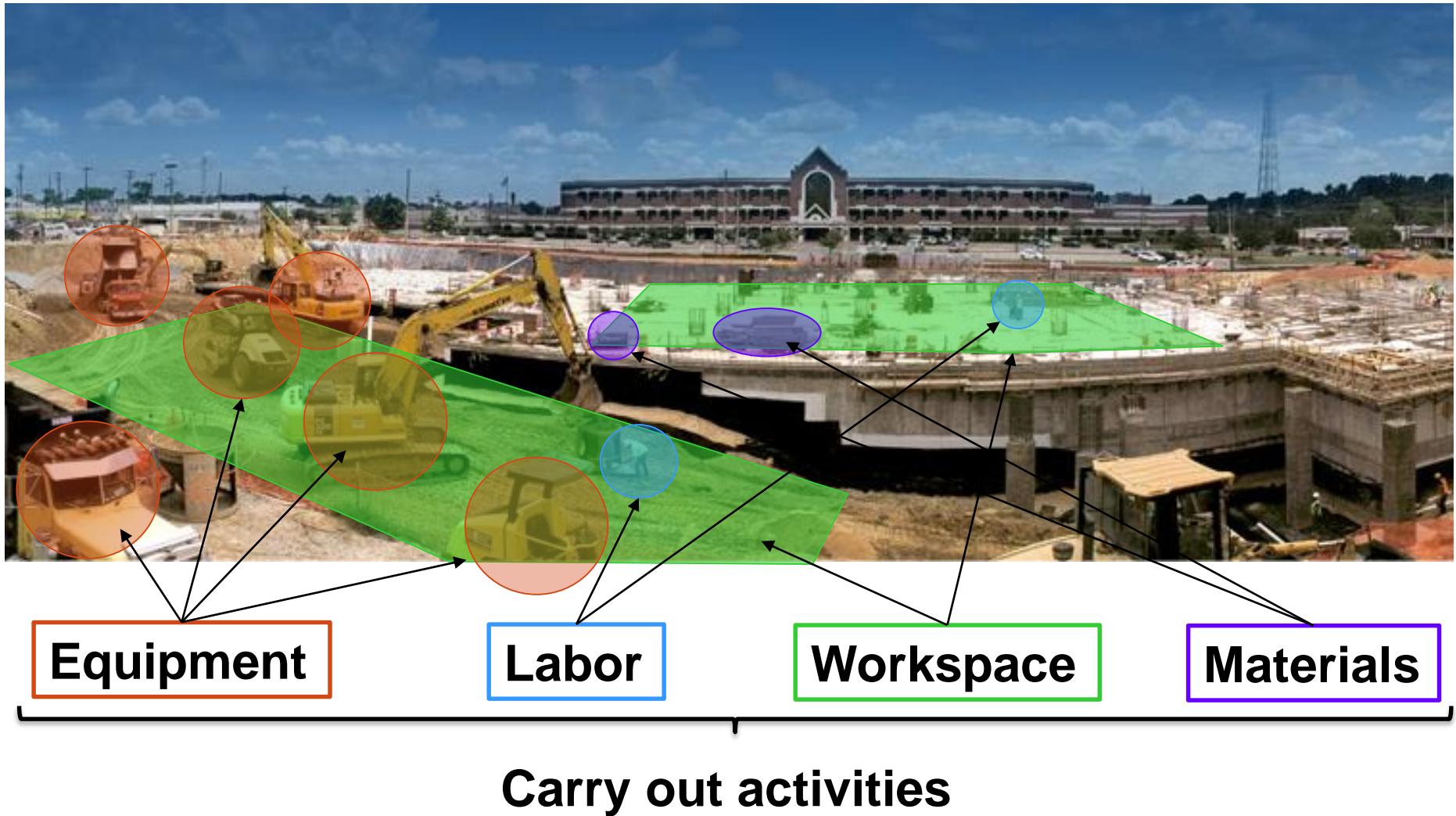


Formally accounting for variability in look-ahead planning

PI: Martin Fischer

RA: Nelly Garcia-Lopez

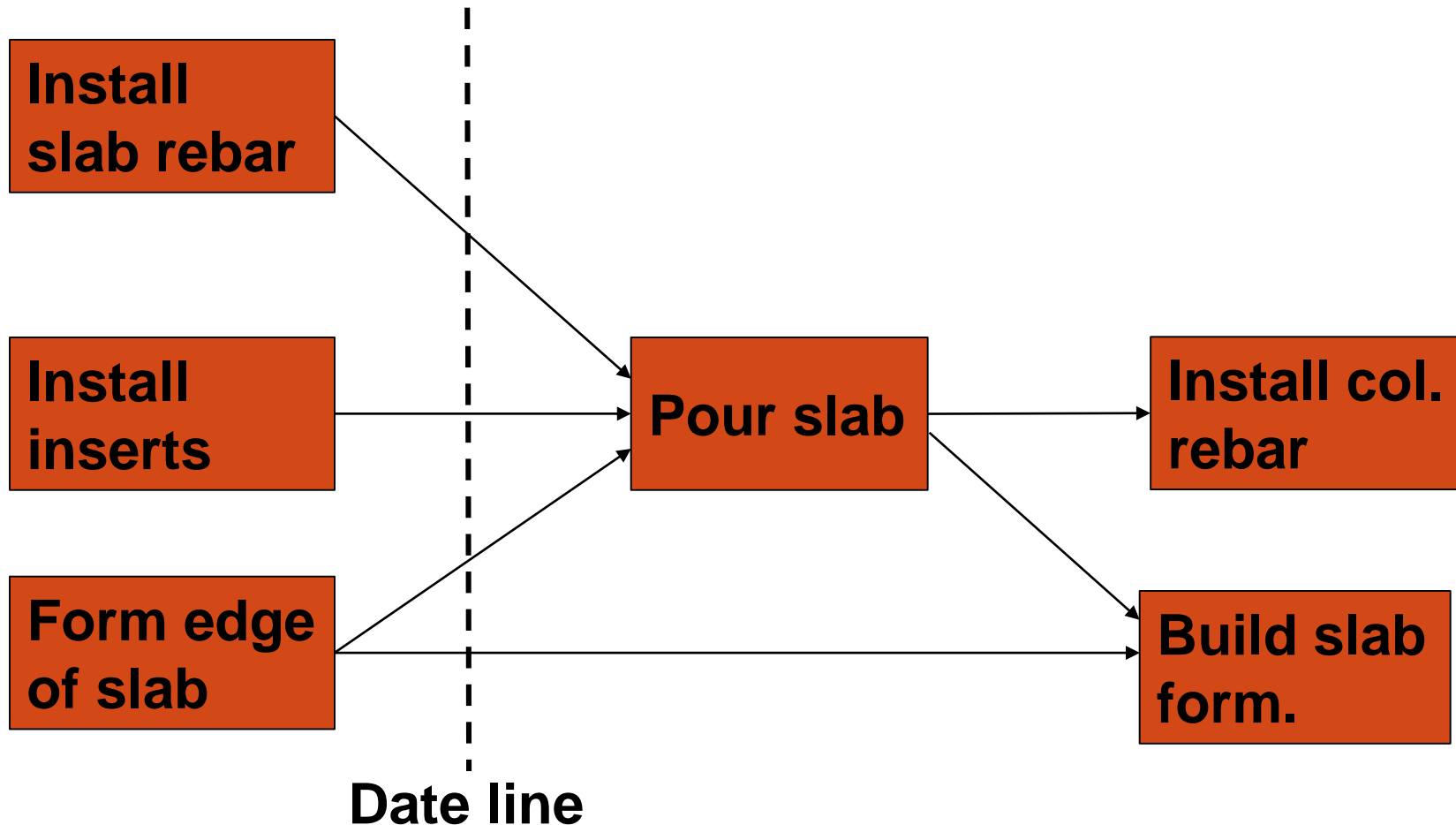
Field managers need to coordinate the different elements that make up the construction workflow



In a nutshell

- Problem: Field managers lack a method to predict impact of workflow variability on downstream activities.
- Solution: A method that leverages a model of construction workflow to analyze in-project activity variability and predict its impact.
- Approach: Develop method and model based on literature and input from field managers, validate by testing on a construction project.

Field managers lack methods to anticipate impact of variability



Field managers lack methods to anticipate impact of variability

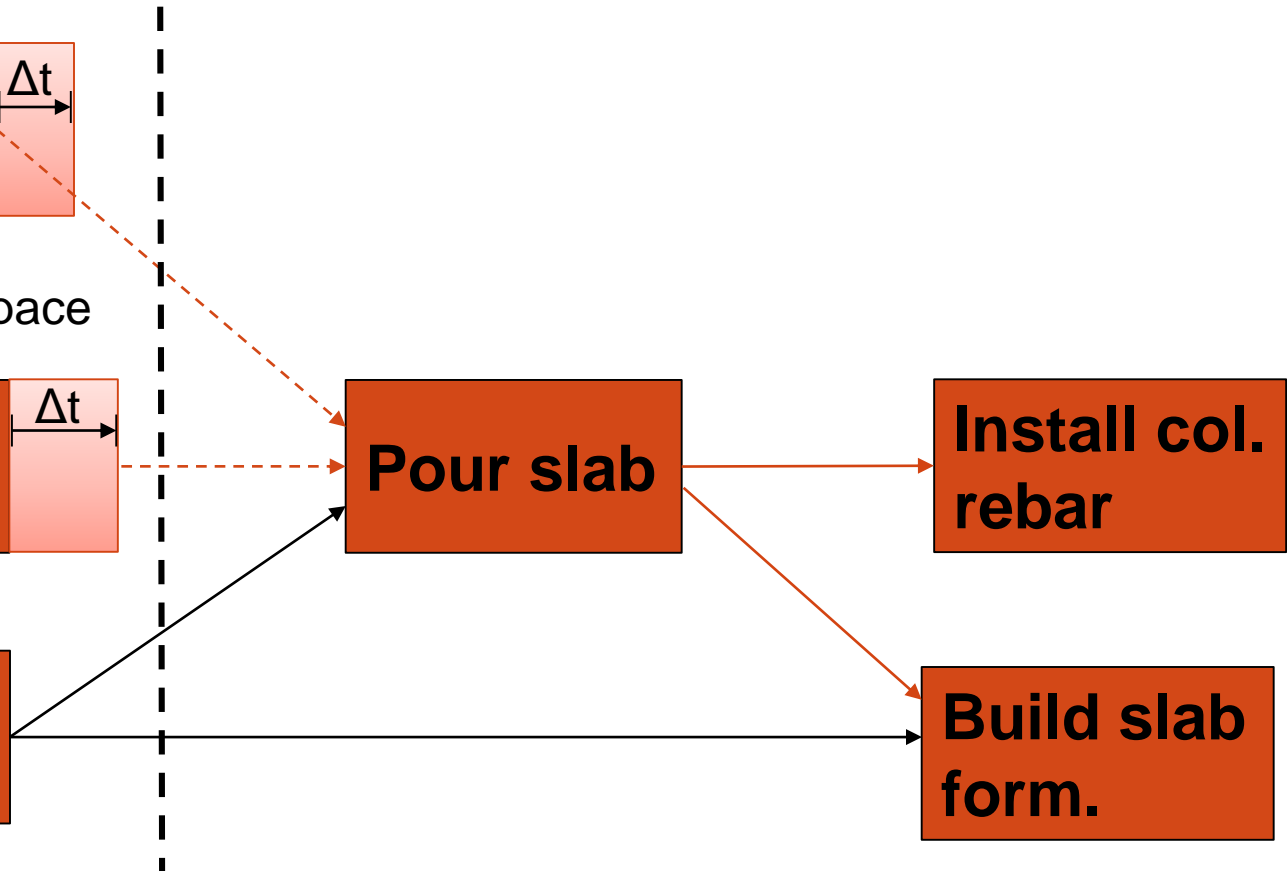
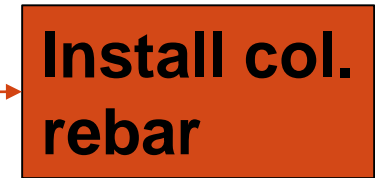
Variability factor:
Manpower availability



Variability factor:
Overcrowded workspace



Date line



Field managers lack methods to anticipate impact of variability

Variability factor:
Manpower availability

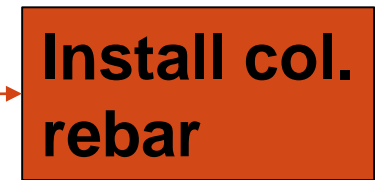


Variability factor:
Overcrowded workspace



?

1. What is the impact on downstream activities?



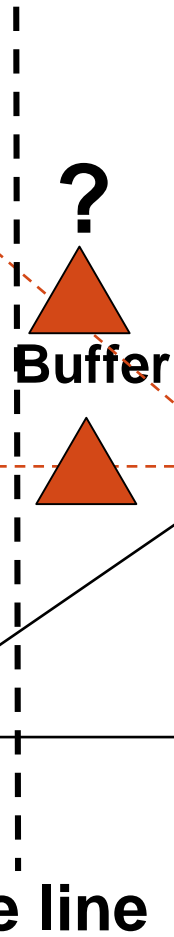
Date line

Field managers lack methods to anticipate impact of variability

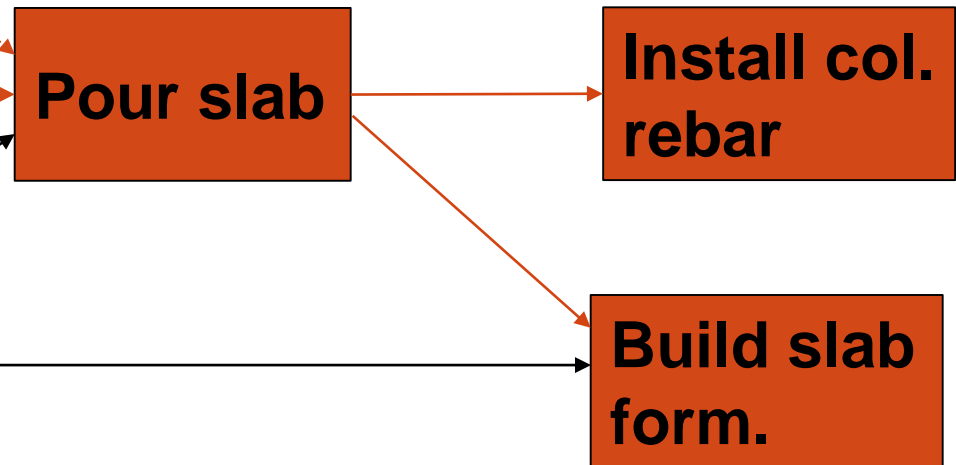
Variability factor:
Manpower availability



Variability factor:
Overcrowded workspace



1. What is the impact on downstream activities?
2. How can it be managed?



Update from 2014 Seed Project

Case studies:

- 2 building projects
- Planning meetings
- 2 month period

Findings:

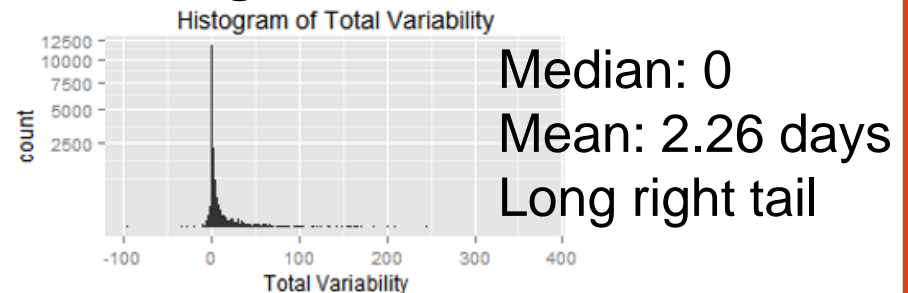
Field managers lack formal methods for managing variability and estimating its impact.

They rely on their intuition and past experience managing variability.

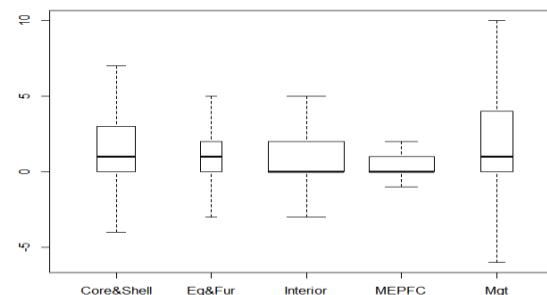
Analysis of activity variability data

- Building project – Last Planner
- 30,000 activity entries
- Manual data cleanup (240 hrs)
 - Activity type, sub type, Uniformat

Findings:



Boxplot of Total Variability by Sub Group (no outliers)



Mgt activities
> variability
MEP activities
< variability

Motivating problem: Curtain wall installation

- Field managers considered that the curtain wall procurement and installation activities were critical.

- **Reasons:**

- Critical path activity
- Opens up work (e.g., finishes)
- Disrupts ongoing work (6ft staging area around the perimeter)



Source: Genzyme Corp

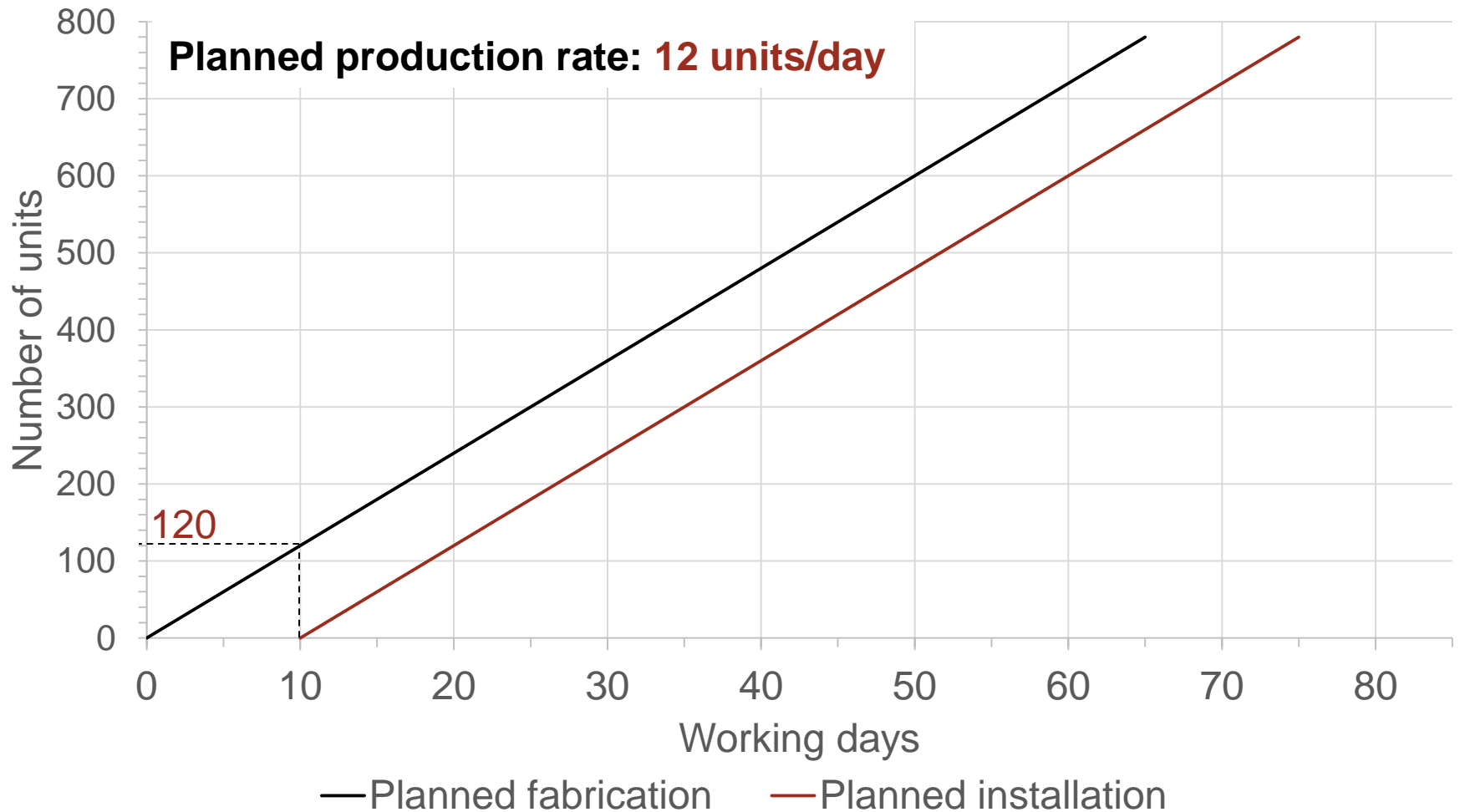
<http://www.sotawall.com/portfolio/United%20States/GenzymeCorporation-8568/>

Field managers were concerned about installation outpacing fabrication

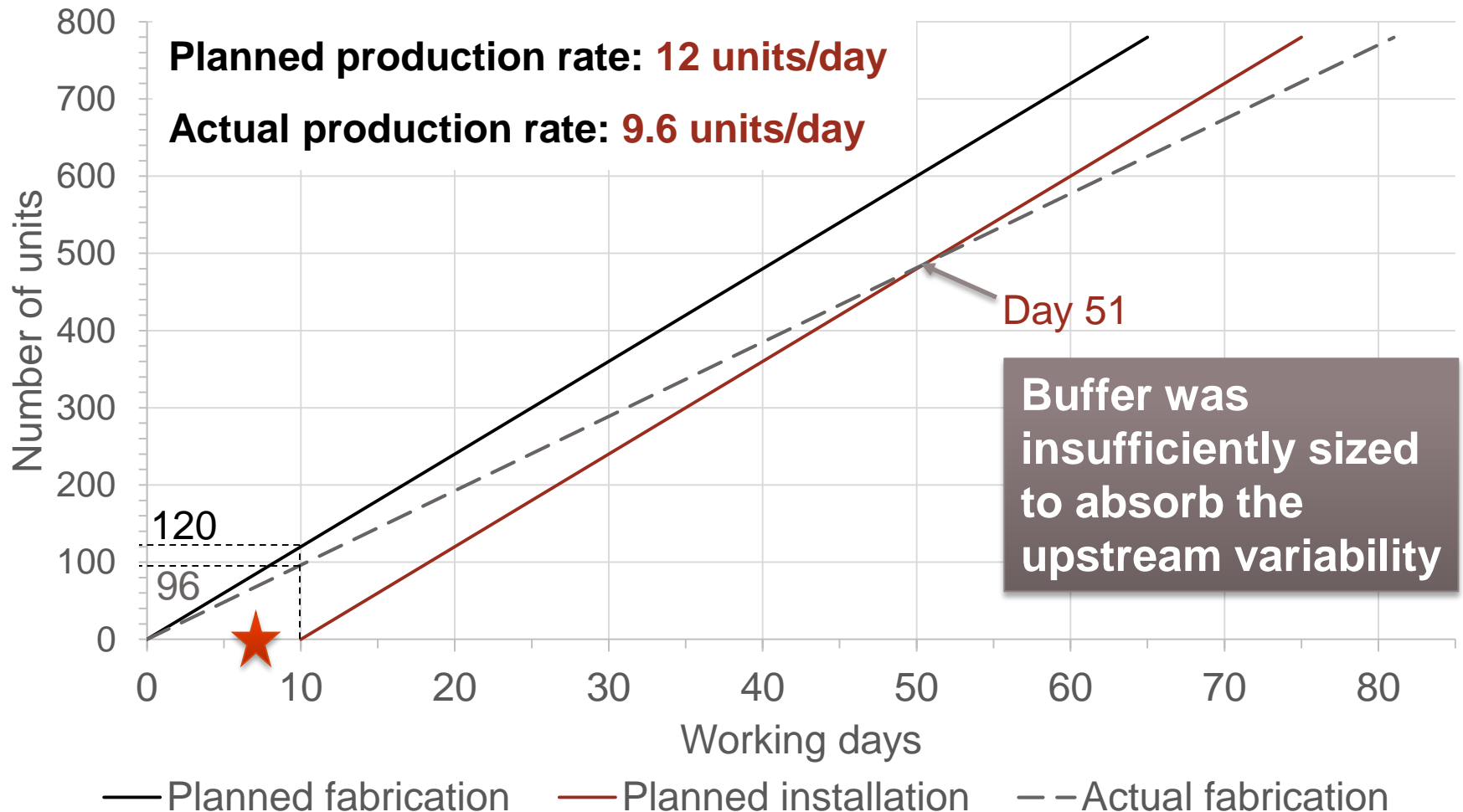
Key:
Actual vs
Planned

Fabrication		Total units	Installation	
SHOP FABRICATION		780 UNITS TOTAL	FIELD INSTALLATION	
DAILY PRODUCTION YESTERDAY	8 7/18		KEY	DAILY PRODUCTION RATE
TO DATE PRODUCTION	77 98	UNITS DAY	TO DATE PRODUCTION	UNITS DAY
PERCENT COMPLETE	98%		PERCENT COMPLETE	%
COMPLETION DATE	10/3 9/26		COMPLETION DATE	10/9

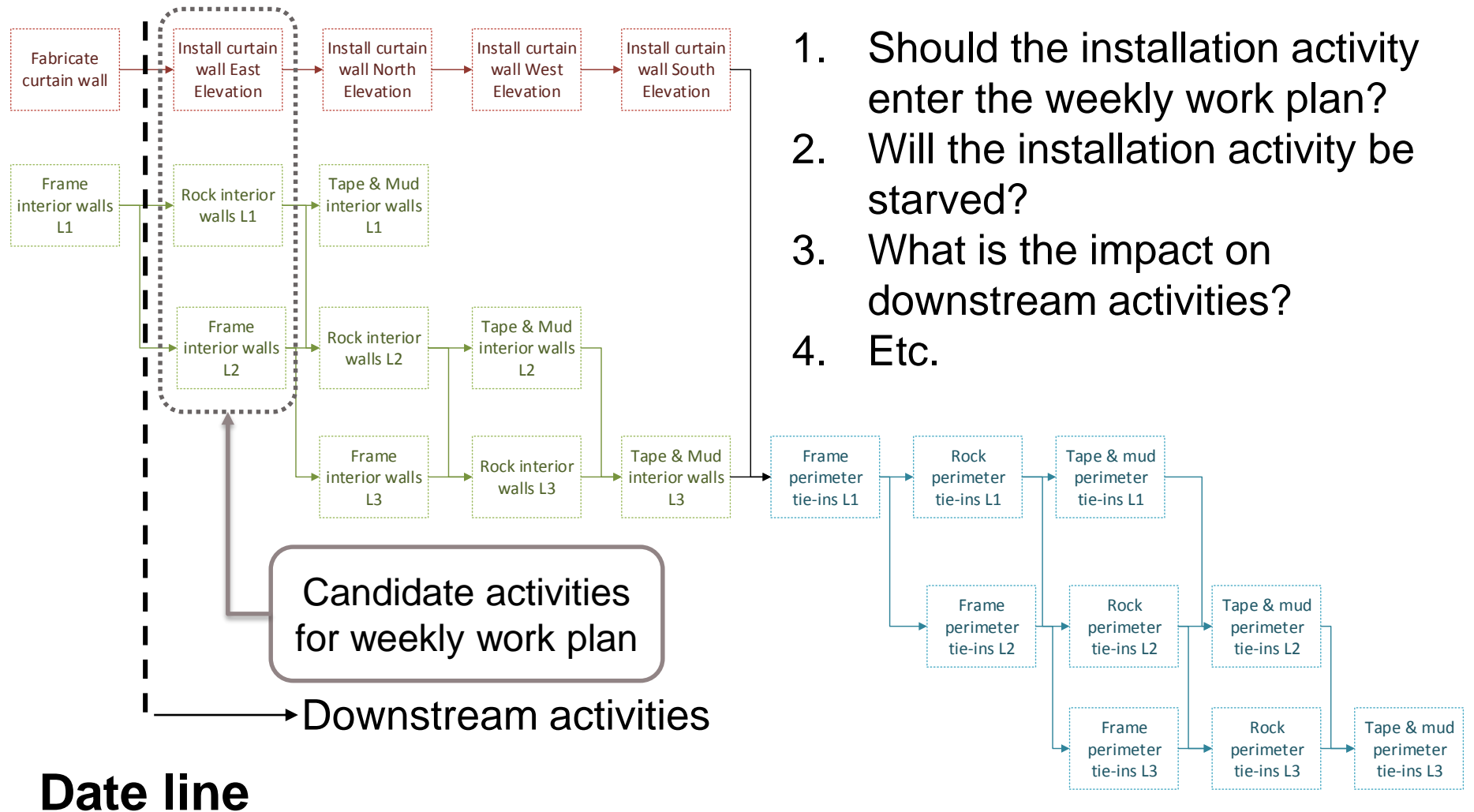
Line of balance view of fabrication vs. installation



Actual fabrication rate was 20% slower than planned



Variability forces field managers to make decisions during look-ahead planning



Date line

Field managers need to manage variability but lack a formal method to do so

Aware of impact of
variability

**Constraint checking during
look-ahead planning**

Intuitive
management of
variability

**Create inventory buffer to
shield installation from
variability in fabrication**

No formal methods
to analyze
variability and
estimate impact

**Will fabrication over/under-
supply the site?
What is the impact on
downstream activities?**

Theoretical points of departure

1. Workflow model of field construction
2. Mechanisms that cause workflow variability
 - i. Variability factors
 - ii. Variability in release of upstream flows
3. Conceptual model and theoretical gaps

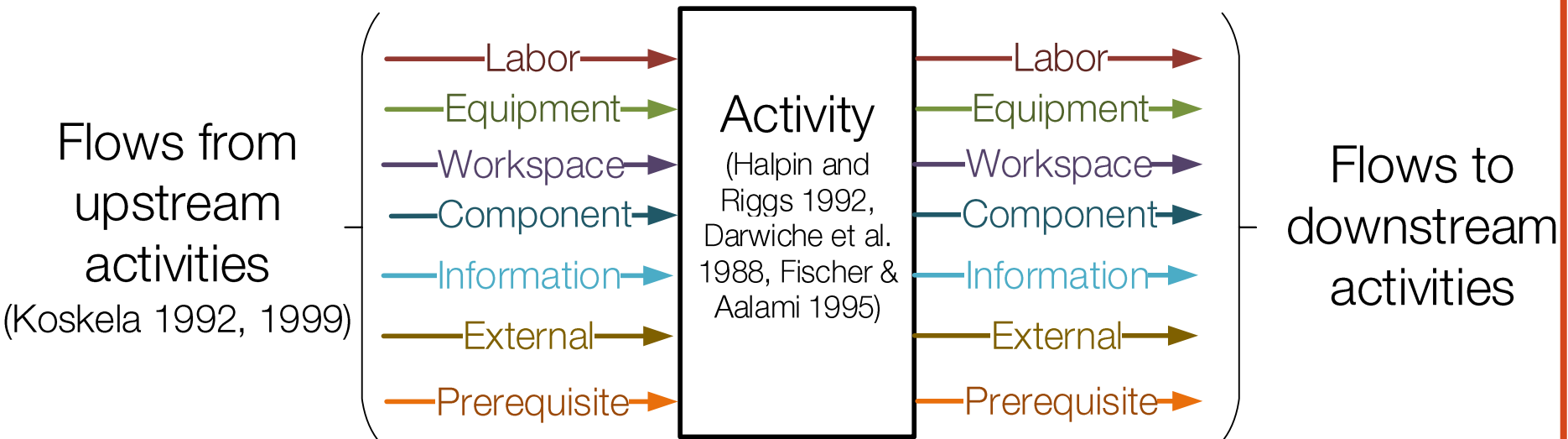
Theoretical points of departure

1. Workflow model of field construction
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Workflow model

- **Workflow:** movement of information, materials, and resources through workspaces performing a sequence of activities on components (LCI 2015, Birrell 1980, Darwiche 1988)

- **Flow view of production:**



Theoretical points of departure

1. Workflow model of field construction
2. Mechanisms that cause workflow variability
 - i. Occurrence of variability factors
 - ii. Variability in release of upstream flows
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Mechanisms that cause workflow variability

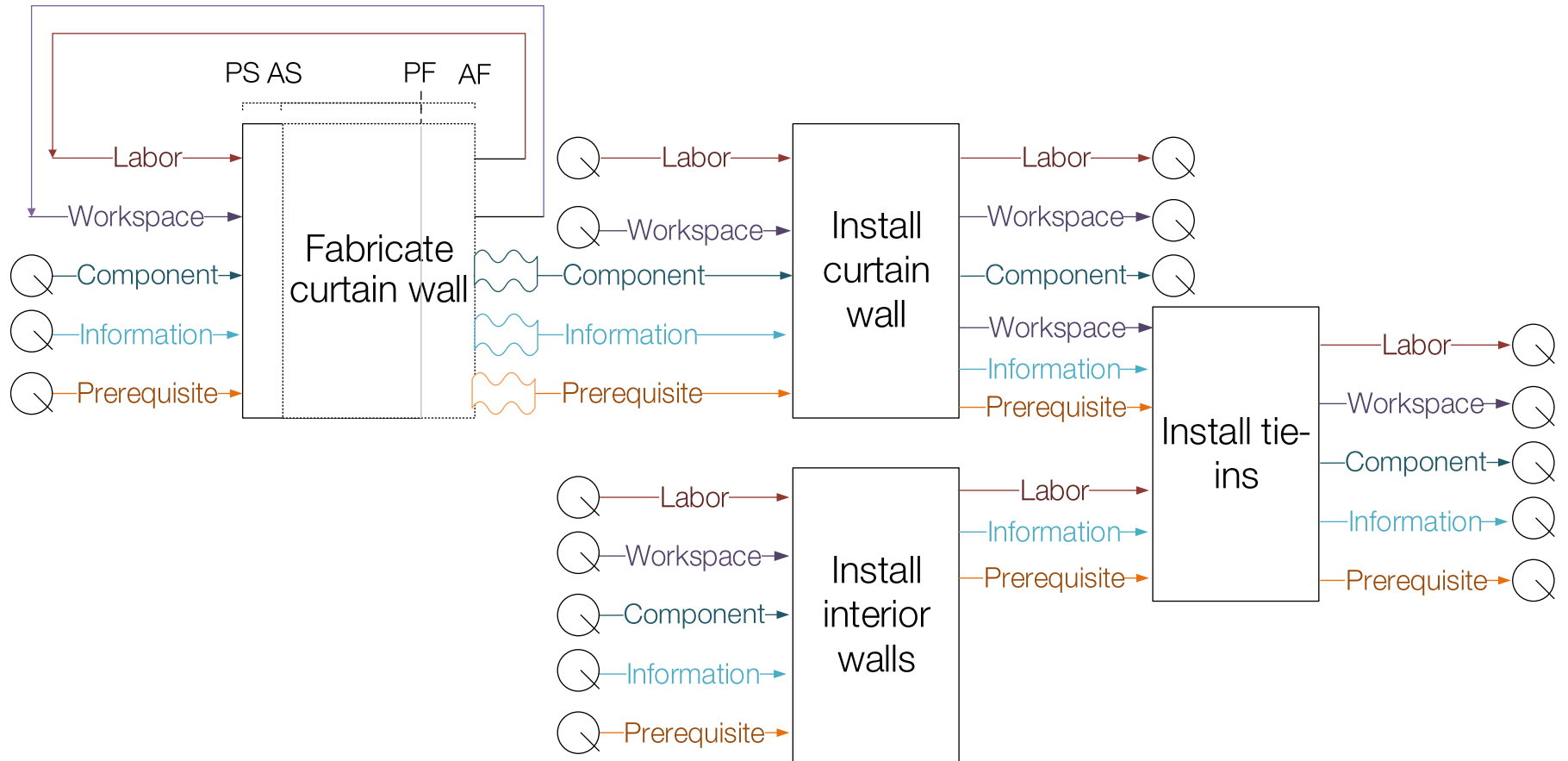
Occurrence of variability factors

- Large body of knowledge (delay analysis, risk management, lean construction, +40 papers reviewed)
- Most recent compilation Wambeke et al. (2011)
- 50 factors classified into:
 - Labor
 - Tools and Equipment
 - Jobsite
 - Materials and components
 - Information and design
 - External conditions
 - Prerequisite work
 - Management

Matches 7 flows
identified by Koskela
(1999)

Mechanisms that cause workflow variability

Variability in release of upstream flows



Legend:

 Flow queues
  Late release of flows

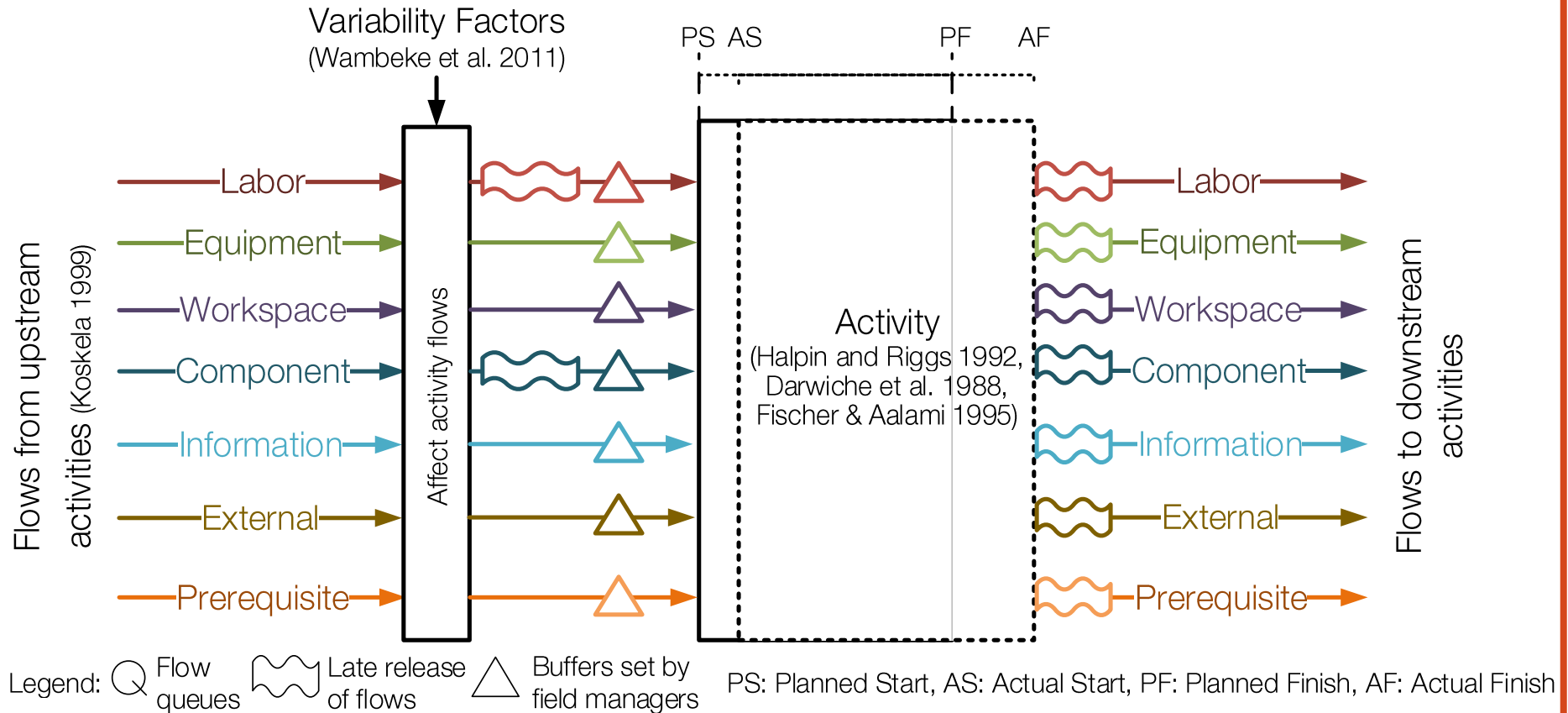
Late release of flows

PS: Planned Start, AS: Actual Start, PF: Planned Finish, AF: Actual Finish

Theoretical points of departure

1. Workflow model of field construction
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Conceptual model and theoretical gaps

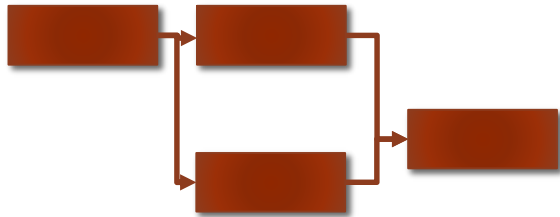


Gaps identified:

- (1) What variability factors affect which flows
- (2) How does flow variability lead to activity variability?
- (3) How to measure the components of the model?

Intuition for Activity Variability Method

Look-ahead schedule

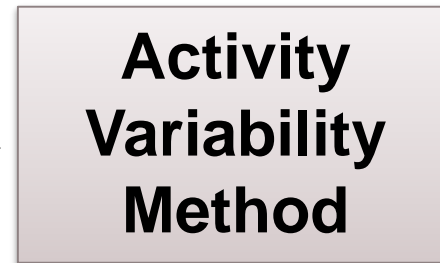


(Ballard 1997)

Weekly activity tracking

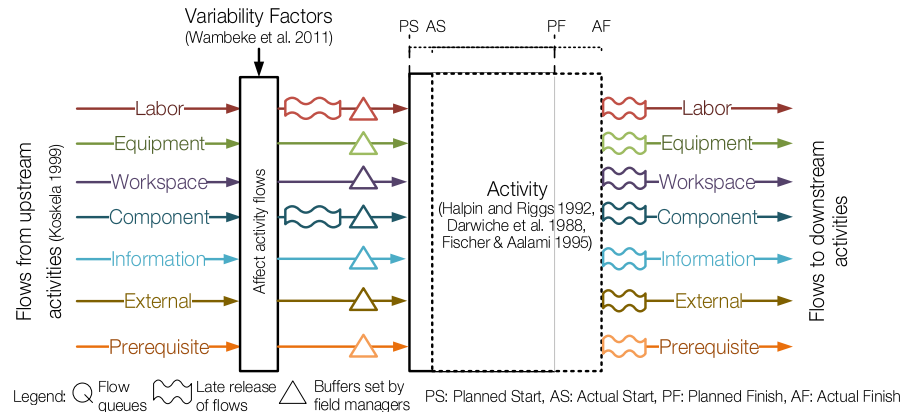
Activity	PS	PF	AS	AF	Reason

(Ballard & Howell 1997)





Variability predictions:
- Flows
- Activities

Construction workflow model

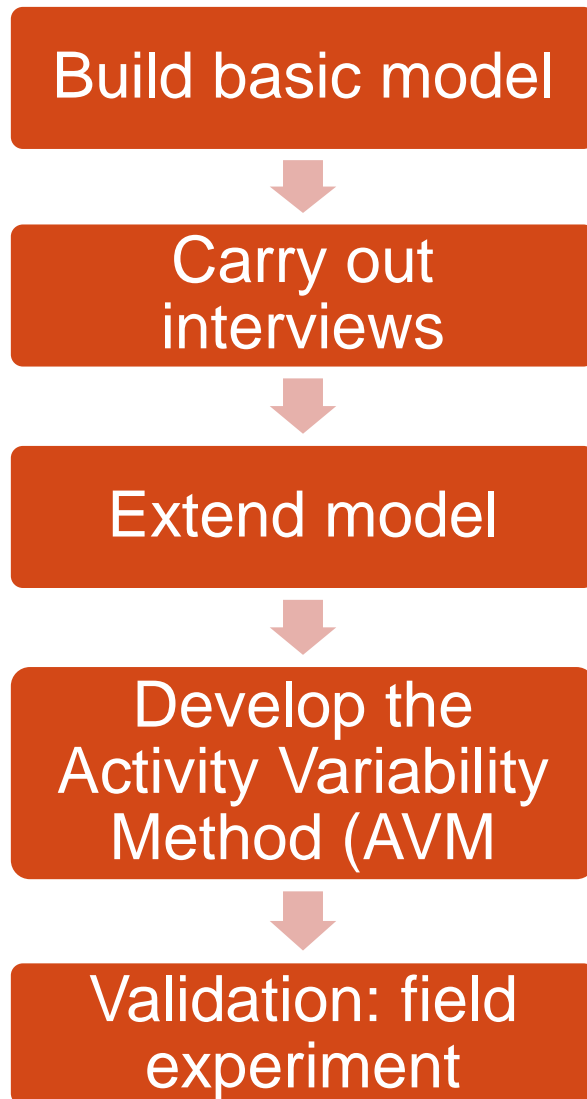


Research methods and tasks

Research questions:

- | | | |
|--|--|---|
| <ol style="list-style-type: none"> 1. What variability factors affect which flows? 2. How does variability in the flows cause variability in the activity? 3. How can and should field managers measure the variability factors, flows, and activity execution? |  | <p>Theory
+
Case studies
+
Interviews</p> |
| <ol style="list-style-type: none"> 4. How can a computational model allow field managers to predict how variability is propagated to downstream activities? 5. How can field managers use the model to manage variability and its impact during look-ahead planning? |  | <p>Theory
+
Input from field managers
+
Field validation</p> |

Research methods and tasks



- **Method:** Theory, case study observations
- **Result:** Model representing activities and flows
- **Test:** Model verification by field managers
- **Method:** Structured interviews
- **Result:** Relationship between variability factors and variability in the flows, data availability
- **Result:** Model representing activities, flows, variability mechanisms
- **Test:** Verify using test cases from interviews
- **Method:** Theory, input from field managers
- **Inputs:** Model, look-ahead schedule, activity variability data collected (commitment tracking)
- **Output:** Variability predictions (flows, activities)
- **Test:** Verify using project variability data
- **Method:** 4-6 week implantation of method
- **Result:** Record planning interactions, carry out interview after experiment

Expected findings

- **Contributions:**
 - A formal representation of construction workflow to predict the impact of workflow variability.
 - The Activity Variability Method (AVM) which helps field managers anticipate the impact of variability during look-ahead planning.

- **Impact:**
 - Field managers can implement targeted measures to manage variability, leading to better schedule conformance and project performance.

Industry involvement

Project data

- Activity tracking data of projects using Last Planner containing planned vs. actual start and finish, reasons for non-completion

Interviews with field managers

- Structured interviews with superintendents, project engineers, and foremen

Feedback and test developed methods

- Field managers willing to evaluate the model representation and the method

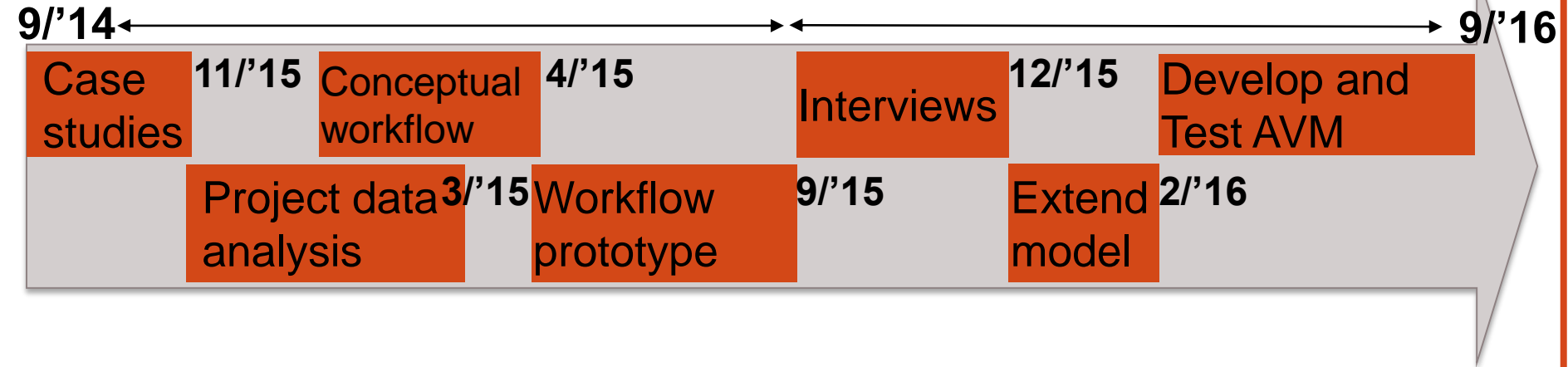
Field study of Activity Variability Method

- Test the AVM implementation for a period of 4-6 weeks

Research milestones and risks

CIFE Seed 2014

CIFE Seed 2015



Risks and mitigation:

- **Difficulty getting project data:**
 - Relationship with CIFE members
- **Difficulty validating model using project data:**
 - Verify model with input from field managers, conduct field experiment

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RA: Nelly Garcia-Lopez (ngarcial@stanford.edu)

Thank you!

Questions? Suggestions?