Process-Based Digital Twin for Industrialized Construction Efficiencies

Presenter Names
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Ankur Podder | @ linkedin.com/in/ankurpodderisonearth/

LEADERSHIP FORUM
About the speaker

Colby Swanson

Colby Swanson is a serial entrepreneur and innovation strategist with 20 years in the building industry. He is currently the Managing Partner at Momentum Innovation Group (MIG), an innovation consulting firm helping clients drive transformation in their business and find unseen areas of opportunity and growth and also serves as the Exec. Director of the Modular Mobilization Coalition (MMC), made up of 15 modular construction companies who own and operate a nationwide network of two dozen factories delivering modular solutions to the apartment, hotels, and single family home markets.
About the speaker

Joseph Louis

Dr. Joseph Louis's research interest lies at the intersection of simulation, visualization, and automation within the context of construction operations. He draws upon concepts in these areas to provide construction managers with better means of planning, monitoring, and controlling their operations to improve safety, maximize productivities, and minimize equipment idle times. Dr. Louis is passionate about engaging with the broader community and has organized university-level TEDx talks.
About the speaker

Ankur Podder

Ankur joined the Industrialized Construction Innovation (ICI) team at NREL in 2019 with a focus on buildings advanced manufacturing and integration science. His research work aims to facilitate the integration of a wide range of energy efficiency strategies and distributed energy resources during factory production of permanent modular buildings. His work involves strategizing the blending of factory information modeling and building information modeling into NREL’s building energy modeling capabilities as well as accelerating whole-building systems integration in upcoming modular net-zero energy buildings.
“The future is already here, it’s just not evenly distributed.”

CHARLES GIBSON
Off-site Construction is Ending Local Monopolies of U.S. Construction

Marriott / DMD Modular

Polish built rooms Modular (168 units)

US built pedestal (traditional)

$0.70/mile

$300Bn of GDP

~1M jobs...hang in the balance
Labor to Material Split

2019 U.S. Total Construction Put-in-Place Value

LABOR

$0

$650,000,000,000

MATERIAL

$1,300,000,000,000
Shift from On-site to Off-site

2019 U.S. Construction Put-in-Place Value

LABOR

OFF-SITE

MATERIAL

$0

$650,000,000,000

$1,300,000,000,000
Embracing Productization and Prefabrication

Components

Assemblies

Modules (Volumetric)

Increasing Levels of Prefabrication
The Modular Factory "Dirty Little Secret"

Many of the ~200 modular factories in North America are struggling to increase production.
Optimizing the Offsite Factory

Many factories operate with daily PLANNED and UNPLANNED activities.

The Invisible Factory Dilemma

Digital Twin and Sensors tell you what ACTUALLY happens.
Bottlenecks in Modular Factory Stations
Bottlenecks in Modular Factory Stations
US Department of Energy
Advanced Building Construction (ABC) Initiative
Industrialized Construction as the prime catalyst and path forward

REduced COST AND TIME

IMPROVED PRODUCTIVITY

IMPROVED ENERGY EFFICIENCY?

40 Newly Selected Ventures Reimagine the “ABCs” of Building Construction to Enhance the Affordability and Effectiveness of Energy-Saving Measures

February 16, 2020

40 projects

$26.3 Million

29 organizations
Digital Twins in AEC Industry

• **What is a Digital Twin?**
  - Virtual model of a process and/or product that enables the pairing of virtual and physical worlds

• **Current Digital Twin Usage in AEC**
  - Building operation and maintenance (Qiuchen, et al. 2020)
  - Construction schedules for project management (Yusen et al. 2018)

• **Current Industry Focus on built product**
• **We want to focus on building process**
Process-based Digital Twin
Process Digital Twin Considerations

- Equipment
- Space
- Labor
- Materials

Discrete Event Simulation-Enabled Virtual Reality
Detailed modeling of work processes
Experimenting with different crew size
Insight into process and space usage
Discrete Event Simulation for Process Analysis

Discrete Event Simulation (DES): Method for simulating processes as discrete activities that are dependent on the availability of resources.
Drag and Drop Creation of Factory
Higher level overview of factory
Understanding resource interdependencies
Data Collection

How to obtain data for the virtual model?
Audio Data Pilot Testing

HAMMERING

Table Saw
Nail Gun
Idle
Hammering
Drilling

Seconds
IMU Data Pilot Testing

Inertial Measurement Unit (IMU)

Data from IMU

Pie chart: Working 40%, Idle 30%, Moving 30%
Computer Vision Pilot Testing: Workers

Quantify time spent by workers on activities
Computer Vision Pilot Testing: Modules

Utilize surveillance cameras
Automatically measure time spent in stations
Integration with existing workflows: Input to FIM

BIM Model of Module

Information Obtained
- Module Dimensions
- Number of Partition Walls

Use in Process Model
- Activity Durations
- Resource Constraints
Process-based Digital Twin

Factory Information Model for Industrialized Construction
Novel Capabilities of Advanced Time-and-Motion Study and Process-Based Digital Twin
Collect Data
Update Analysis

PHYSICAL FACTORY

Improve Insight

DIGITAL TWIN

<table>
<thead>
<tr>
<th>Station 1</th>
<th>Station 2</th>
<th>Station 3</th>
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Partner with leading factories and showcase projects to achieve optimal integration of energy systems within the emerging advanced manufacturing industry for buildings.
An Integrated Workflow to deliver Efficient Buildings

Input
- BIM Model
- Identified Energy Efficiency Strategies

Analysis
- Resource Requirements
- Discrete Event Simulation + Process-based Digital Twin

Output
- Key Performance Metrics
  - Time, Cost, Energy Efficiency Improvements
Energy Efficiency Strategies for Off-Site Integration

Selected strategies currently under study leveraging Process-Based Digital Twin

1- Advanced Envelope Strategies
   - Off-Site Wall Framing with Thermally Broken Studs for Low-Cost Thermally Efficient Envelopes
   - Aerosol-Based Sealing Technology for improved Airtightness of modular units

2- Smart Apartment Controls Platform
   - For Modular Grid-Interactive Efficient Buildings (modGEBs)
   - Occupant engagement platform

3- Integrated Mechanical Pod solution (Factory-Installed, In-Unit)
   - For Space Conditioning, Energy Recovery, and Water Heating

4- Factory-Assembled Building Solar Systems (FABSS)
   - For Solar PV, Building-integrated PV (BiPV), and In-Unit Battery Storage
Pilot Demonstration using Process-Based Digital Twin

In-Factory Aerosol-Based Sealing Process for Improved Air-Tightness of Built Product

Baseline: On-Site Sealing

Data Collection from Business-As-Usual Air Sealing Process for Site-Built

Time, Cost, Energy Efficiency Improvements
Pilot Demonstration using Process-Based Digital Twin

In-Factory Aerosol-Based Sealing Process for Improved Air-Tightness of Built Product

Strategy: In-Factory Sealing

Advanced Time and Motion Study: In-Factory Data Collection

Time, Cost, Energy Efficiency Improvements
Pilot Demonstration using Process-Based Digital Twin

In-Factory Aerosol-Based Sealing Process for Improved Air-Tightness of Built Product

Comparative Analysis using Discrete Event Simulation + Digital Twin

Baseline: On-Site Sealing

Strategy: In-Factory Sealing

**Efficient:** Starting at lower ACH than on-site

**Faster:** Reduce prep and sealing time by 40%-60%

**Efficient:** Have kits and tools ready as plug-and-play at the factory-floor

**Affordable:** Reach better product at lowest additional cost
Ongoing **Comparative Analysis using Process-Based Digital Twin**

In-Factory Wall Framing with On-Site installation of Continuous Insulation  
(vs)  
In-Factory Wall Framing with thermally-broken studs with no requirement for Continuous Insulation

**Baseline**  
**Strategy**

Time, Cost, Energy Efficiency Improvements
Ongoing Comparative Analysis using Process-Based Digital Twin

Centralized MEP System (vs) In-Unit Integrated MEP Pods

Baseline

Strategy

Time, Cost, Energy Efficiency Improvements
Guidance on Automation Integration and Continuous Improvement

Drag-Drop-Swap Station Module Geometries with real-time update to Performance Metrics

Increasing Levels of Automation: From Fully Manual Framing to Human-Supervised Machine-Mediated Framing

Time, Cost, Energy Efficiency Improvements
Process-Product Innovation

Integrated Design for Manufacturing and Assembly

- Better Product
  Affordable, net zero, and healthier
- Better Process
  Improving productivity, quality, and affordability of building construction processes

- Process Innovation
- Optimized Improvements
- Product Innovation
Impact of Digital Twin in Offsite Construction

Courtesy: MSC Cruises

Francis Henry Newbery