Trusting Shared Digital Content: Enhancing Multi-Trade Prefabrication

John Cribbs, Ph.D., CDT, LEED AP
Let’s Start Small...

851 Square Feet

Modular/Prefab Residence – “SHADE”

Aggressive Schedule, Demand for High-Quality, Intricate Systems & Low Budget
It’s Easy… It’s Just A Process… A Better Design…

1: radiant barrier + closed-cell, spray foam insulation
2: phase change materials (PCM)
3: clay finish (controls humidity)
4: shade
5: efficient living
6: natural ventilation
7: photovoltaic panels
8: led lighting
9: radiant heating/cooling
10: fan coil unit
It’s Easy... It’s Just A Process... A Better Design...
It’s Easy… It’s Just A Process… A Better Design…
It's Easy... It's Just A Model... A Better Design...

We Started Small... So What...?
It's NOT Easy...!
It's A Process... Not Just A Model!
A Better Design Doesn’t Mean Better Planning & Follow-through!

**Takeaway Question:** “How can a BIM better translate from design to construction in order to enhance the physical construction process?”
Let’s Go BIG...!

1 Million Square Feet
State of the Art, High-Volume Semiconductor Manufacturing Facility (Fab)
8 million man hours, “Class 10” clean room, complex systems & $3 billion investment
It’s Personal... It’s A Quest... A Drive Towards Better...
It’s Personal… It’s A Quest… A Drive Towards Better…
We Went BIG... So What...?

Complexity Can Be Simplified...!
It’s Still Just A Process...!
Better Planning & Follow-Through is Just As Critical...!

**Remaining Takeaway Question:** “How can a BIM better translate from design to construction in order to enhance the physical construction process?”
Let’s Look At Industry @ Large…!

Unlimited Square Feet
Diverse Construction Types
Demand for Reduced Schedule, Higher Quality, Cutting-Edge Components & Tight Budgets
The (Billion Dollar) Problem...

The US will spend $177.5 Billion in labor costs on non-optimal activities.

Source: FMI, 2018
The (Billion Dollar) Problem...

The US will spend $177.5 Billion in labor costs on non-optimal activities.

Source: FMI, 2018
The (Billion Dollar) Answer...
The (Billion Dollar) Answer...
But How Do We Get Here...?
“How can a Building Information Model (BIM) better translate from design to construction, in order to enhance the physical construction process?”
Which Led To Another...

“Can on-site headcount be reduced during construction?”
And Another... And Another...

“...construction of what?”

“...total headcount or job-specific headcount?”

“...physical construction or digital construction?”
Understanding the Inquiry

- Building Information Modeling (BIM)
- BIM & Interoperability
- Integrated Project Delivery
- Lean Construction

- Semiconductor Manufacturing Facilities
- Retrofit Construction Project Management
- Retrofit Construction Existing Conditions Capture
- BIM in Retrofit Construction

- Offsite Construction Techniques
- PPMOF
- Shipbuilding / Automotive / Aerospace
- BIM + Prefabrication

BIM Content Generation
“How can a **Building Information Model (BIM)** better **translate from design to construction**, in order to enhance the physical construction process?”

“Can on-site **headcount** be **reduced** during construction?”

**And Led To An Inquiry Defined:**

*Hypothesis*: Accuracy of geometry is the key component.
Focusing On The Inquiry To Validate

- Off-Site Fabrication
- MEP/Process & Specialty Piping
- Labor Time Utilization Rates
Single Trade Test:
Virtual VS. Traditional Construction
An Introduction to the “Cutting-Edge”

**Virtual Construction**
- Design Model generated
- Fabrication sheets plotted from design model
- Fabrication/Kitting
- “Just in Time” delivery
- Assembly per labeled kits

**Traditional Construction**
- Design and planning performed on site
- Estimated material orders
- Manual layout and installation on site
On With The Experiment!
Ok guys, time's up. Let's look at the numbers.
“Making prefabrication successful requires a cultural mindset, CEO’s, project managers, estimators, superintendents – everyone has to buy into it. It needs to be throughout the entire company, top to bottom. That is the only way it will work effectively.”

Aaron Thompson, VP of Design & Fabrication – Corbins Electric (2017)
Case Study Analysis:
Defining & Scaling the prefabIM Workflow
Current State Process for Retrofit Prefabrication

- **Source:** John Cribbs, PhD Candidate - Arizona State University
- **Data Collection Period:** 28 April, 2015 to 17 June, 2015

Type of Geometry

- **Archived Geometry**
- **Construction Original Information**
- **Design Original Information**

**Dynamic Scheduling**
- Tool Layout Package
- Federated Model
- Laser Scanning

**Critical Scheduling**
- Design P&ID
- Construction Model
- Spool Drawings
- Installation Drawings

**Project Timeline**

**Nodes:**
- Owner
- A/E
- BIM Coordinator
- Trades
Use of Geometry

Current State Process for Retrofit Prefabrication

- Design Original Information
- Construction Original Information
- Archived Geometry

Dynamic Scheduling

- Tool Layout Package
- Federated Model
- Laser Scanning

Critical Scheduling

- Design P&D
- Construction Model
- Spool Drawings
- Installation Drawings
- Archived Model/Drawings

Source: John Cribbs, PhD Candidate - Arizona State University
Date: 21 June, 2016
Timing of Geometry

Current State Process for Retrofit Prefabrication

Design Original Information

Construction Original Information

Archived Geometry

Dynamic Scheduling

Critical Scheduling

Owner

A/E

BIM Coordinator

Trades

Source: John Cribbs, PhD Candidate - Arizona State University
Date: 21 June, 2016
Initial Observations

- Need to utilize a **more efficient** approach to utilization of headcount
- Lacking a **verifiably** structured and **coordinated** approach to **prefabrication**
- **Field** conditions constantly in a **state of flux**
Value Add vs. Non-Value Add vs. Necessary (LEAN framing)

- Current State of Performance
  - Direct Work – **Value Added Time**
    - Modeling a component to be pre-fabricated
    - Modeling detail needed for installation
  - Support Work – **Necessary Non-Value Added Time**
    - Processes needed to correctly model
  - Delays – **Non-Value Added Time (Waste)**
    - Re-verification
    - Re-work

Aggregate Totals Initial State

- Total Direct: 19%
- Total Support: 56%
- Total Delays: 25%

Source: John Cribbs, PhD, LEED AP, CDT
Data Collection Period: 28 April, 2015 to 17 June, 2015
Type of Geometry

Dynamic Modeling Process for Retrofit Prefabrication

- Design Original Information
- Base-Build Model
- Background Federated Model
- Construction Model
- Fabrication Model
- Installation Model
- Laser Scanning
- Verification
- Validation

Critical Scheduling
- Tool Model
- Design P&ID

Proactive Scheduling

Critical Scheduling
- Background Federated Model

Static Geometry
- Laser Scanning
- Verification

Dynamic Geometry
- Validation

Project Timeline

Source: John Cribbs, PhD Candidate - Arizona State University
Date: 23 June, 2015
Dynamic Modeling Process for Retrofit Prefabrication

Timing of Geometry

Critical Scheduling
Proactive Scheduling

Drawing:

Source: John Cribbs, PhD Candidate - Arizona State University
Date: 23 June, 2015
Testing The Ideal State

- Trade Intervention Process
  - **Compressed Schedule** (opposite of prefaBIM recommendation) – Focusing on TIMING of Geometry
  - **Laser Scan based modeling process** (modeling tool vs. prefaBIM verification/validation tool) – Focusing on TYPE & USE of Geometry
Aggregate Direct Observations (BIM) – Compressed Schedule

• Direct Work – **Decreased by 6%**
  • Shifted to necessary support work
  • Demand to meet schedule reduction

• Support Work – **Increased by 11%**
  • Cheaper than paying for non-value added time (delays)
  • Non-Standard Reality capture process – *increased trade coordination*
  • Addition of 2-man laser scanning crews (*per trade*) vs. additional modelers (*INCREASED COST!*)

• Delays – **Decreased by 5%**

Source: John Cribbs, PhD, LEED AP, CDT
Data Collection Period: 28 April, 2015 to 17 June, 2015
Aggregate Direct Observations (BIM) – Laser Scan Based Process

• Direct Work – **Decreased by 6%**
  • Shifted to necessary support work
  • Realized the importance of accurate geometry to expedite prefabrication

• Support Work – **Increased by 14%**
  • **Cheaper** than paying for non-value added time (delays)
  • 5% less time spent in preparatory and model setup work – *verified existing conditions* and agreed upon tolerances
  • 6% less time coordinating due to lack of trust across trades - *Standard reality capture process to generate accurate, assumed geometry!*

• Delays – **Decreased by 8%**

Source: John Cribbs, PhD, LEED AP, CDT
Data Collection Period: 28 April, 2015 to 17 June, 2015
Scaling the Question:
So What...?
Prefabrication is prevalent...

Project inefficiencies and improved technologies are driving prefabrication.

The amount of project work using prefab has almost tripled between 2010 and 2016.

Photo Credit: FMI/BIMForum 2017
But It Requires A Different Mindset!

FMI/BIMForum Survey Results
Prefabrication Study
2017

Opportunity = 86% of industry!
A Fundamentally Different Mindset!

Three key challenges for making prefabrication effective:

- Culture
- Lack of Commitment
- Outdated Control Mindset

48% of respondents see less than 5% in savings on total annual labor hours related to prefabrication.
Conclusion

“The **planning efforts** surrounding the development of **accurate** and **reliable/trusted geometry** is the most important component for **successful** implementation of a **BIM workflow** when transitioning from design to construction.”
“There is no single silver bullet solution for productivity... Lean, BIM and collaboration are all powerful tools, but they need to be used together to deliver the most dramatically improved results.”

“The challenge with doing prefab is, it’s not just thinking about prefab. Instead, it’s more about thinking of how your prefab strategy fits within the overall strategy of delivering a project.”

Atul Khanzode, Ph.D. – Head of Tech. & Innov., DPR Construction (2017)
Scaling the Solution
Ongoing & Future Opportunities
Focused Approach

- Prefabrication
  - BIM to Shop Floor Drawings (Cut Sheets)
  - Lean Construction Setup for Production of Prefab Components

- Exterior Insulation & Finish System (EIFS)
  - Balloon Framed Building Design
  - Integral Color & Finishing Requirements
Panelized System - EIFS

Exterior EIFS Panel Materials
1. Metal framing
2. Substrate
3. Water proofing
4. Adhesive
5. Foam insulation
6. Mesh
7. Base coat
8. Primer
9. Finished texture
10. Water proofing
Engaging BIM – Direct Output from Model
Leveraging Manufacturing – 24 Production Stations
Where We Currently Stand

- 9 Cameras installed in prefab facility
- Several months of recorded data (hundreds of hours of footage)
- Machine learning has allowed cameras to recognize
  - Objects in prefab facility
  - Workers on the assembly line
  - Prefabricated panels in production

Discussion - Up & Coming

- Interject **Machine Learning** and **Artificial Intelligence (AI)** Technology
  - Automate data capture
  - Enhance data processing and analysis
- Compare, intervene and scale towards an “Ideal State” Workflow
Type, Use & Timing of Geometry Matters Most!

Dynamic Modeling Process for Retrofit Prefabrication

- **OWNER**
- **A/E**
- **BIM COORDINATOR**
- **TRADES**

Design Original Information

Base-Build Model

Intelligent Construction Information

Critical Scheduling

Tool Model

Background Federated Model

Static Geometry

Laser Scanning

Verification

Proactive Scheduling

Design P&ID

Construction Model

Fabrication Model

Installation Model

Verification

Dynamic Geometry

Project Timeline

Source: John Cribbs, PhD, Candidate - Arizona State University
Date: 21 June, 2015
Thank You!

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