Evaluating Multiskilling in Residential construction projects Using Regional Industry Simulation

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IGLC 2019
Makerhoods

- Newark, NJ, USA
- 66 Residential apartments
- 10 Workshops for “Makers”
- Shopping/Food Court
- Founder w/ Lean Background
- Part of “Newark, NJ, Housing Market Area Central Submarket”
Research Questions/Goals

- How could Lean-informed production/project management strategies improve project outcomes?
  - Both singly and when multiple improvements used together
- How are the effects moderated by the context of multiple projects in the same market competing for subcontractor labor?
Main Method: Simulation

- **Benefits**
  - Allows testing of multiple different scenarios
  - No exogenous factors

- **Agent-Based Modelling (ABM)**
  - Agents, their attributes and behaviors
  - Agent relationships and methods of interaction
  - Environment  (Macal and North 2010)
  - Emergent behavior
Main Method: Market-wide Simulation

Reasons

- The negotiation between Subs and GCs over labor-resource allocation can be understood through the lens of game theory (Sacks and Harel 2006)
- Subs are engaged in multiple parallel negotiations with the projects they serve, and their eventual allocation of work crews to any given project is influenced by the contract terms negotiated (Korb 2019)

Expected Learning

- How will the adoption of a given improvement in a single project among a sea of other traditionally-managed projects affect project outcomes (early adopter/innovator)
- What are the effects on a given project if improvements are adopted across the market (new paradigm)
Lean Interventions

- Reduce Batch Size

- Multiskilled Teams
  (Sacks and Goldin 2007)

- Contracting with more than one Sub for each trade
  (Sacks, Korb, and Duka 2019)
Research Platform: LeapconX

- Models an entire local construction market
- Addresses broader issues of systemic changes in industry
- First example of multi-project simulation (previously un-represented in the literature)
LeapconX
LeapconX Simulation Components

Agents:
- Buildings
- Apartments
- GCs
- Subs
- Crews

Main Processes:
- Price Negotiation
- Weekly Work Planning
- Daily Work Processes

Project Timeline
- Negotiation Date
- Start Date
Input Data

- Distribution of buildings and apartments built in a year
- Building sizes
- Trades involved in work
- Work sequence
- Work quantity per apartment
- Customization levels in market
- Work rates by trade/work package

# Experimental Design Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Batch Size</th>
<th>Trade Skills</th>
<th>Contracted Subs</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Traditional</td>
<td>Floor</td>
<td>Single</td>
</tr>
<tr>
<td>02</td>
<td>2Subs</td>
<td>Innovator</td>
<td>Floor</td>
</tr>
<tr>
<td>03</td>
<td>New paradigm</td>
<td>Floor</td>
<td>Single</td>
</tr>
<tr>
<td>04</td>
<td>OPF</td>
<td>Innovator</td>
<td>Apartment</td>
</tr>
<tr>
<td>05</td>
<td>New paradigm</td>
<td>Apartment</td>
<td>Single</td>
</tr>
<tr>
<td>06</td>
<td>OPF &amp; 2Subs</td>
<td>Innovator</td>
<td>Apartment</td>
</tr>
<tr>
<td>07</td>
<td>New paradigm</td>
<td>Apartment</td>
<td>Single</td>
</tr>
<tr>
<td>08</td>
<td>Multi</td>
<td>New paradigm</td>
<td>Floor</td>
</tr>
<tr>
<td>09</td>
<td>Multi &amp; OPF</td>
<td>New paradigm</td>
<td>Apartment</td>
</tr>
</tbody>
</table>

100 Simulation Runs For Each Scenario
Duration of Interior Finishing and Systems Works, in weeks

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>95.0</td>
<td>4.3</td>
</tr>
<tr>
<td>2Subs Innovator</td>
<td>93.4</td>
<td>2.5</td>
</tr>
<tr>
<td>New paradigm</td>
<td>96.3</td>
<td>5.0</td>
</tr>
<tr>
<td>OPF Innovator</td>
<td>69.3</td>
<td>2.9</td>
</tr>
<tr>
<td>New paradigm</td>
<td>72.7</td>
<td>7.5</td>
</tr>
<tr>
<td>OPF &amp; 2Subs Innovator</td>
<td>68.1</td>
<td>2.3</td>
</tr>
<tr>
<td>New paradigm</td>
<td>71.7</td>
<td>5.9</td>
</tr>
<tr>
<td>Multi Innovator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New paradigm</td>
<td>90.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Multi &amp; OPF</td>
<td>New paradigm</td>
<td>36.7</td>
</tr>
</tbody>
</table>
Example Results: OPF and Two Subcontractors, Innovator

- **Traditional** - $\bar{x}: 95.0 \text{ s}: 4.3$
- **OPF-2Subs-I** - $\bar{x}: 68.1 \text{ s}: 2.3$

**Duration of finishing works in project (weeks)**
- **Traditional** - $\bar{x}: 55.6 \text{ s}: 4.9$
- **OPF-2Subs-I** - $\bar{x}: 27.3 \text{ s}: 7.0$
General Tendencies

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Intervention</th>
<th>Impact on Interior works duration</th>
<th>Impact on Apt. cycle time</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
</tr>
<tr>
<td>2</td>
<td>Reduced Batch Size (OPF)</td>
<td>- 27%</td>
<td>- 32%</td>
<td>- 49%</td>
</tr>
<tr>
<td>4</td>
<td>Additional Subs</td>
<td>- 2%</td>
<td>- 41%</td>
<td>+ 4%</td>
</tr>
<tr>
<td>6</td>
<td>OPF and Additional Subs</td>
<td>- 28%</td>
<td>- 45%</td>
<td>- 51%</td>
</tr>
<tr>
<td>8</td>
<td>Multi-skilling</td>
<td>- 5%</td>
<td>- 96%</td>
<td>- 80%</td>
</tr>
<tr>
<td>9</td>
<td>OPF and Multi-skilling</td>
<td>- 61%</td>
<td>- 99%</td>
<td>- 79%</td>
</tr>
</tbody>
</table>
Conclusions

- **OPF:**
  - Reduces Mean Project Durations, but Increases Variation
  - Similar effect on Apartment Durations, expect for those already multiskilling
  - Reduces Sub Entrants
  - For TP scenarios, improved even the “Traditional” group

- **2 Subs:**
  - Tended to reduce mean durations and standard deviations, though less in the NP scenarios.
  - Increased sub entrants
  - Some improvements to Traditional group in TP

- **Multiskilling:**
  - Reductions in durations of both projects and apartments, and less variation
  - Insular improvement – no impact on Traditional group
Conclusions

Market wide vs single project simulation

- If GCs are not getting the subcontractor resources they need, it is because the are sending their crews to other projects
- This can be due to over commitment on the part of the sub, or the sub’s assessment of the GC’s project as less lucrative: less stable (requested work quantities will not match actual work that can be performed), lower work volume offered, lower price
- Results for a given project depend on the level of market penetration of the improvements
Evaluating Multiskilling in Residential construction projects
Using Regional Industry Simulation

Thanks for Listening!
Questions?