AEC Supply Chain Optimization
John Cribbs – PhD Candidate Arizona State University
Setting the Stage – Semiconductor Manufacturing
Current Situation

- Early Tool Set/Ramp Tool Set (Man-loading – Phased On-boarding)
  - 2000 workers in ballroom size space (stacked trades – reactive vs. proactive)
  - 300 tools in active install state
  - Lack of space for simultaneous operations
    - (linear vs. revolving schedule)
- Effects
  - $5 million / tool (owner driven)
  - Install schedule increases in duration
  - First to market becomes an issue
    - (dynamic nature of business model)
CONGESTION!

Image: Courtesy of Steering Committee

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Research Problem Statement

• Can headcount be reduced during tool installation?
  • Initial Observations
    • More efficient approach to utilization of headcount
    • Structured and coordinated approach to prefabrication
Platform to Begin Observations

Table 2. Relative value of BIM² for stakeholders

<table>
<thead>
<tr>
<th>Management Tier</th>
<th>Stakeholder</th>
<th>Relative Value of BIM²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 1: Business Operations</td>
<td>Owner - Operator</td>
<td></td>
</tr>
<tr>
<td>Tier 2: Project Management</td>
<td>Project Management Team (Owner, A/E, CM,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sub contractors)</td>
<td></td>
</tr>
<tr>
<td>Tier 3: Work-face Implementation</td>
<td>Work-face (Modeler, Foremen and Labor)</td>
<td></td>
</tr>
</tbody>
</table>

Image: Courtesy of Ghosh et al.
Platform to Begin Observations

**Focus**
- i1 – inconsistencies in as-built
- i3 – Clash on site (after installed per model)
- i4 – Waiting for communication

**Side Effect**
- i2 – Rework on prefabricated components
- i6 – Incomplete scope of other trade / scope not reflected in federated model

**Process Improvement**
- i5 – Non-value added time spent on avoidable manual work due to lack of technology use

Image: Courtesy of Ghosh et al.

Interruptions on site due to error in BIM

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Concept

• Hypothesis:
  • By preplanning for a geometrically reliable BIM, with accurate connections and embedded prefabricated components, we will reduce the amount of worker’s onsite.

Images: Courtesy of Steering Committee

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Concept

• Hypothesis:
  • By preplanning for a geometrically reliable BIM (CAD), with accurate (tolerant) connections (static geometry vs. dynamic geometry) and embedded prefabricated components (volumetric approach vs. linear approach), we will reduce the amount of worker’s onsite (per tool – revolving schedule/critical chain vs. stacked schedule)

Images: Courtesy of Steering Committee

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Is BIM necessary for successful off-site prefabrication?

Exploration into alternative installation (multiple opportunities)

• **STEP ONE:** Building Information Modeling (BIM)
  • Coordination - advanced technology workflow
  • Enables off-site opportunities through alignment

• **STEP TWO:** Focus = Off-site fabrication
  • Displacement of labor – essential labor still embedded on-site
  • Controlled environment (for the manufacturing of static components)
  • Overlap in scheduling (theoretical decrease in duration) –
  • On-site installation = dynamic component (validation needed to close the loop)
Current State Process Map
Current State Process for Retrofit Prefabrication

Design Original Information

Construction Original Information

Archived Geometry

Background Model

Dynamic Scheduling

Critical Scheduling

Source: John Cribbs, PhD Candidate - Arizona State University

Date: 31 June, 2016
Current State Process for Retrofit Prefabrication

Source: John Cribbs, PhD Candidate - Arizona State University
Date: 21 June, 2015
Step One - Immersion

• Methodology
  • Direct Observations
    • 8 week period
    • 7 modelers - 3 trades
    • Random + Scattered Scheduling
  • Un-structured Interviews
  • Participant Observation
    • Weekly PIT Meetings
    • Weekly Electrical + Mechanical Trade Meetings

<table>
<thead>
<tr>
<th>Total Duration of Observations</th>
<th>Total Duration of Meetings Observed</th>
<th>Average Observations per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>3930 Mins</td>
<td>1260 Mins</td>
<td>741.43 Mins</td>
</tr>
<tr>
<td>65.50 Hours</td>
<td>21.00 Hours</td>
<td>12.36 Hours</td>
</tr>
<tr>
<td>786 Data Points</td>
<td>252 Data Points</td>
<td>148.29 Data Points</td>
</tr>
</tbody>
</table>

Source: John Cribbs, PhD Candidate – Arizona State University
Data Collection Period: 28 April, 2015 to 17 June, 2015
Aggregate Direct Observations (BIM)

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

Source: John Cribbs, PhD Candidate – Arizona State University
Data Collection Period: 28 April, 2015 to 17 June, 2015
Building Information Modeling - NNVAT

Avg. time spent coordinating due to lack of trust
1.5 hours / 10 hour workday
(can be reduced)

Avg. time spent in a virtual facility
1.68 hours / 10 hour workday
(key)

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

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Delays on average:
1.4 hours / 10 hour workday
is due to re-modeling and re-verifying (Waste)

Source: John Cribbs, PhD Candidate – Arizona State University
Data Collection Period: 28 April, 2015 to 17 June, 2015
Building Information Modeling – Duplicated Time

Duplicate time on average:
1.75 hours / 10 hour workday

Waste – Time Shouldn’t Exist

Root Cause:
Incorrect federated model / lack of alignment with existing conditions / mistrust between trade models / overproduction

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

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Next Steps

• Introduce a **TOP-UP** Approach to Building Information Modeling

• Virtual Relationship to Physical Facility
  • **Timing** – Frozen Data: Reliability of handoffs
  • **Order** – Revolving Critical Issue for Fabrication (IFF): Reverse design process
  • **Proof** – Validation: install-to-model audit process to close modeling loop

• Adaptable Information
  • **Unified** – Standards: Model-based parameters for handoffs
  • **Propagation** – Perpetual Updates: Organic accuracy (model stacking)

Source: John Cribbs, PhD Candidate – Arizona State University
Ideal State Process Map
Dynamic Modeling Process for Retrofit Prefabrication

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

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

Source: John Cribbs, PhD Candidate - Arizona State University

Date: 22 June, 2015
Dynamic Modeling Process for Retrofit Prefabrication

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

- **Owner**
- **A/E**
- **BIM Coordinator**
- **Trades**

**Design Original Information**

- **Base-Build Model**

**Intelligent Construction Information**

- **Background Federated Model**

**Assumed Geometry**

- **Tool Model**
- **Laser Scanning**

**Static Geometry**

- **Critical Scheduling**
  - **Tool Model**
  - **Design P&ID**

- **Proactive Scheduling**
  - **Construction Model**
  - **Fabrication Model**

**Dynamic Geometry**

- **Validation**
- **Installation Model**

**Project Timeline**

Source: John Cribbs, PhD Candidate - Arizona State University
Date: 23 June, 2015
prefaBIM

• Reverse engineering a dynamic process
  • BIM + Uncertainty Principle
  • Technology + first to market
• Existing conditions capture / verification
• Ownership/Accountability of base-build DNA

Photos: Courtesy of Dr. Allan Chasey – Arizona State University

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Redefine Model Coordinator

Model Stacking = Perpetual Updates

Perpetual Updates = Organic Accuracy

BIM Commissioning Agent
Redefines the Model Coordinator
Discussion

• Rigorous front-end planning for BIM defines: prefaBIM
  • Proactive vs. Reactive - Redefine “Ownership” & Restructure “Accountability”
• Purpose
  • Define prefabrication constraints (creation of rules) – Construction DNA
  • Deliver reliable geometry within a virtually constrained environment (trust the rules) – Collaboration based on volumetric coordination
  • Disseminate reliable information to stakeholders (delivery) – Individual approach to the “I” in BIM
• Goal – Planned prefabrication within a constrained virtual framework will make physical installation more efficient (thus reducing on-site headcount)
Thank you!

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