From BIM to VDC to the Digitalization of Construction

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- Director, CIFE (Center for Integrated Facility Engineering)
- Foreign Member, Royal Swedish Academy of Engineering Sciences
- 100% funded by industry
  - Building owners
  - Design and construction companies
  - Software and hardware vendors
- 1988-2000
  - Building Information Modeling (BIM)
- 2000-2010
  - Virtual Design and Construction (VDC)
- 2010+
  - Optimize Facility Performance
VDC Certificate Program Introductory Course at Veidekke, Jan. 23 to 27, 2017
VDC Overview

- Client Business Objectives
- Project Objectives
- Integrated Concurrent Engineering (ICE)
- Product Modeling BIM++
- Project Production Management
Productivity Paradigm

Productivity in construction lags productivity in other industries

Labor Productivity for construction industry vs. all non-agricultural industries

By Paul Teicholz
Based on U.S. Department of Commerce data
Why do we call it Virtual Design and Construction?

• Term created by CIFE around 2002
• Highlight
  • Integration of design and construction
  • Virtual (which was quite new then)
• Sound familiar and new
• Include entire life cycle perspective
• Focus on design and construction because they largely shape a facility’s life cycle performance

• Key relationships
  • BIM is a key element of VDC, but BIM does not equal VDC
  • VDC is a method to carry out Integrated Project Delivery (IPD)
These capabilities have changed dramatically

Digital modeling

Amount of data we can handle

Communication

©2017 Pictures courtesy SPS, Beck, and DPR
Better Buildings
Owner Value Through Technology and Applied Innovation

©2017

CLARK PACIFIC
Precast. Building for Life.
Clark Pacific’s BIM Value on Projects
Good VDC practice looks like this ...
... and achieves performance like this

Everyone is working on the right tasks at the right time all the time.

We are designing what the client wants.

We will be productive as possible next week.

We are certain that everything fits.

We are sure that we are build everything safely and with the best methods.

We are installing everything fast and right the first time.

We are installing everything accurately based on the latest, correct information. Paper-free.

We gave the client exactly what he wanted.
VDC method to give the client everything he wants

Open whole scope of hospital on budget and 30% earlier than typical

Highly reliable construction

Confirm constructability of detailed design

Combine everyone’s detailed design

Everyone works with the same plan
Framework to organize digitalization factors

Factors driving firm’s efficiency
Factors driving market

Factors not under firm’s control
Factors under firm’s control

Framework developed together with Carlo Ratti at the Bouygues Innovation and Sustainability Board meeting on Oct. 13, 2015.
Factors driving firm’s efficiency

3D printing
Knowledge dissemination
Cloud-based project management dashboard
Parallel cloud computing
Big data
Augmented Reality
Automated Laser Scan to BIM
Cloud-based information delivery to sites

Factors driving market

Productization
Product as a service
Optimization
Virtual Reality
Telerobotics
## Additively Manufactured vs. Conventionally Manufactured Curtain Wall Bracket

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>AM</th>
<th>CM</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Technology Applicability</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>S Schedule (hours)</td>
<td>5-17</td>
<td>2</td>
</tr>
<tr>
<td>E Environmental impact (kg CO₂ eq.)</td>
<td>25-55</td>
<td>141</td>
</tr>
<tr>
<td>C Cost ($)</td>
<td>411 - 1,064</td>
<td>95</td>
</tr>
</tbody>
</table>
Knowledge Dissemination

Mother Of 4 Builds House From Scratch By Watching YouTube Videos

©2017
Cloud-based project management dashboard

START OF DAY

- Create Material Requests for planned work on SiteMan App
- Write Requests on Smart Card
- Collect Material at Plant
  - Data captured by Cabin Controller and Vehicle Unit
- Verify at Weigh-Station
  - Data captured by Cabin Controller and Vehicle Unit
- Whole day’s activity visualized and analyzed on Software portal
- Work plan for next day created based on recommendations by Einsite

END OF DAY

- Drop material at work-site, and perform work using relevant machinery
- Acknowledgement made by supervisor ID card on device
- Enter Daily Progress Reports
- Entries cross checked with device Data

- Reduced data-entry (only once at start and end of day)
- Minimal Training required
- All data and activities verified by Device based Locational and Transactional Data, in the context of the project plan and operations
Productization

Materials List

- Wire-in Photocell for Outdoor Lights (2 wire installation)
- Basic Tools
- Electrical Taps
- Electrical Caps
- Glue Gun

Connect the other photocell wire to the light fixture.

How to Convert Any Outdoor Light to Turn on Automatically at Night

MiniSun E27 Edison Screw 3 W "Dusk to Dawn" LED Bulb [Energy Class A] by MiniSun

Price: £9.99 & FREE Delivery in the UK on orders dispatched by Amazon over £20. Details

In stock.

Want it delivered by Today, 6pm-10pm? Order within 9 hrs 23 mins and choose Evening Delivery at checkout. Details

Dispatched from and sold by Amazon. Gift-wrap available.

Note: This item is eligible for click and collect. Details

2 new from £9.99 5 used from £8.91

Colour: 3W Edison Screw E27

- MiniSun Branded LED Dusk Till Dawn Sensor Light Bulb
- Automatically Switches on When it Goes Dark, and Switches off When it Goes Light
- Ideal for Providing Effective Security Lighting
- 15 x SMD (Surface Mounted Diodes) LED Chips. 250 Lumens. 120 Beam Angle
- Use in Suitable Enclosed Outdoor Light Fittings to Illuminate Driveways, Garden Patios, Porches and More

See more product details
Product as a Service

Material Health

Careful consideration of the individual components that go into our wide portfolio of flooring products is a vital part of Shaw’s commitment to sustainability. Our vigilant perspective on minimizing the impact of the materials used in the manufacturing of our products led us to align with the Cradle to Cradle philosophy, which focuses on creating products that are safe, and that can be reused and recycled.

Certifications

We are committed to transparency and third party verification of our rigorous sustainability efforts. Our product certifications include Cradle to Cradle Certified™, GREENGUARD, CRI Green Label Plus, FloorScore, NSF 140, and numerous others. To further support our transparency efforts, we also maintain Health Product Declarations (HPDs) for all commercial carpet products and Living Building Challenge (LBC) Compliant Declare labels for EcoWorx® tile products.

Our commitment to transparency: inventory, disclose, assess, validate, optimize
Accurate, timely look-ahead schedules would be helpful for complex projects in the finishing phase.

- 12 types of crews
- 210 rooms per floor
- 20 operations per room on average

Precedence constraints
- Crew availability
- Room availability and priority
- Blocking constraints
- Zone constraints

Carnegie Mellon University (CMU) campus project in Doha, Qatar
Collaboration with CCC
Content of a LAS for the finishing phase

<table>
<thead>
<tr>
<th>Room ID</th>
<th>When</th>
<th>What</th>
<th>Who</th>
</tr>
</thead>
<tbody>
<tr>
<td>COR1</td>
<td>1/2/2009</td>
<td>[E001]; [Conduit and Box]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/5/2009</td>
<td>[E001]; [Conduit and Box]</td>
<td></td>
</tr>
<tr>
<td>ELE1</td>
<td>1/6/2009</td>
<td>[C001]; [Dry Wall]</td>
<td></td>
</tr>
<tr>
<td>ELE2</td>
<td>1/7/2009</td>
<td>[C001]; [Dry Wall]</td>
<td></td>
</tr>
<tr>
<td>IDF1</td>
<td>1/8/2009</td>
<td>[C001]; [Dry Wall]</td>
<td></td>
</tr>
<tr>
<td>IDF2</td>
<td>1/9/2009</td>
<td>[C001]; [Dry Wall]</td>
<td></td>
</tr>
<tr>
<td>PLT1</td>
<td>1/12/2009</td>
<td>[C001]; [Dry Wall]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/13/2009</td>
<td>[C001]; [Dry Wall]</td>
<td></td>
</tr>
</tbody>
</table>

05/05/08 → 05/19/08 → 07/10/08 → 07/17/08 → 07/31/08 → 08/14/08 → 08/21/08
With automation the optimal resource allocation can be determined.

The schedule with the shortest duration is not the schedule with the lowest cost.
Working in **as many locations as possible** does not lead to a schedule with minimum cost.

Making **crews as busy as possible** leads to the schedule with minimum cost.
Flow-based Construction Site Management

Nelly Garcia-Lopez
In Collaboration with Graña y Montero

September 2016
Case study: Applying the flow-based site management method

Project info:
• Graña y Montero jobsite in Peru
• 11 basements + 21 floors
• 18-week period (8 weeks on site)
• Structural phase

Objectives:
1. Can the flow-based model represent the look-ahead plan?
2. Does the method help field managers make decisions during look-ahead and daily planning?
Case study project used best practices for production planning

- **Master plan**
  - Processes
  - Gross constraints

- **Takt plan**
  - Sector definition
  - Quantities
  - Trade sequence
  - Crew balancing

- **Look-ahead plan**
  - Constraints analysis
  - Productivity
  - PPC + reasons

- **Daily plan**
  - Quantities
  - Productivity
  - Daily PPC
  - Visual planning
Existing construction models do not formally represent, track, or quantify the activity flows.

What flow?

Build deck form A1 → Install slab rebar A1 → Pour slab A1

What caused the delay?

Concrete crew idle
Steel crew availability

Did one of these flows fail? By how much?

Are we representing all the flows?

Flow Key:
- Labor
- Workspace
- Precedence
- Materials/components
- Information
- Equipment
- External (Permits, inspections)
GyM case study data (18 weeks)

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Per week</th>
</tr>
</thead>
<tbody>
<tr>
<td># Activities</td>
<td>1,153</td>
<td>64</td>
</tr>
<tr>
<td># Flows</td>
<td>4,192</td>
<td>232</td>
</tr>
<tr>
<td># Data points</td>
<td>415,008</td>
<td>23,056</td>
</tr>
</tbody>
</table>

Large dataset for supporting:

- Performance analytics
- Predictive models (data mining + machine learning)

Total additional data collection effort: 45 hours
Augmented Reality

VeriCon HoloLens test at Riboton
https://www.youtube.com/watch?v=zyEZpwMmuLs&feature=youtu.be
Automatic as-built BIM from laser scans

In collaboration with Iro Armeni, Silvio Savarese, Amir Zamir, and Ozan Sener
“You will not find any paper drawings on this site.”
Mark Bartley, General Superintendent for General Contractor DPR on the $750M UCSF Mission Bay Hospital project in San Francisco, October 4, 2013
Optimizing Constructability to Reduce the Cost of Wind Energy

Research lead by Forest Flager in collaboration with EDF, AWS, and Mortenson
Roosevelt: Optimized Turbines

KEY

- = Existing Roads
- = Collector System
- = New Roads
- = Turbines
- = Buildable Area
## Roosevelt Results

<table>
<thead>
<tr>
<th>Design Alternative</th>
<th>Construction Cost (M USD)</th>
<th>Net Energy (GWh)</th>
<th>Cost of Energy (USD / MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>As Built</td>
<td>90.37</td>
<td>1450</td>
<td>36.28</td>
</tr>
<tr>
<td>Optimized Turbine Positions</td>
<td>-6.90 (8.2%)</td>
<td>1448</td>
<td>-0.22 (0.64%)</td>
</tr>
</tbody>
</table>
Design review by users with in a virtual reality room
Telerobotics

https://www.youtube.com/watch?v=p1HmgP9l4VY
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<td>dashboard</td>
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<td>Automated Laser Scan to BIM</td>
<td>Telerobotics</td>
</tr>
<tr>
<td>Cloud-based information delivery to sites</td>
<td></td>
</tr>
<tr>
<td>Opportunities</td>
<td>Threats</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>… it had access to perfect as-built and as-working data on existing buildings for free?</td>
<td>… others had perfect data about existing buildings</td>
</tr>
<tr>
<td>… it could offer truly meaningful performance guarantees, i.e., really give the customer what s/he wants?</td>
<td>… building owners demanded performance guarantees before you can offer them?</td>
</tr>
<tr>
<td>… it was engaged not only for projects but also for “building products”?</td>
<td>… engineering, coordination, and design and construction management became part of a product and not a service?</td>
</tr>
<tr>
<td>… it could automate 50% of its work?</td>
<td>… 50% of current work was automated by others?</td>
</tr>
<tr>
<td>… attracted the top graduates?</td>
<td>… all the smart graduates worked in small project teams put together from their network with fluid and massive IT support?</td>
</tr>
<tr>
<td>… it could offer engineering, coordination, and management for free?</td>
<td>… others offered engineering, coordination, and management for free?</td>
</tr>
</tbody>
</table>
The future looks **different**, but the future is **now**

**Strategic Implications**

- Projects vs. Corporate
- Staff Development
- Partners