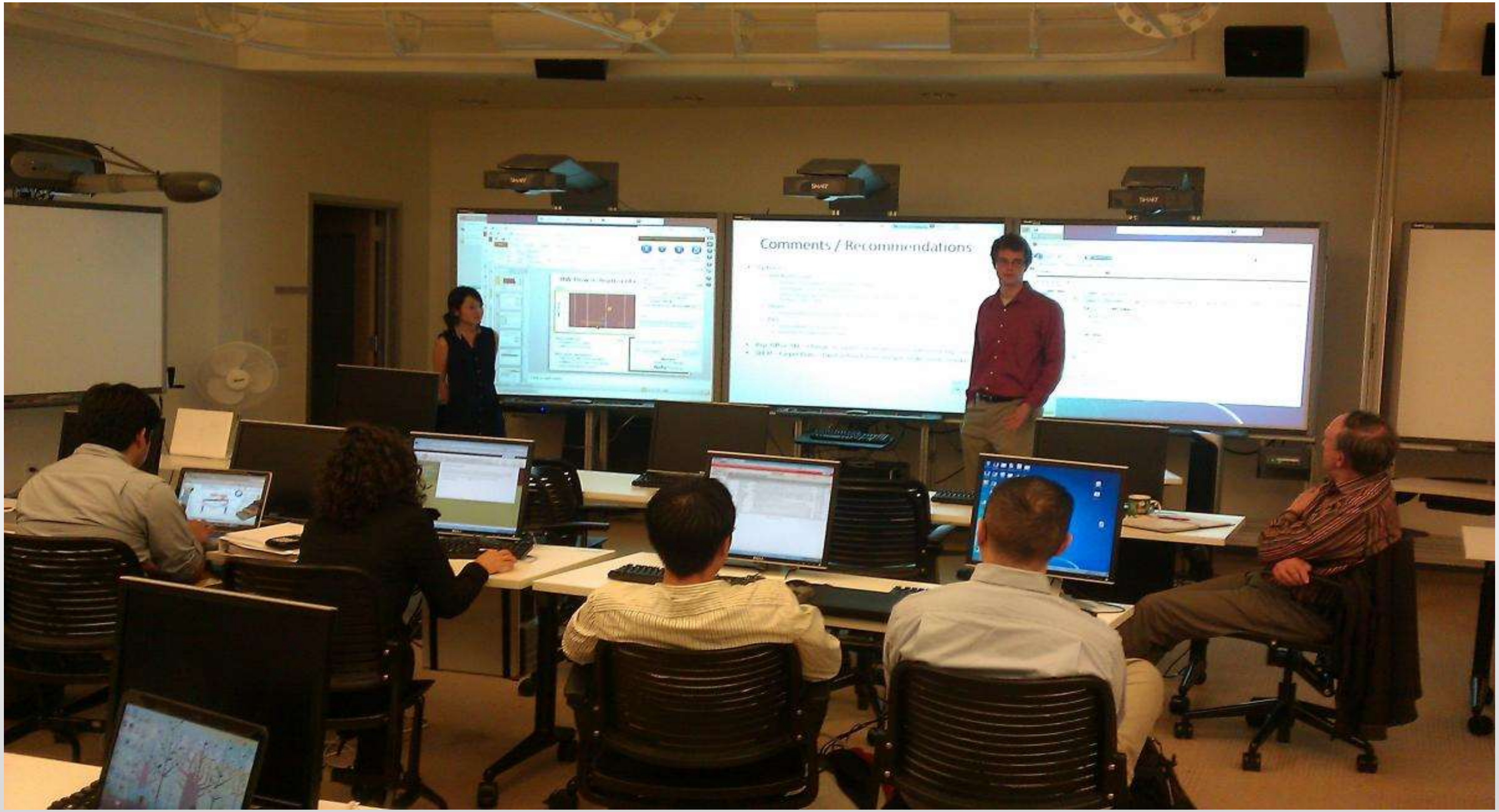
- i-room = integration room, intelligent room, interactive room
- Complex construction aspects are simulated virtually, not on site
- Project team is face-to-face
- Immediate decision making, resolutions, minutes of decision and response latency, not weeks
- Environment stimulates innovative solutions that would not otherwise be developed
- i-rooms are windowless, contain seats for 25, three SmartBoards, those in attendance bring their lap tops
- There are 2 much smaller ‘break-out’ rooms for small group sub-sessions within the ICE session

A standard i-room set up of three SmartBoards and their uses

Virtual 3D model	POP matrix	Active commentary

An i-room in use

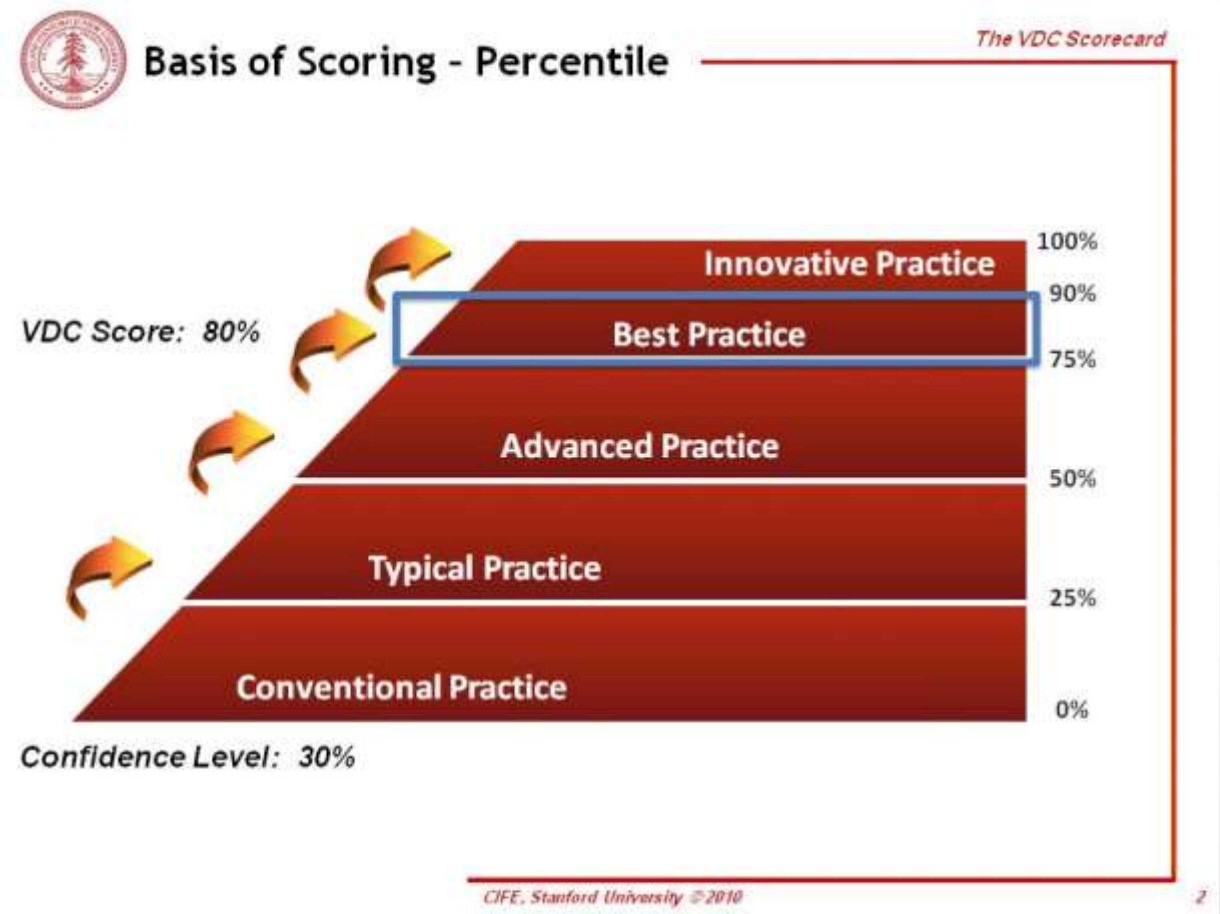
An i-room in action



Working in an i-room

VDC scores and construction achievements versus lesser project outcomes

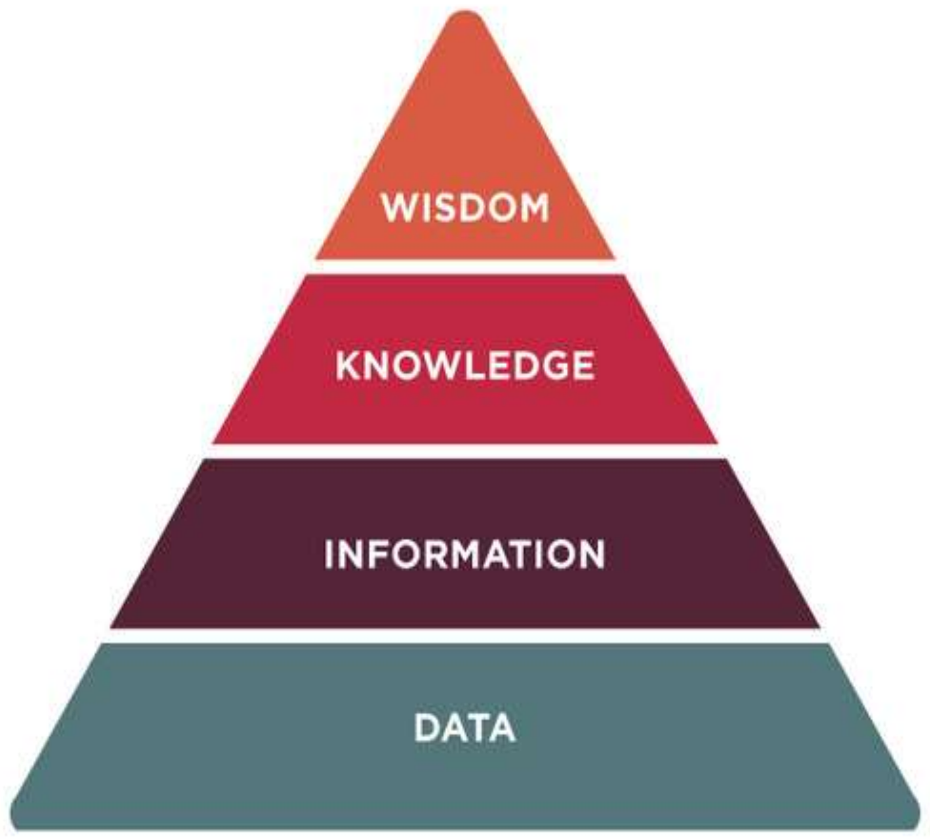
Driving AEC towards a culture of measurement such as already possessed by manufacturing



From data to wisdom with iTWO and VDC

- Data → information → knowledge → wisdom

- *D* Raw unconnected data
  Just symbols, no significance beyond its existence
- *I* Organized into useful answers
  Has meaning of “what”, “when”, “where” and “who”
  Structured and useful
- *K* The achievement of education
  The application of acquired information to find the “how” through action — This is *learning*
- *W* Rendering a thoughtful judgment by a wise man
  A moving from the learning of knowledge to *understanding*
  Gives rise to the appreciation of “why” in the wise individual



VDC research centers

Stanford University — Palo Alto, California

CIFE — **C**enter for **I**ntegrated **F**acility **E**ngineering

Carnegie Mellon University — Pittsburgh, Pennsylvania

MOSAIC — **M**anagement of m**O**del based **S**ensor driven **A**dvanced **I**nfrastructure and **C**onstruction systems

Georgia Tech — Atlanta, Georgia

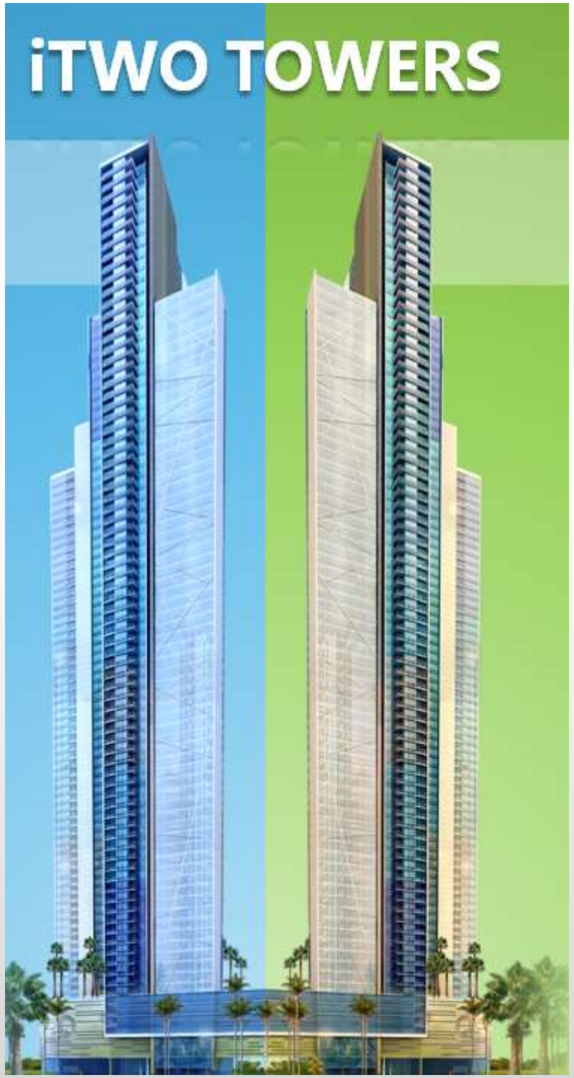
DBL — **D**igital **B**uilding **L**aboratory

University of Texas — Austin, Texas

FSCAL — **F**ield **S**ystems and **C**onstruction **A**utomation **L**aboratory

iTWO towers in Atlanta

Research partnership with Georgia Tech



Disruptive technology

Disruptive technology

VDC and BIM are "disruptive technologies." What is a disruptive technology? How is it defined? Why is it called "disruptive"? Why can it be important to you? How can they affect your life?

The term was first published in a 1995 article by Harvard's Clayton Christensen. A disruptive technology is a **new** technology, but the disruption isn't caused by the mere existence of the technology but by the changes caused by a **new application** of the new technology.

Large corporations, by nature (not by chance), succeed by working with **sustaining** technologies (not disruptive ones). These are existing ways and methods of performing the tasks needed for the business entity to do well. They continuously develop and, by increments, improve the existing technologies for current, established products or services and are very good at it. But because they are continually working with sustaining technologies, they fail to see the importance of new technologies that can eventually get them. They dismiss them, they don't see the importance at that time.

Disruptive technology

A disruptive technology is one which begins as a rough thing and does not possess a way in which it can be applied to the market in a meaningful way. Only a small number of people look at the new object and say, “That’s a really good thing. Let’s use it to . . . . .”. The new technology may have many errors and problems because of its newness and these may cloak the potential that the new thing commands.

The unimaginative management will call it “impractical” and “useless”, a “plaything”, if they even are aware of it at all. Their blindness does not let them see value in the new things that, even though they might even see something in the new items, they quickly banish those thoughts because they are menacing to the status quo of their operations.

They don’t see how these new things can save them tremendous amounts of money, time, and chances at bigger markets because these new technologies do not appear to have anything to do with the company’s tasks. Then they wonder in stupefied astonishment why they are losing market share and are about to go out of business. It is because it is impossible for their brains to distinguish between their familiar **sustaining** technologies and disruptive ones. Eventual failure occurs if this inability to distinguish continues.

Disruptive technology

As a disruptive technology matures, it gets better and better, less expensive, more easily used and, due to new applications that allow it to be used by a truly wide audience, a true market, it begins to disrupt the established businesses tied to their sustaining technologies.

Much of the refusal of the established, sustaining technology using companies is that when a new technology becomes somewhat available, the non-wealthy, low profit customers are the ones who first welcome and adopt it. The sustaining technology entities do not have an interest in serving or working with this low-margin, small market set of people. But they will when the set grows.

But then it may be too late and they are left behind. There are few things that are more sad and more preventable by knowledgeable individuals.

Disruptive technology

"I don't like the sound of 'disruptive' ... can we get some mildly troubling technology?"

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Thank you