Activity-Flow Work Structuring Method

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Activities require a set of flows to be executed

Façade brick construction (Frederikskaj project)

Flow Key:
- Labor
- Materials
- Precedence
- Workspace
- Equipment
- Information
- External

Façade brick construction (Frederikskaj project)

2m around building perimeter

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Make-ready process = Ensure activities in plan are sound

- Make-ready increases planning reliability by:
  - Identifying and removing activity constraints
  - Committing to “sound” activities

- Case study make-ready process: ≈ 80% of weekly meeting
Can the field managers track readiness of all flows?

Off-site flows
Delivered to the jobsite

Off-site flow
e.g., concrete delivery

Activity 1

On-site flows
Released by upstream activities

Activity 2

On-site flow
e.g., concrete crew

Activity 3

<table>
<thead>
<tr>
<th>Reason for non-completion</th>
<th>% related to flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Off-site</td>
</tr>
<tr>
<td>Predecessor</td>
<td></td>
</tr>
<tr>
<td>Labor availability</td>
<td>4.50%</td>
</tr>
<tr>
<td>Change of priority</td>
<td>13.90%</td>
</tr>
<tr>
<td>Equipment availability</td>
<td>8.23%</td>
</tr>
<tr>
<td>Equipment overcapacity</td>
<td></td>
</tr>
<tr>
<td>Information unavailable</td>
<td>1.73%</td>
</tr>
<tr>
<td>Quality inspection failed</td>
<td>1.73%</td>
</tr>
<tr>
<td>Materials delivery</td>
<td>0.43%</td>
</tr>
<tr>
<td>Underestimated</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14.89%</strong></td>
</tr>
</tbody>
</table>

Most reasons for non-completion relate to on-site flows
Current construction models do not represent all the flows

Field managers commit to activities based on readiness “perception”
(Pikas et al. 2012)

Week | Action | Area
--- | --- | ---
1 | Build deck form | Area 1
2 | Install slab rebar | Area 1
3 | Pour slab to | Area 1
4 | Build deck form | Area 2
5 | Install slab rebar | Area 2
6 | Pour slab to | Area 2

Date line for Weekly planning

What flow? Flow performance?
Proposed activity-flow construction representation

Date line for Weekly planning
Proposed activity-flow construction representation

Flow type: Labor
Flow class: Concrete crew
Flow failure %: 80%
Avg. flow delta: 2.2 days

Flows ready?
Prob. flows ready: 90%

Is activity sound?
Objective - Develop activity + flow - based model to:

- Formally manage activities and flows
- Make data-driven decisions e.g., Resource and buffer sizing
- Predict delays in downstream activities
Computational representation of the AFM

Activity
- activityName
- plannedStart
- plannedFinish
- actualStart
- actualFinish
- deltaStart
- deltaDuration
- deltaFinish

ActivityType
- activityTypeName <CA>
- uniformatL4

Stakeholder
- stakeholderType <R>
- company

Flow
- flowType
- flowStatus
dueDate
- dateReady
- predPF
- predAF

ReasonForVariation (Ballard 2000)
- reasonForVariation

LaborFlow
- flowName

EquipmentFlow
- flowName

MaterialFlow
- flowName

WorkspaceFlow
- flowName

InformationFlow
- flowName

ExternalFlow
- flowName

Garcia-Lopez 2016
Developed Activity-Flow App
Work structuring + Production control

Work structuring

Activity + Flow Structuring Method
(transform schedule into Activity-Flow representation)

Weekly planning and control

Update look-ahead and weekly plan
(Carry out daily tracking)
(Present analytics in weekly planning meeting)

Set-up meeting on Fredrikskaj project

Collaborative look-ahead update on Equilibrium project

Tracking using mobile device on Fredrikskaj project

Weekly planning meeting on Ichma project
Work Structuring: Definition + Gaps

Definition:

• Work structuring entails connecting the facility design (product) with the processes, typically in the form of schedules, used to deliver the physical facility (Ballard et al. 2001; Tsao et al. 2004)

Research Question:

• How can we extend existing work structuring methods (e.g., Takt planning and Ballard’s Lean method) to enable field managers to structure all the construction flow types and generate activity-flow schedules?
Research Methodology

Theoretical Point of Departure

Field observations

AFWSM development

AFWSM Testing

Validation in 3 projects
(Thomsen et al. 1999, Ho et al. 2009)
Activity-Flow Work Structuring Method (AFWSM)

- Consists of 7 steps that allow field managers to visually represent activities and flows in a construction fragnet or process.
- Example:

  **Fragnet:** Build concrete structure
AFWSM: Step 1 – Define fragnet’s prototypical activities

EXAMPLE:
Fragnet: Build concrete structure

- Install column rebar
- Install column forms
- Pour column concrete
- Install slab scaffolding
- Install slab rebar
- Pour slab concrete
AFWSM: Step 2 - Sequence fragnet’s prototypical activities based on precedence constraints

- Install column rebar
- Install column forms
- Pour column concrete
- Install slab scaffolding
- Install slab rebar
- Pour slab concrete
AFWSM: Step 3 – Identify workspaces and their sequencing
AFWSM: Step 4 – Identify on-site flows

Zone n

1. Install column rebar
2. Install column forms
3. Pour column concrete
4. Install slab scaffolding
5. Install slab rebar
6. Pour slab concrete

Zone n+1

1. Install column rebar
2. Install column forms
3. Pour column concrete
4. Install slab scaffolding
5. Install slab rebar
6. Pour slab concrete
AFWSM: Step 5 – Identify off-site flows

Zone n

- Rebar
- Loading permit
- Inspection
- Concrete pump
- Concrete

Install column rebar
Install column forms
Pour column concrete
Install slab scaffolding
Install slab rebar
Pour slab concrete
AFWSM: Step 6 – Identify interfaces with other fragnets

Zone n
- Install column rebar
- Install column forms
- Pour column concrete
- Install slab scaffolding
- Install slab rebar
- Pour slab concrete

Level released by self-climbing scaffold
AFWSM: Step 7 – Identify stakeholders responsible for the flows

Zone n

- Install column rebar
- Install column forms
- Pour column concrete
- Install slab rebar
- Install slab scaffolding
- Pour slab concrete

Zone n+1

- Install column rebar
- Install column forms
- Pour column concrete
- Install slab rebar
- Install slab scaffolding
- Pour slab concrete

Stakeholders:
- Rebar crew
- Carpentry crew
- Concrete crew
- Loading permit
- Inspection
- Concrete pump
- Level released by self climbing scaffold

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Field managers can use the AFWSM’s outcome to create activity and flow-based schedules.
## AFWSM implementation results

<table>
<thead>
<tr>
<th>Project</th>
<th>Ichma</th>
<th>Equilibrium</th>
<th>Frederikskaj</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building type + phase</td>
<td>Office/Structural</td>
<td>Residential/Foundations</td>
<td>Residential/Finishes</td>
<td></td>
</tr>
<tr>
<td>Test period</td>
<td>18 weeks</td>
<td>4 weeks</td>
<td>4 weeks</td>
<td></td>
</tr>
<tr>
<td># Fragnets</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td># Activity types</td>
<td>26</td>
<td>11</td>
<td>28</td>
<td>65</td>
</tr>
<tr>
<td># Flows</td>
<td>85</td>
<td>31</td>
<td>80</td>
<td>196</td>
</tr>
<tr>
<td>Avg. Time (mins)</td>
<td>17</td>
<td>10</td>
<td>18</td>
<td>15</td>
</tr>
</tbody>
</table>

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Feedback from field management teams

“Identifying and mapping the flows in a visual way allows all of the contractors to be on the same page and understand the plan better.”

Project Superintendent Frederikskaj

“Keeping track of the historical flow performance is key. We might have a hunch about what flows are consistently late, but we don’t have the data to identify performance issues.”

Project Engineer Ichma

“It's very useful that we now have a tool that formally maps the flows that are needed to execute an activity … we think about these things, but there is no formal tool that allows us to check that all the flows are ready so the activity is not in danger.”

Project Engineer Ichma

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Conclusions and Future Work

Conclusions:

• Considering flows during work structuring enables better understanding and communication of the plan among stakeholders
• The Activity-Flow Work Structuring Method (AFWSM) enables field managers to formally represent and manage flows
• The AFWSM should lead to schedules with higher planning reliability since flows should be better synchronized between activities

Future Work

• Testing effect of work structuring method on schedule performance
• Developing methods for automating / speeding transformation from work structuring to activity-flow-based schedules
Questions?

Thank you!

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