Aalto University
School of Engineering

Operation Management in Construction
Lecture #7 Lean construction and waste

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Topics, Lecture #7

- Learning objectives of Lecture #7
- TFV theory for lean construction
- Key concepts of lean – variability, waste, buffers
- Batch size reduction
- Wasted effort in construction

Intended learning objectives for this lecture

- ILO 5**: Students can explain** the significance of work and labor flow and how flow can be achieved in construction
  - *ILO reinforced – Lean Construction*

TFV-theory of production Transformation, Flow, Value (Koskela 1992)

- **Theory of production that recognizes three competing schools of thought**
  - Transformation
  - Flow
  - Value

- **In lean construction, all three are pursued at the same time**

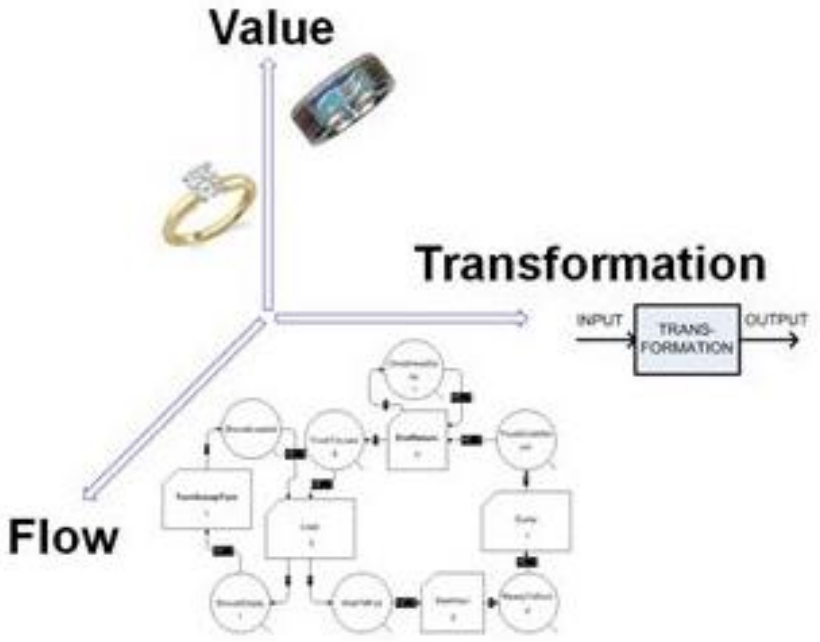
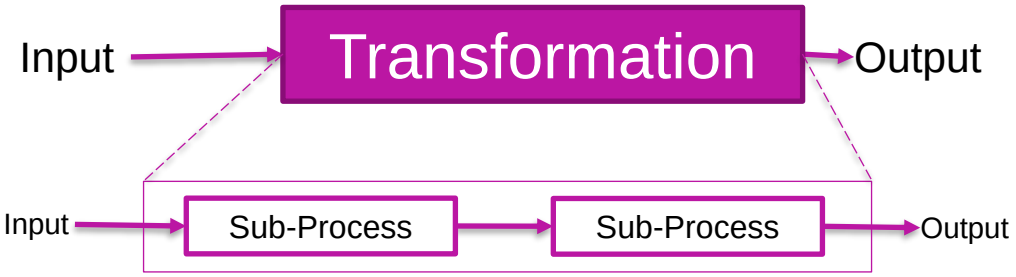


Image source: Iris D. Tommelein

Transformation view of production

- **Traditional view of production**
- **Transform inputs (labor, material) into outputs (e.g. drywall) as efficiently as possible**
- **Solutions:**
  - Taking care what is in the contract
  - Divide the project into small tasks/contracts and perform each of them efficiently
  - Select actors based on lowest price



(Koskela, 2002)

Key aspects of Transformation

- **Planning:**
  - Divide work to take care of what has to be done efficiently
  - Plan centrally

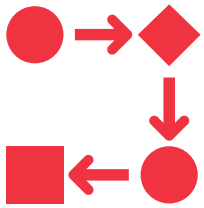
- **Operations**
  - Push the plan into operation
  - Reduce deviation from planned (= prioritize starting tasks on time and getting more resources if there are delays)

- **Improvement**
  - Replace humans with technology or improve efficiency with new work methods
  - Add resources

Transformation View of Production: Challenges

Problems:

- Focus on starting tasks, leading to waste
- Most problems happen in grey areas between tasks (i.e., lack of space, materials, design, previous work etc.)
- Buffers are included in task durations

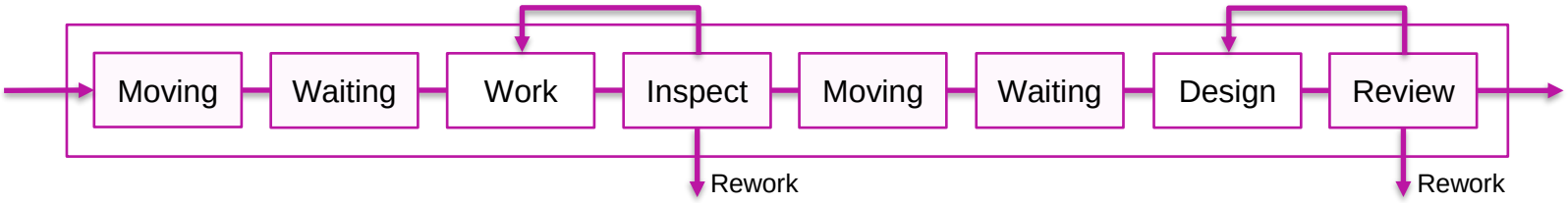


Problematic assumptions:

- Starting early leads to finishing faster
- Pre-planned schedules can be followed exactly
- It is the responsibility of project management to command and control the progress of work

Flow View of production: Key Concepts

- There is waste in production because the flow between transformation tasks has problems
- Goal: remove waste
- **Principles:** Reduce waste, reduce the lead time (e.g., batch size and buffers), reduce uncertainty (do not start without requirements), simplify, and increase flexibility and transparency



(after Koskela, 2002)

Key aspects of Flow view

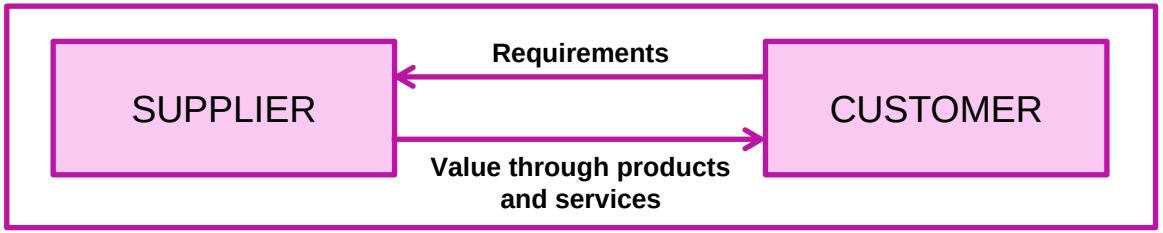
- **Planning**
  - Collaborative planning to find out waste
  - Focus on interfaces and prerequisites of tasks
  - Eliminate unnecessary buffers

- **Operations**
  - Pull tasks that are ready for execution

- **Improvement**
  - Root cause analysis of problems – continuous improvement

Value view of production

- **Main goal: fulfilling of client requirements. Elimination of wasted value**
- **Principles: documentation of requirements, moving of requirements in supply chain, improved ability of production system**
  - Everyone understands what the customer needs!



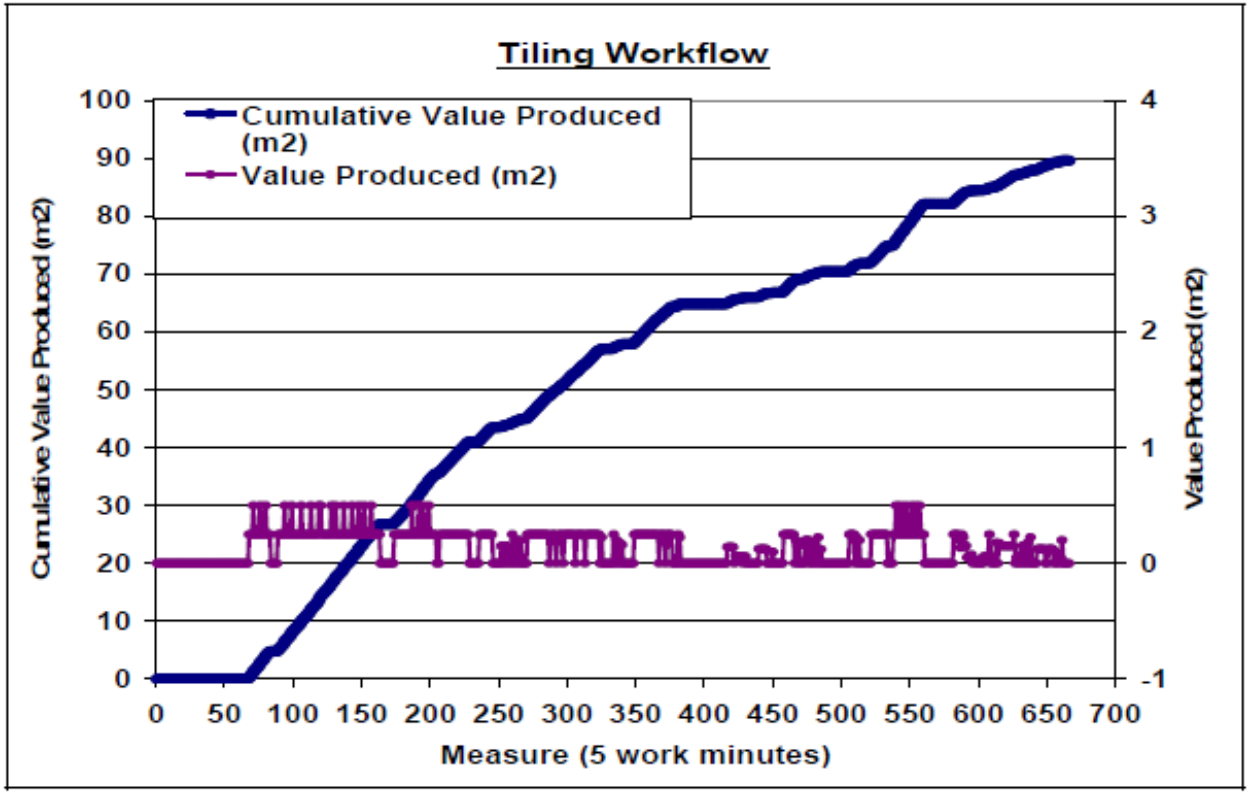
(Koskela, 2002)

Key concepts of flow view

- **Variability**
- **Waste**
- **Buffers**

Two key sources of variability

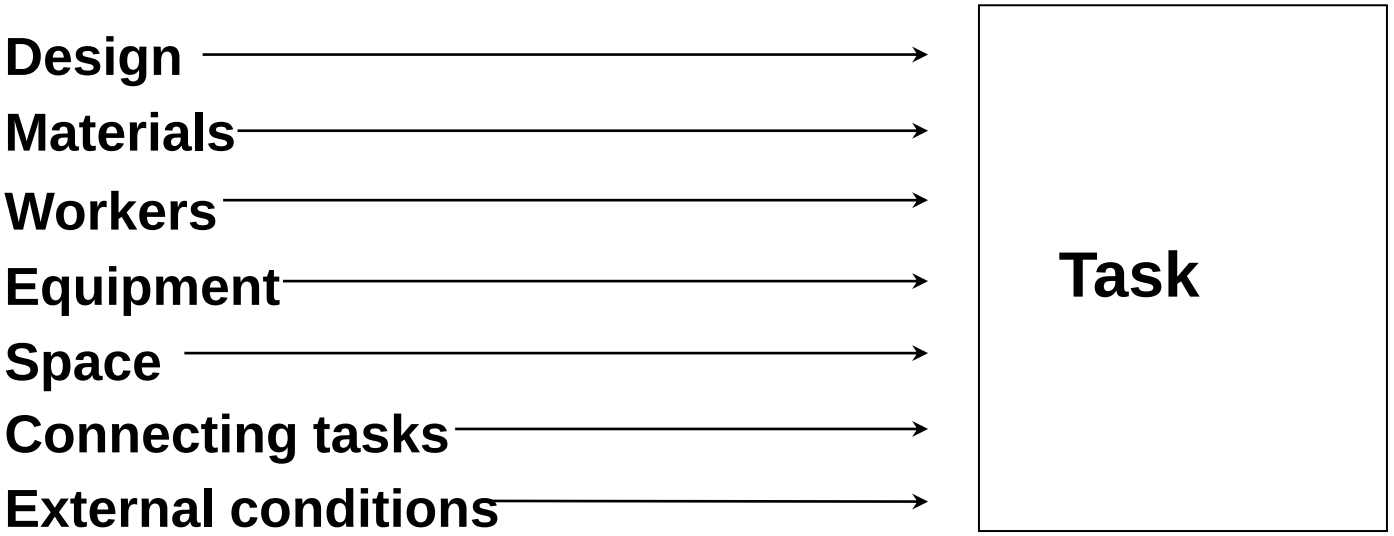
1. **Inherent variability**
   - Production rates differ even for the same individual in different parts of task
   - Big skill differences between individuals
   - Locations are not standard etc.



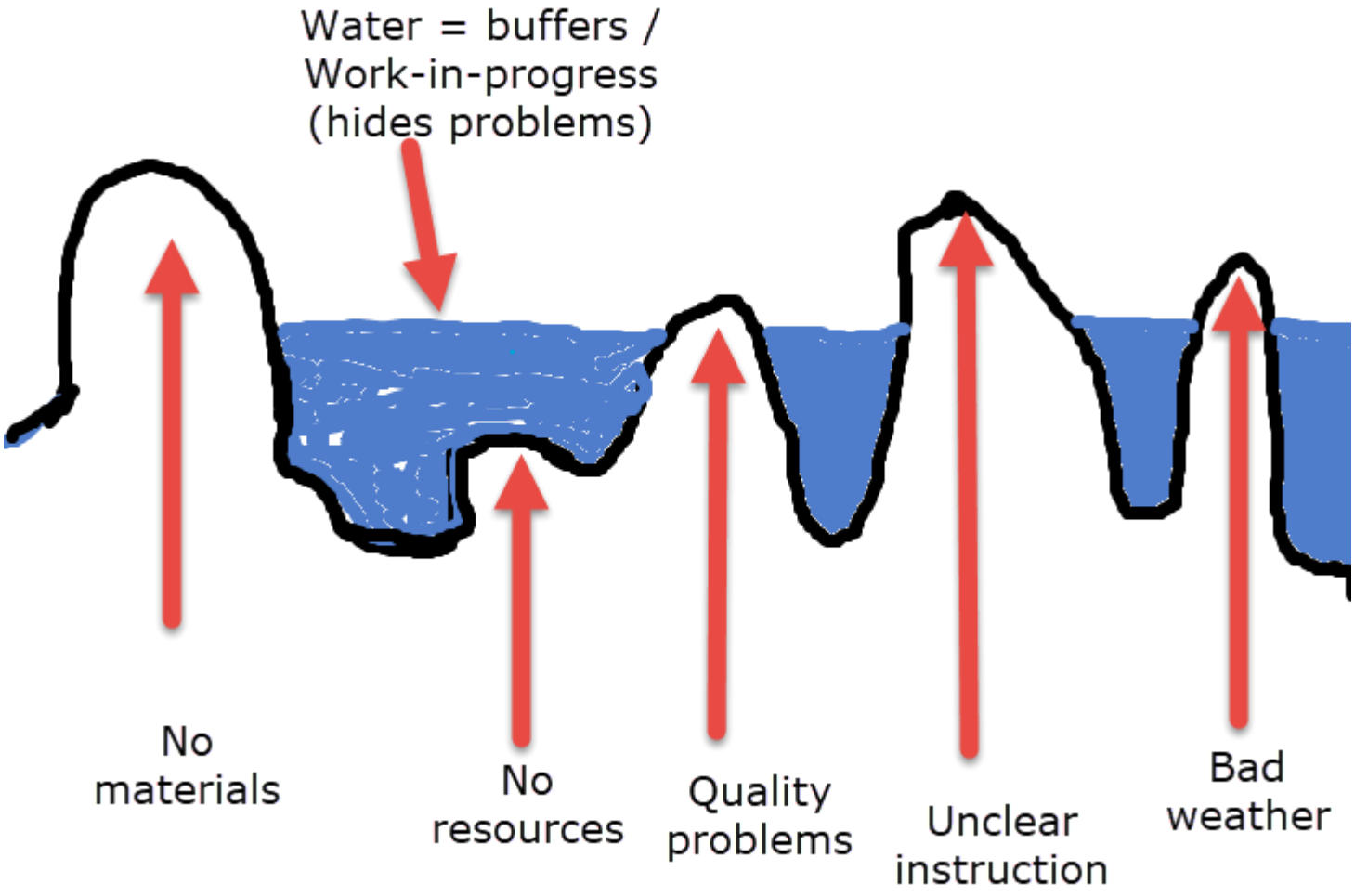
Brodetskaia & Sacks (2007)

Variability related to prerequisites

2. Each one of the prerequisites is variable



Buffers are hiding variability



The goal is to remove variability and decrease buffers

No late materials

Right resources in the right place

Protected from weather

Everyone knows what to do

Dual nature of buffers

Problems?	Solutions?
Increase project durations	All variability cannot be removed
Hide problems	All systems need buffers
Prevent continuous learning	Prevent cascading delays
Wasteful and should be eliminated	

- **What is the right balance?**
- **Lean way:**
  1. Lower the water to hit the rocks (= decrease buffers)
  2. Solve the problems by asking 5x ”why” and continuously improving
  3. When it is going smoothly again, go back to 1

Smaller batches improve flow

- **Batch = Size of one completed unit of work**
  - In construction, for example the size of location / length of takt time
  - 5 days vs. 1 day vs. 4 hrs vs. 15 minutes?

- **Smaller batch size = smaller black box = more opportunities for learning and measuring performance**

Benefits and challenges of smaller batch size

Benefits	Challenges
Easier to track progress	If variability is the same, more problems in shorter time
Concrete, smaller goals	Additional supervision needs
More opportunities to learn	Challenges in logistics
Easier to forecast	Challenges in quality checking
More tasks ongoing – duration reduction without increased resources	Everything must work in smaller batches!

- **Selecting the right batch size is important!**
- **Decrease the batch size when things are going smoothly**

Batch size reduction is key to flow efficiency and shorter durations

E.g. Takt formula (Nezval et al. 1960, Binninger et al. 2018)

$$(\textbf{Takt areas} + \textbf{wagons} - 1) * \textbf{Takt time} = \textbf{Duration}$$

”Normal” 5day schedule: (5 + 10 -1)* 5 d = **14weeks**

2 day takt: (12,5 + 10 -1)* 2 d = **8,6weeks (-39%)**

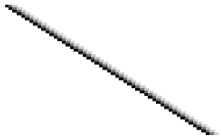
takt time shorter 60%,
no. of takt areas increases by 60%

1 day takt: (25 + 10 -1)* 1 day = **6,8weeks (-51%)**

(50% takt time)

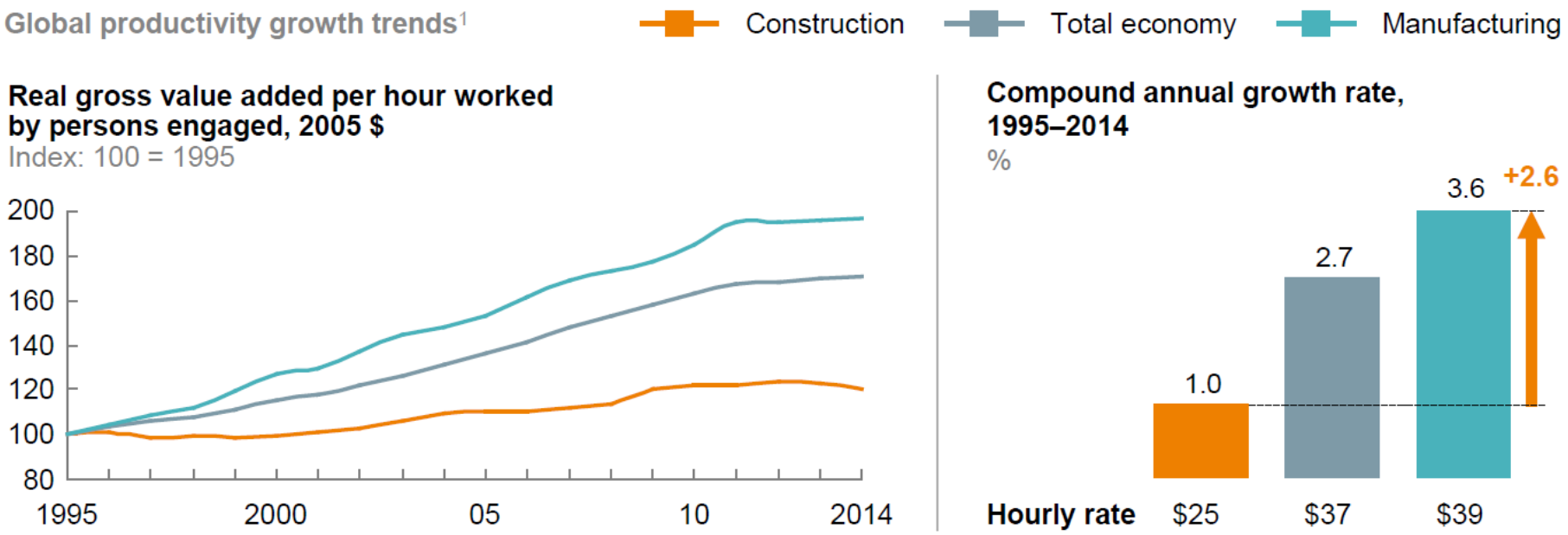
4h takt: (50 + 10 -1)* 4 h = **5,9weeks (-58%)**

(50% tahtiaika)



End of video 1

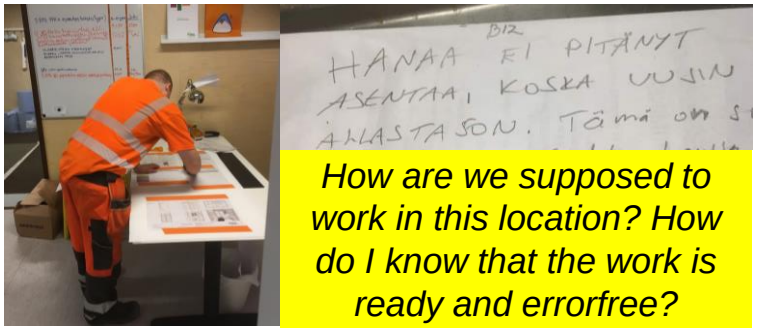
Productivity problem of construction



1 Based on a sample of 41 countries that generate 96% of global GDP.

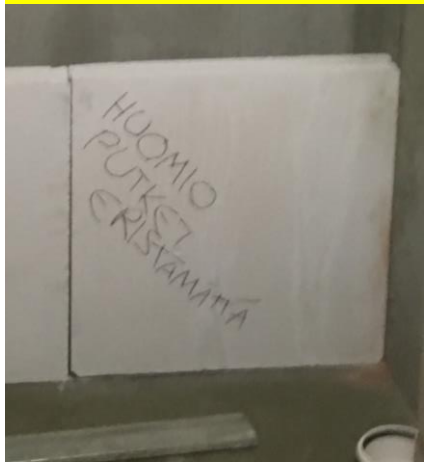
McKinsey 2017: Reinventing Construction: A route to higher productivity

Worker view of productivity



How are we supposed to work in this location? How do I know that the work is ready and errorfree?

Why is the location not ready for us?



1

3

Is the worker productively working on task X, location Y and time Z?

4

2

Where are our tools and materials?

How and when the work should be done?

Adapted from: Fira/Otto Alhava 2017

Poor productivity is mainly caused by wasted effort

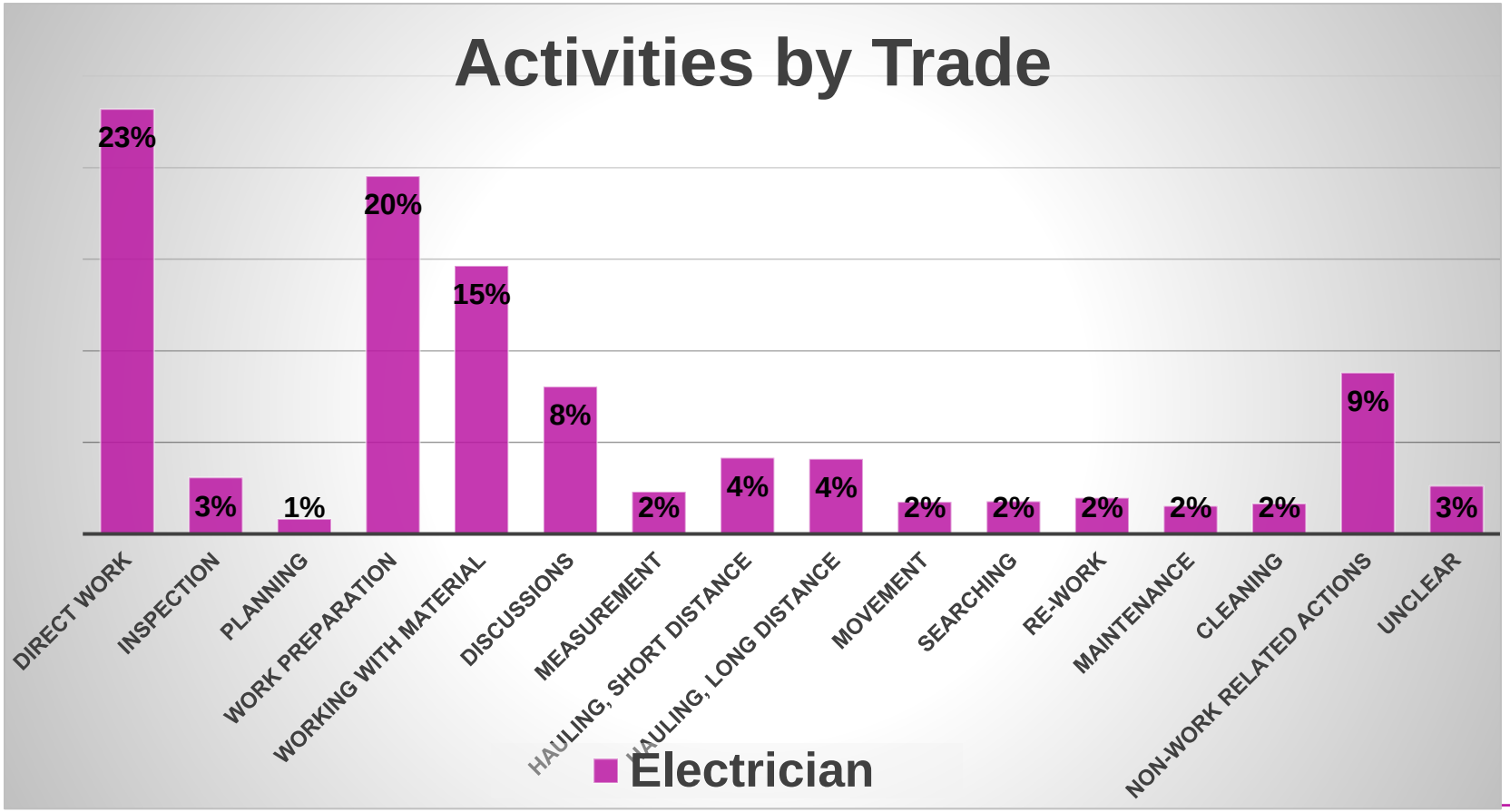
- **Wasted effort because workers do not have what they need for productive work**

- **Construction has moving work stations, so it is harder to organize so that everyone has:**
  - Right materials at hand
  - Right equipment at right time
  - Knows exactly what to do next

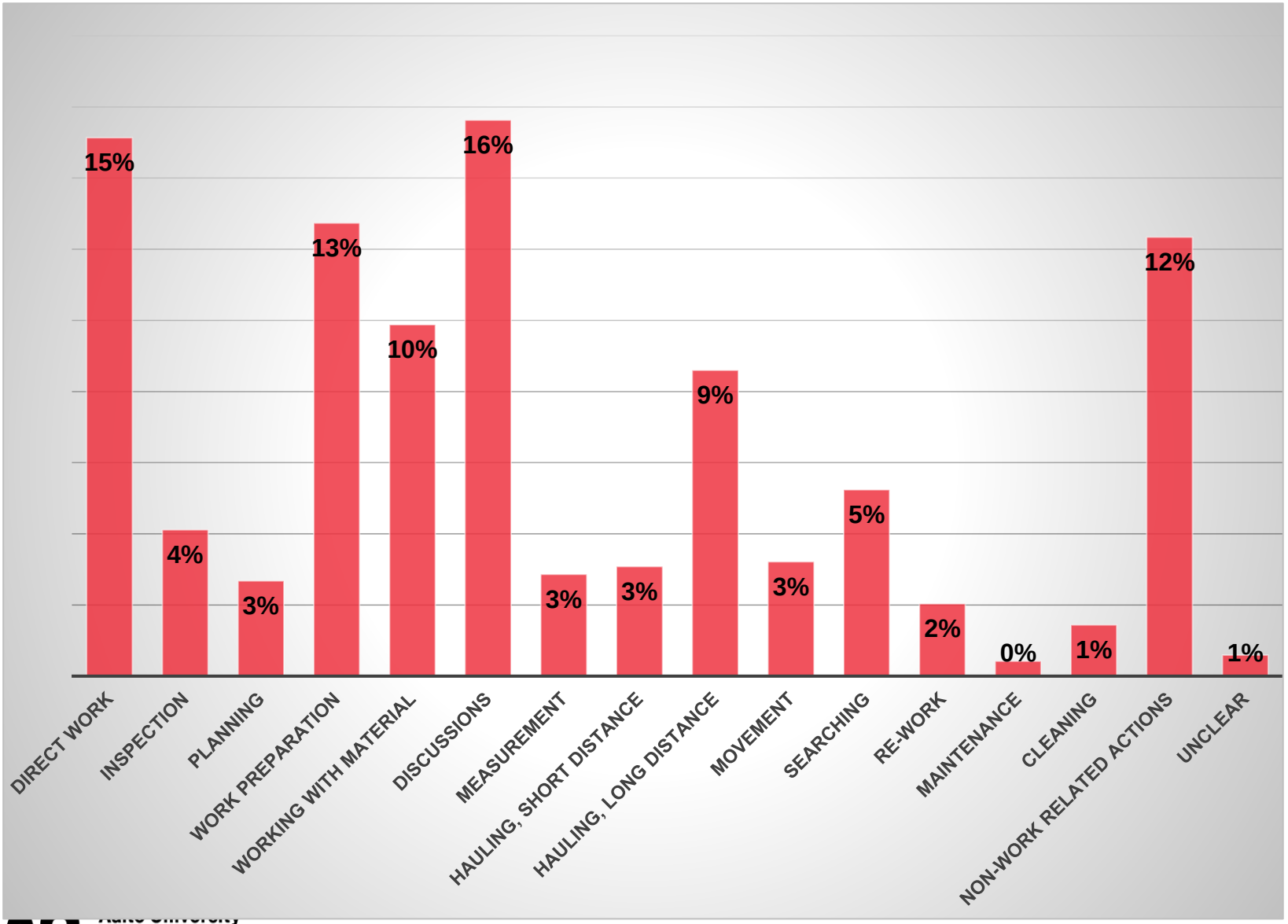
Helmet camera study to investigate waste in HVAC / Electrical installation

- 14 volunteering installers / foremen
- 408 h video material
- Interviews of participants

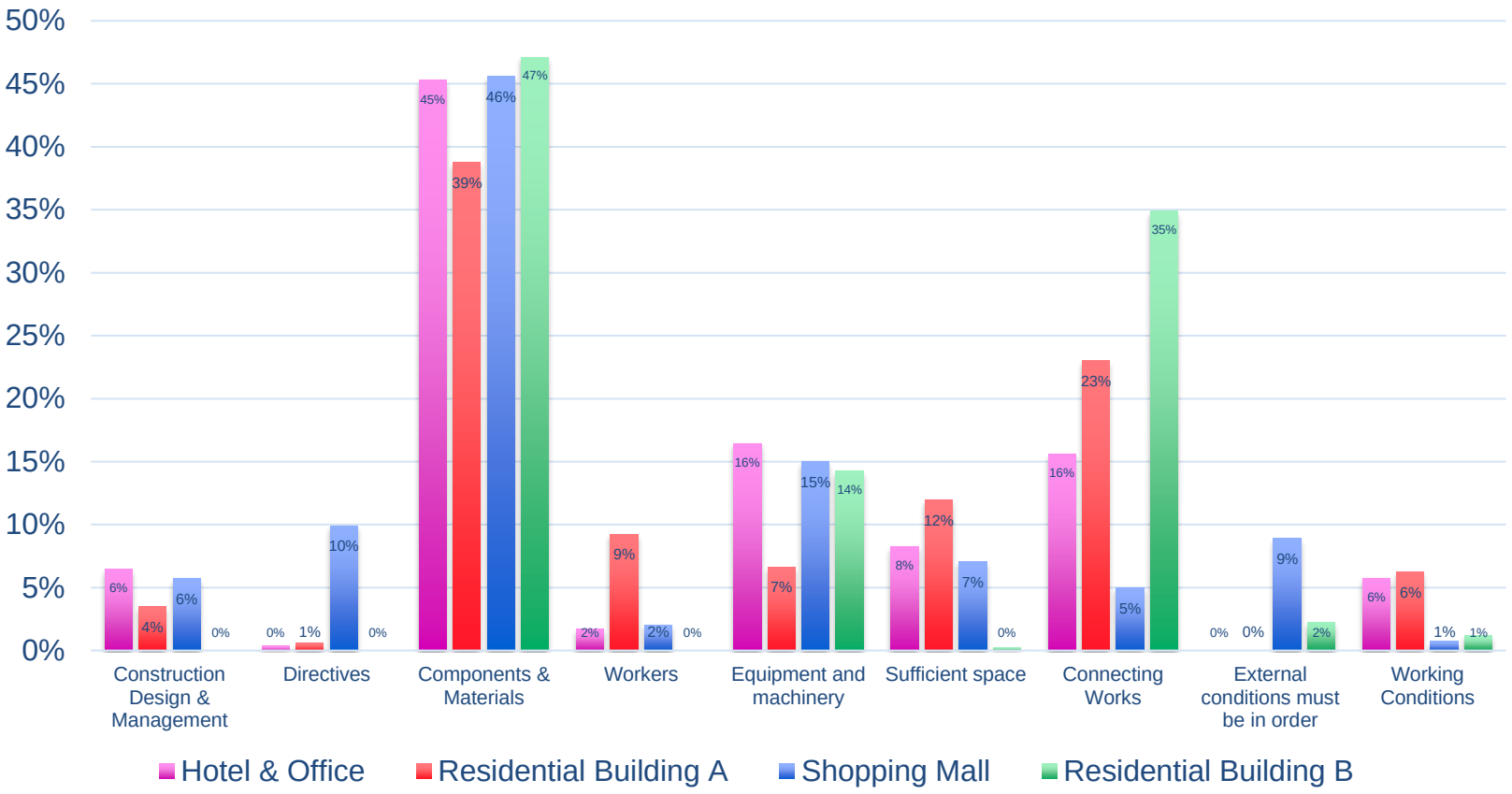
Results: just 23% of electrical work is direct work



Plumbing – even worse, 15%



Reasons for waste



Root causes

- **Communication**
  - More information to installers
  - Clearer command chains
- **Scheduling and production control**
  - Not detailed enough or up-to-date for productivity
- **Logistics and material handling**
  - Unpredictable material needs, scattered storage areas, materials of others on way
- **Quality and level of detail of design**
  - Hanger design missing, not coordinated, models did not use actual parts
- **Large part of preparation work**
  - Many short movements which lead to a large share of total time

Recommendations

Category	Interventions	Potential impact
Communication	• More data to workers before project • Daily huddle meetings on site • Command chains known by all	2-5% productivity increase
Improved constructability of design	• Systematic design reviews before construction • Rules for design on site • Installer-level coordinated designs	10% electrical 20% plumbing

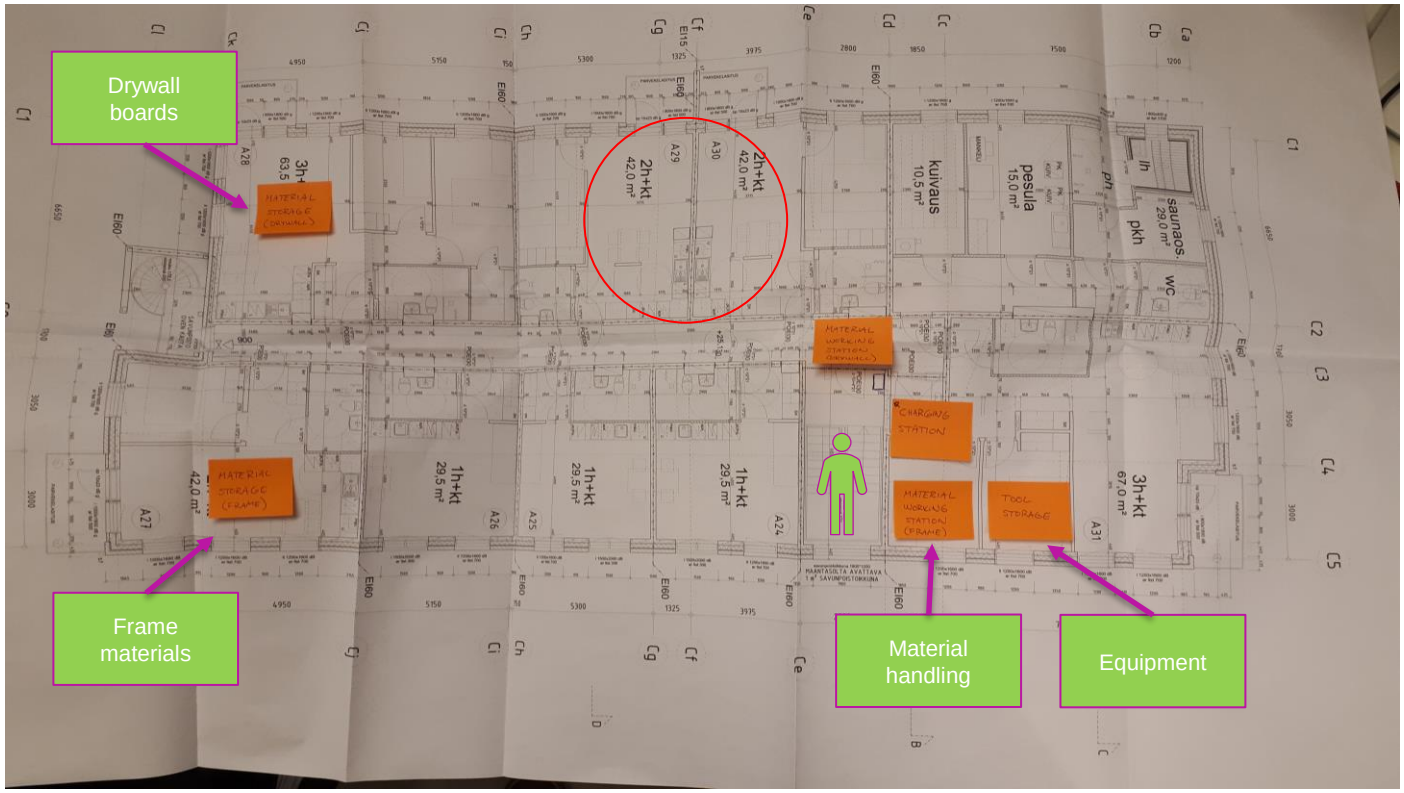
Recommendations

Category	Interventions	Potential impact
Logistics	• Improved material orders • Better organization of storage areas • “Everything on wheels” • Just-in-time logistics	Plumbing 5%, Electrical 1% Electrical 5%, HVAC 10% Electrical 10%, HVAC 20%
Increased prefabrication / preparation on site	• Preparations on site (on ground level) • Factory prefabrication	Increased productivity esp. on ceiling installations 5-25% productivity increase (including additional detailing, prefabrication and installation)

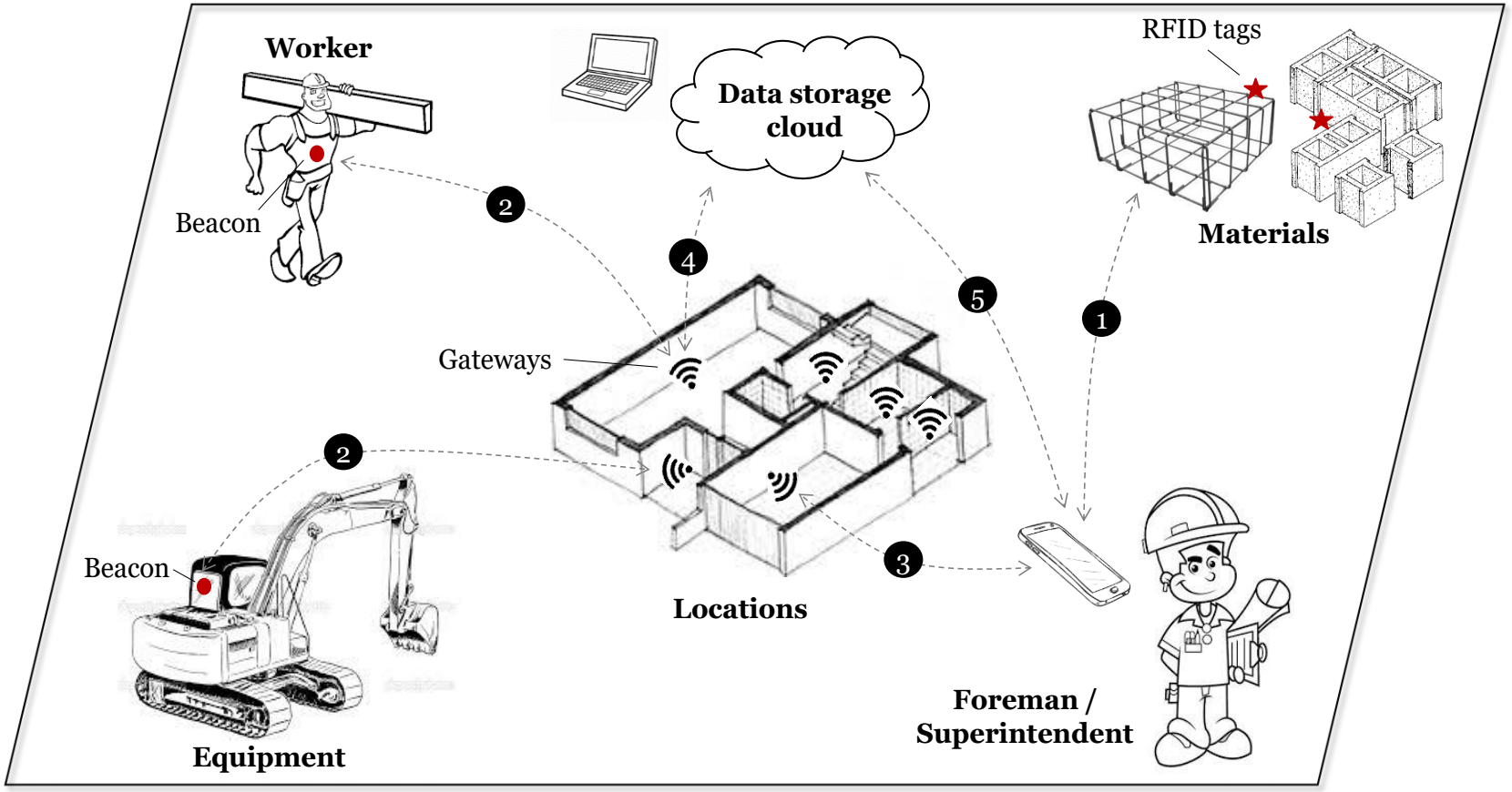
Recommendations

Category	Interventions	Potential impact
Scheduling and production control	• Wide implementation of takt production • Participation of workers in planning • Continuous updates of schedules	Potential 10-20% in Electrical and HVAC works

Waste is often seen as movement

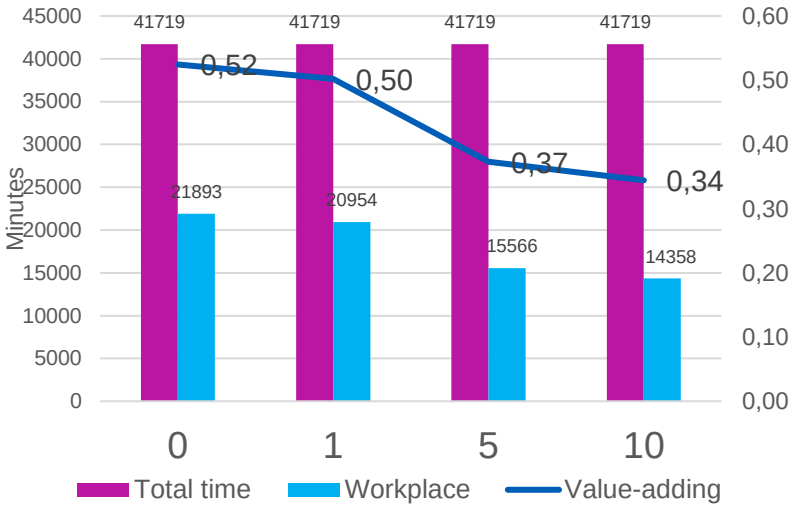


Resource positioning can measure waste

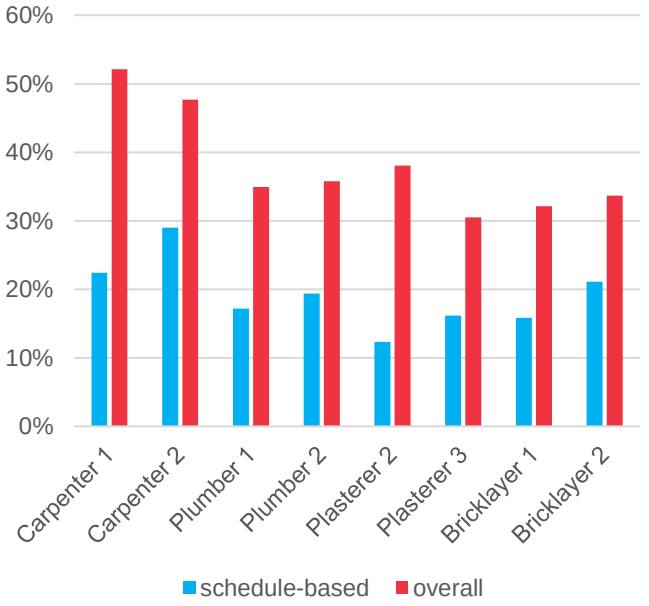


Resource positioning results

- **Workers in a work location more than x minutes at the time**



- **Workers in the correct work location**



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Waste KPI's based on uninterrupted presence

1. **Presence Index, PI**

   Uninterrupted presence / actual duration

   Measured average 34.5%, large variation

2. **Presence-to-plan, PP**

   Uninterrupted presence / planned duration

   Measured average 33.8%

- Conclusion: worker has to be present just 1/3 of work time in order to achieve schedule objectives

(Zhao et al. 2021)

Thank you
Questions & Comments