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
- What is lean production?
- Key concepts of lean – variability, waste, buffers
- Resource vs. flow efficiency
- Batch size reduction / single piece flow
- TFV theory for lean construction
- How can waste be measured?

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*

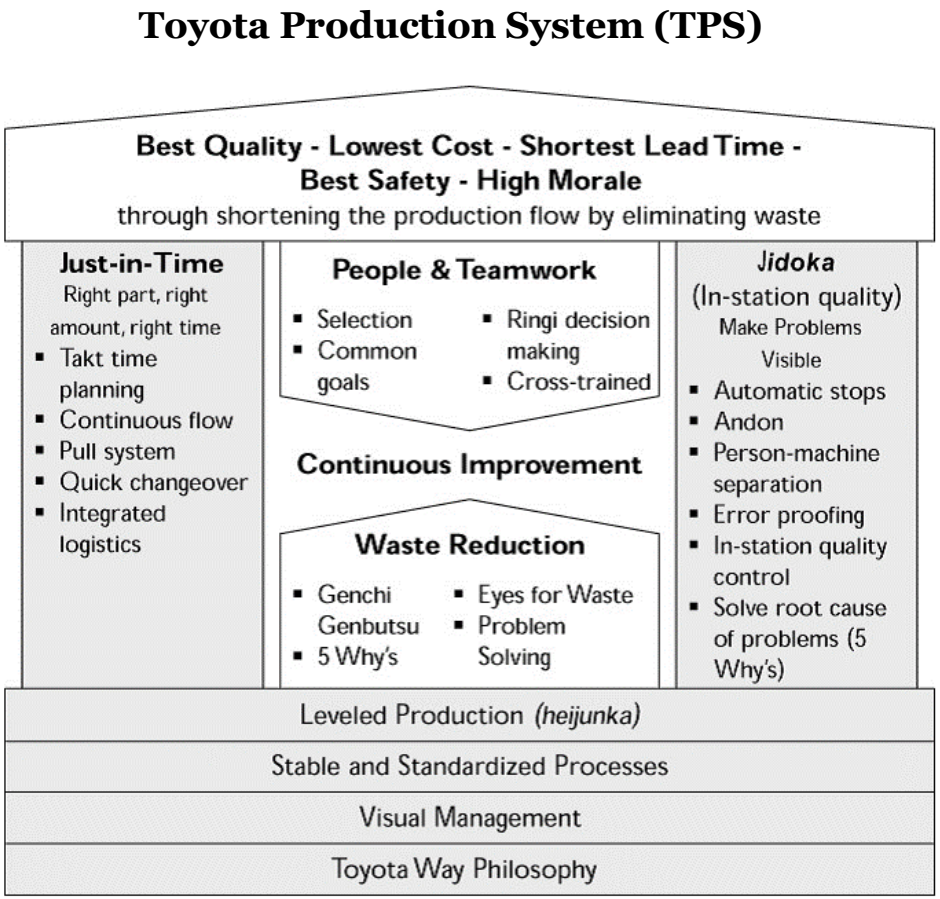
What is lean production?

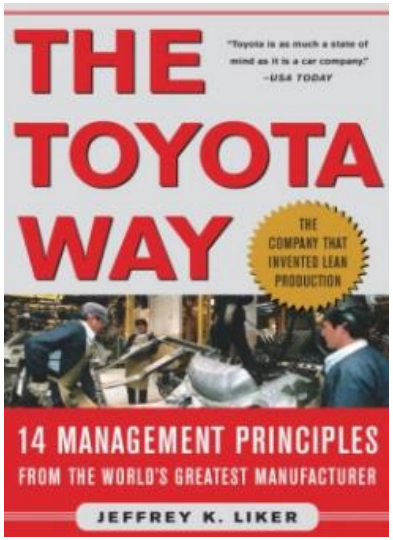
- **Medicine against waste (Womack & Jones 1996)**
  - Improving productivity by decreasing waste
  - Waste is any activity which consumes resources but does not create value (Womack & Jones 1996)

- **Customer determines what value is!**
- **Key points of emphasis:**
  - Respect for people
  - Everyone is responsible for looking for and eliminating waste
  - Standardized processes as starting point for continuous improvement
  - Continuous improvement is critical – failures are acceptable
  - Problems are opportunities!

Toyota Production System

Genchi genbutsu = ”Go and see for yourself”



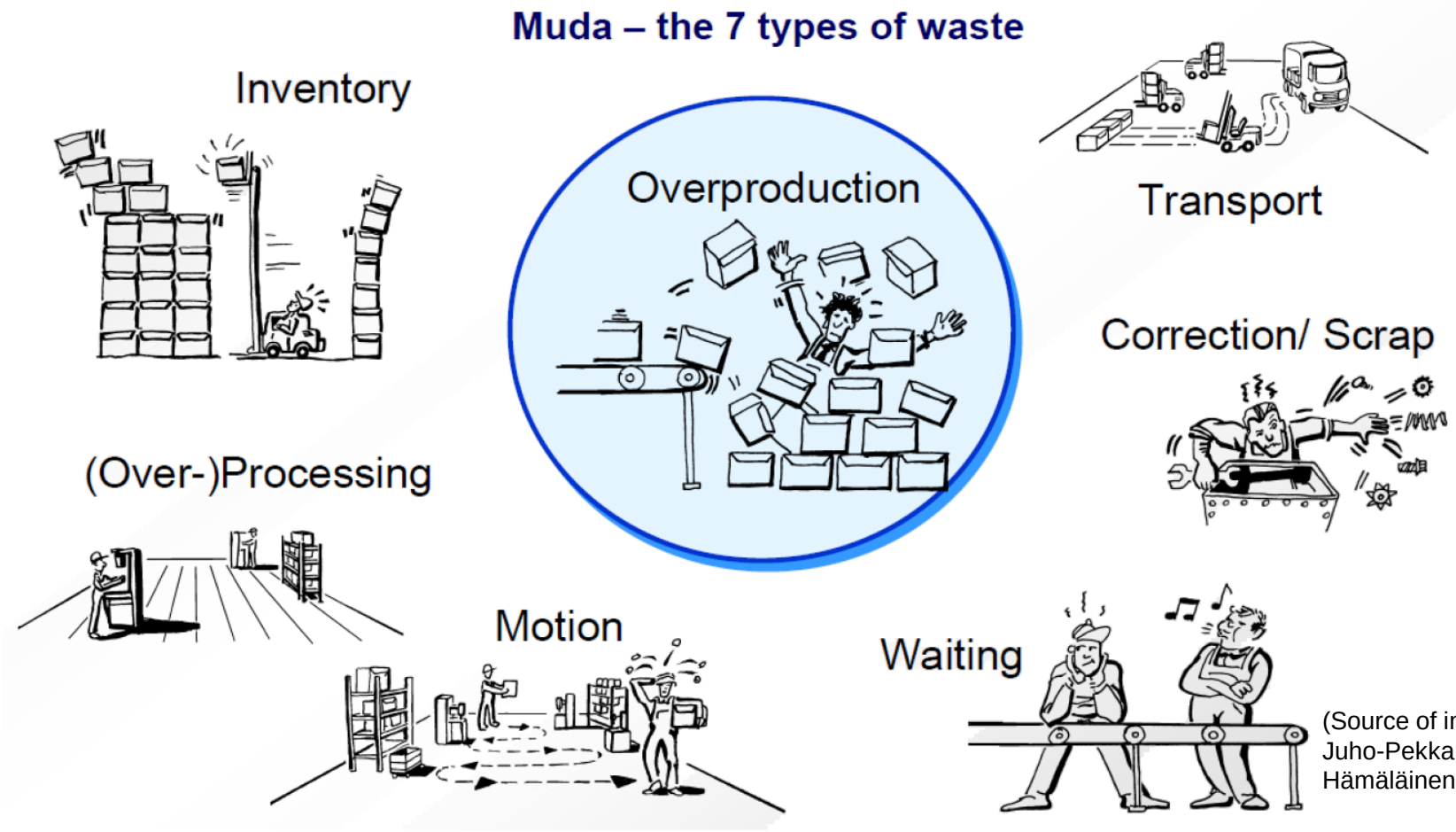


What is waste?

- **Waste is any step or action in a process that is not needed to complete a value-adding process successfully**
- **Value is a desired outcome**
- **Waste is using more resources than needed, or achieving an undesired outcome (Bolviken et al. 2014)**
  - Waste can be either waste in production process or undesired end products of a process (poor quality).

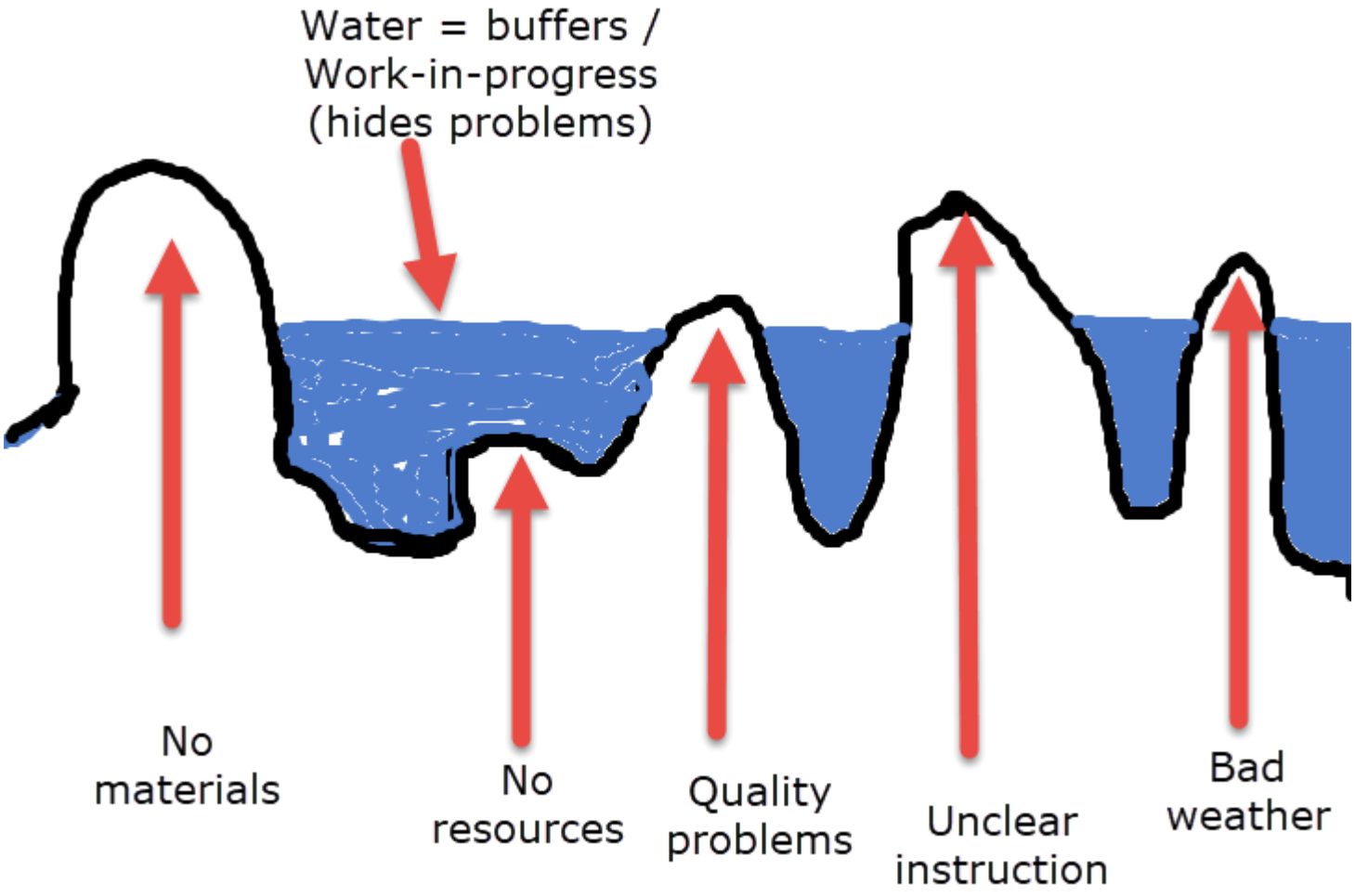
7 wastes by Ohno

Wastes in all our processes lead to higher costs and longer lead times.



(Source of images: Juho-Pekka Hämäläinen / Skanska)

Variability is the enemy number one



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

Buffers are part of the problem...

- **Increase project duration**
- **Hide problems**
- **Prevent continuous learning**
- **Unnecessary buffers are waste and should be eliminated**

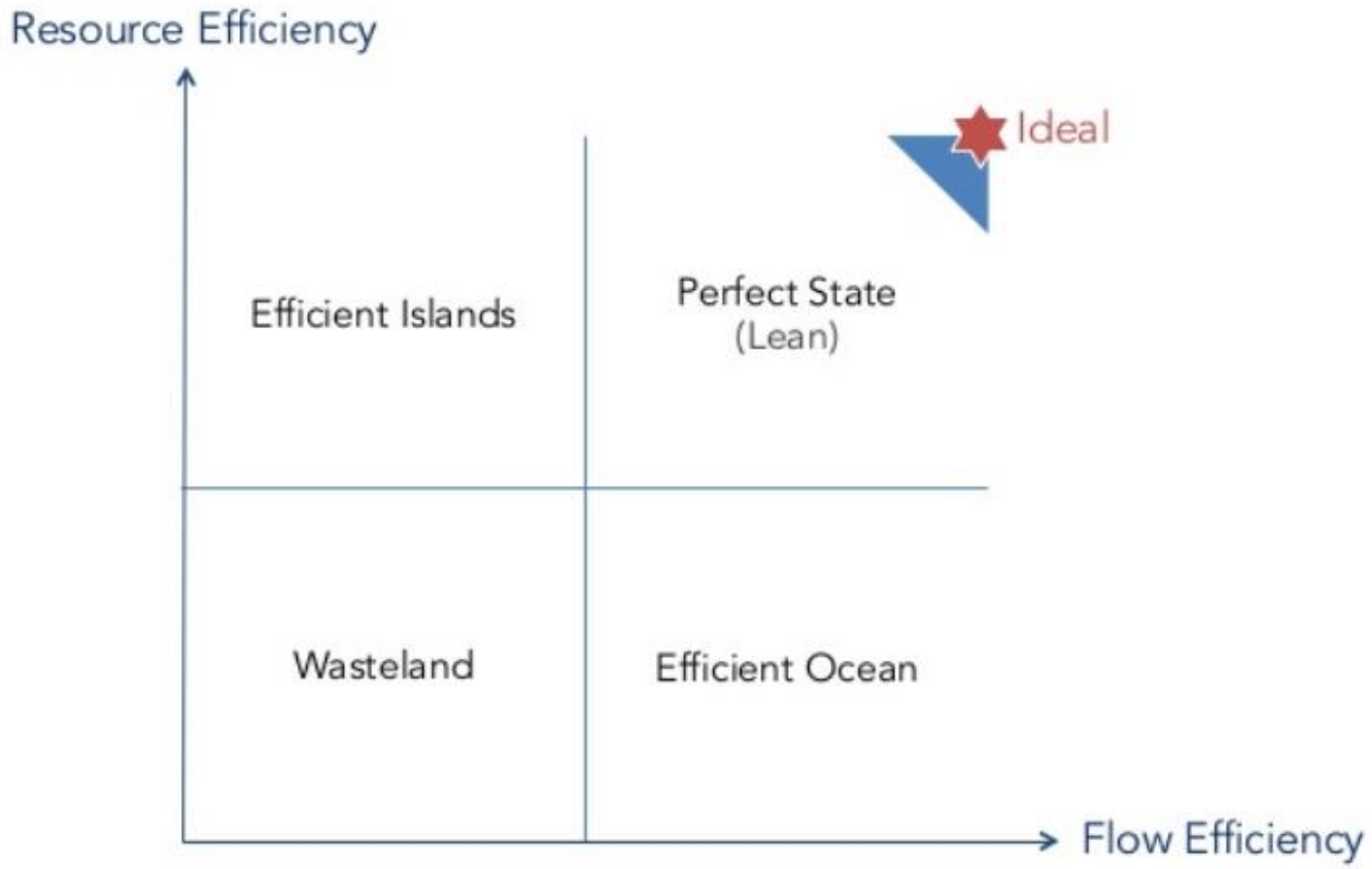
...but all variability cannot be removed

- **There will always be some remaining variability**
- **Every production system needs some buffers**
- **Lean philosophy:**
  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
- **Problems are opportunities!**

Resource vs. flow efficiency

- **Resource efficiency = Workers should not wait for work**
- **Flow efficiency = Work should not wait for workers**
- **Traditional way focuses on resource efficiency**
  - everyone should be busy all the time
- **Lean focuses more on flow efficiency**
  - work should progress all the time in a location

Resource vs. flow efficiency



Measurement of resource vs. flow efficiency

Flow:
Camera in a room

Resource
Camera on a helmet

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%)**

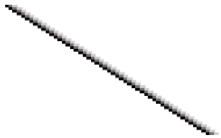
takt time shorter 60%,
no. of takt areas increases by 60%

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)



However, required effort in daily management increases when batch size decreases

- **If variability is the same, short takt time results in a large number of problems in short time periods – need for additional supervision**
- **Batch size should be considered another type of buffer – implicit buffer (Kenley & Seppänen 2010)**
- **Decreasing takt time and takt area size is like decreasing buffers – reveals problems!**

End of video 1

Lean construction

- International Group of Lean Construction founded in 1993
- Lean Construction Institute 1997
- Lean Construction Institute Finland 2008

- Goal: To develop theory of lean construction based on lean principles adapted to construction industry

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**

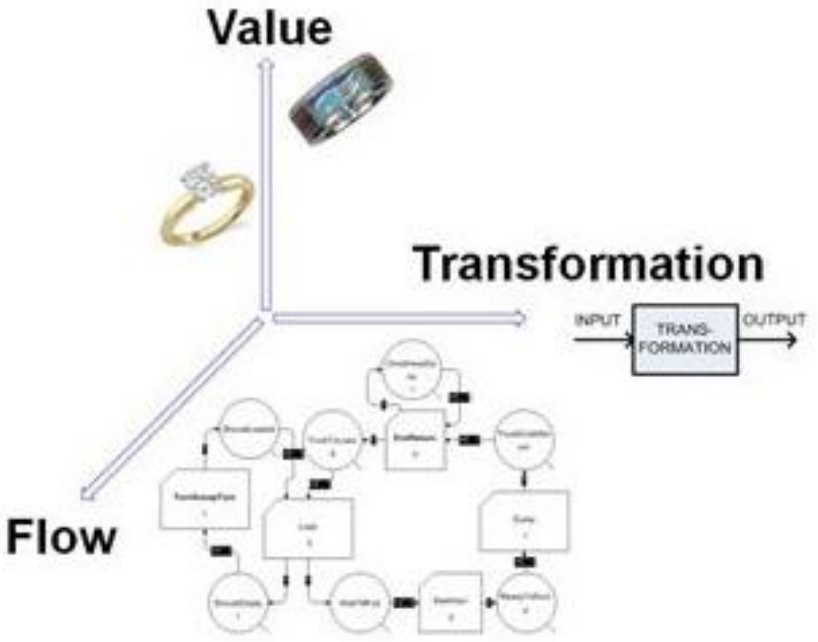
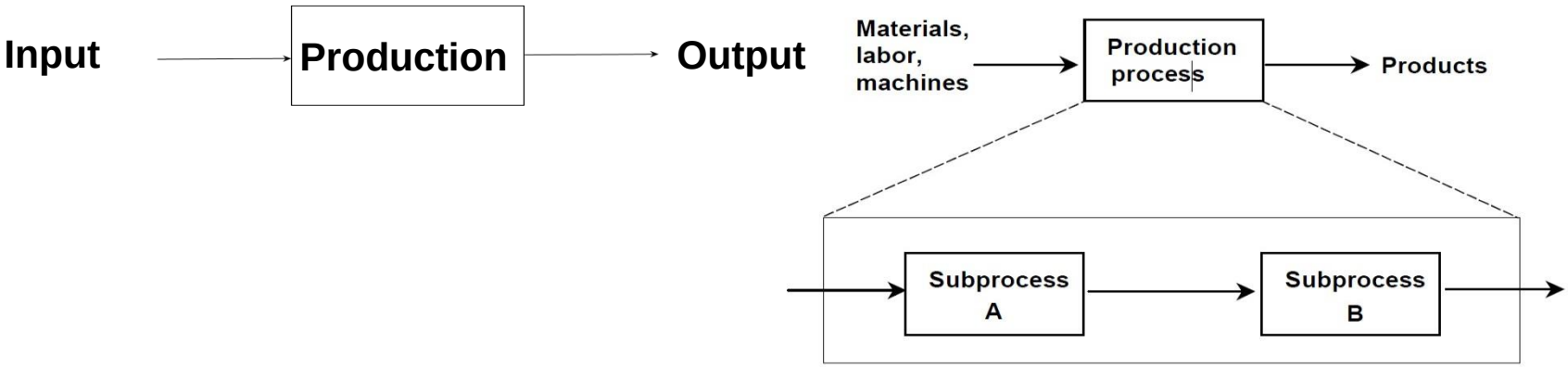


Image source: Iris D. Tommelein

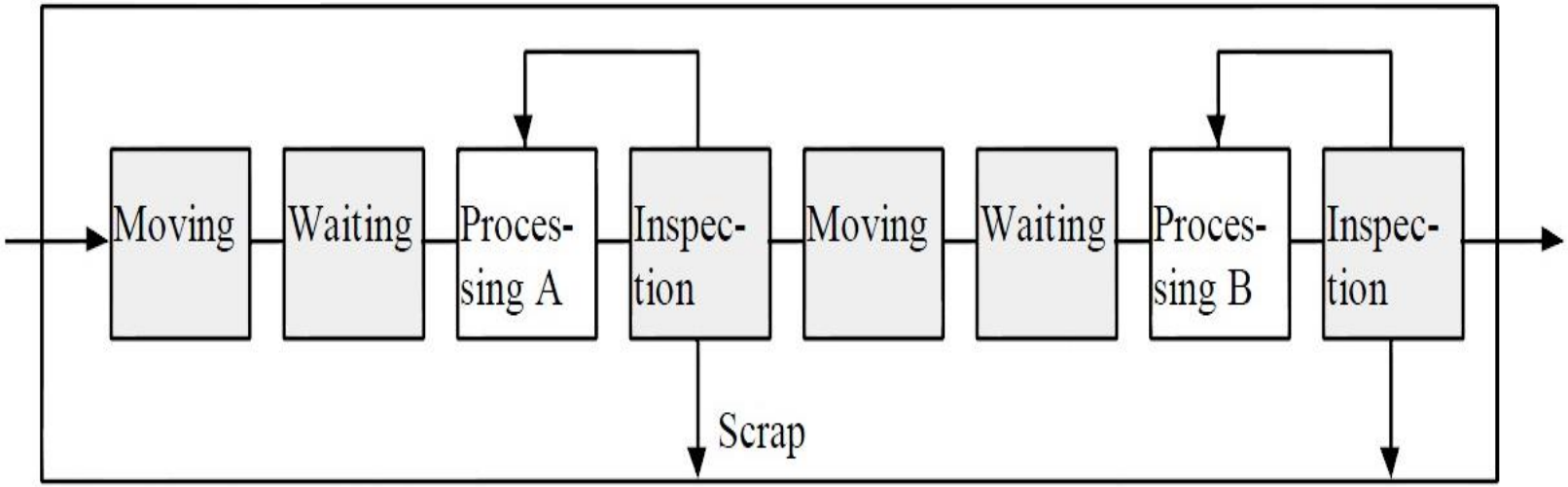
Transformation view of production

- Traditional view
- Main goal: perform value adding operations as productively as possible
- Principles: Divide project into small parts, optimize the parts



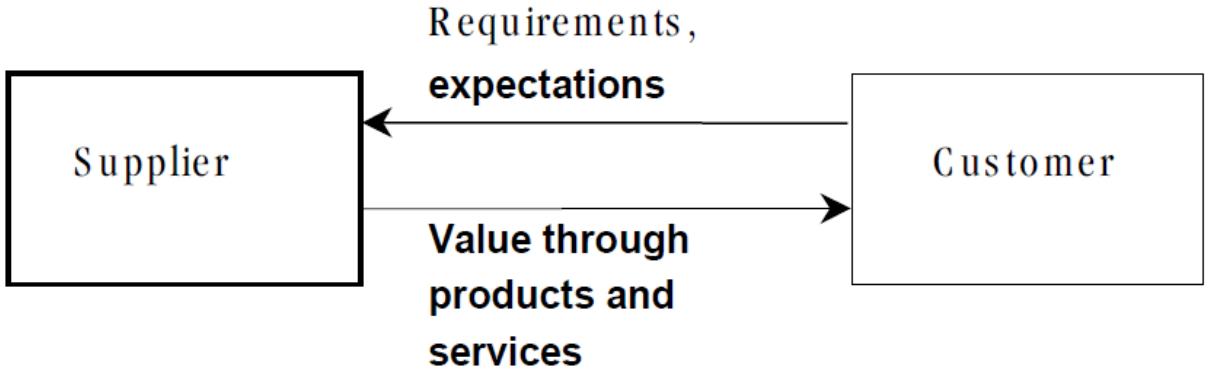
Flow view of production

- **Main goal: remove waste**
- **Principles: shorten cycle time, decrease variability, simplify, increase flexibility, increase transparency**
- **Continuous flow, pull control, continuous improvement**

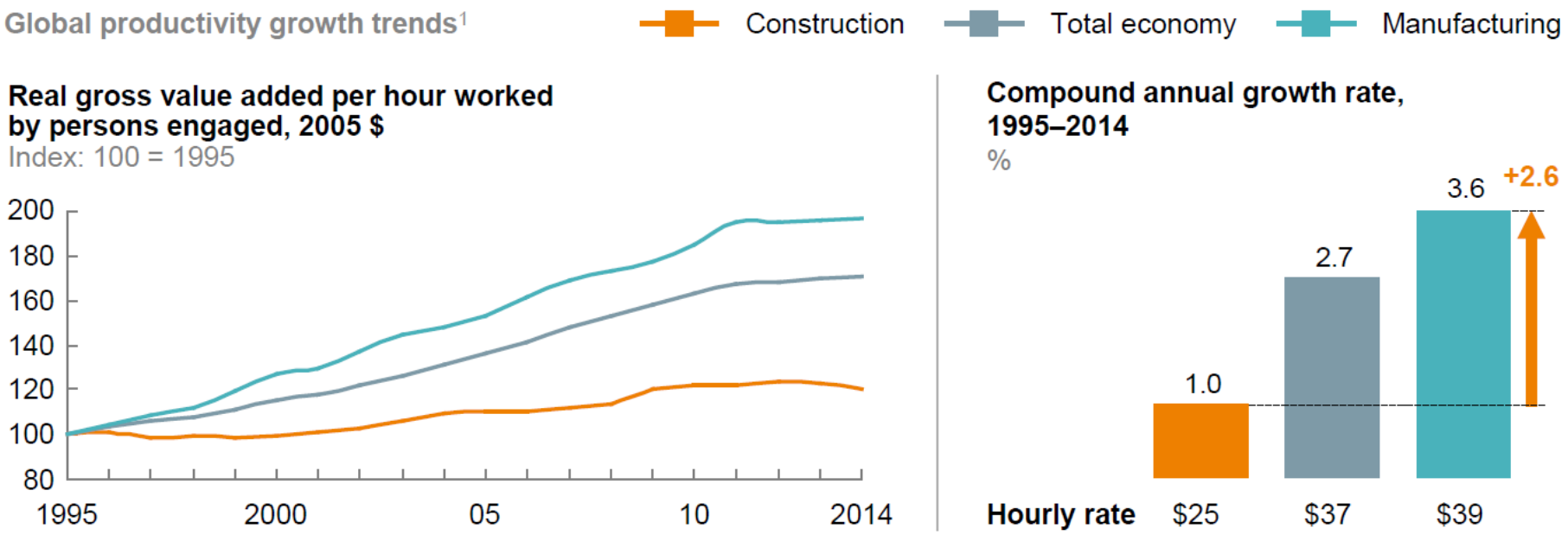


Value view of production

- **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**



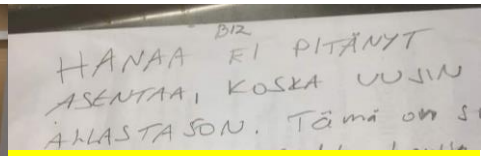
Productivity problem of construction



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

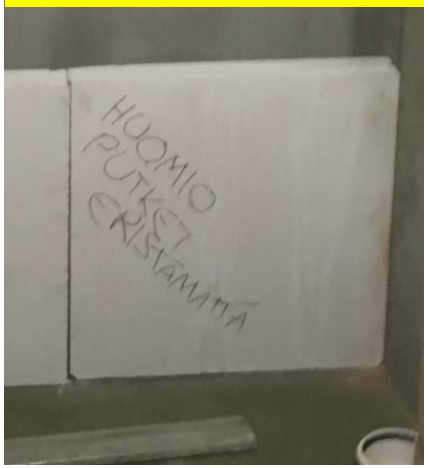
McKinsey 2017: Reinventing Construction: A route to higher productivity

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

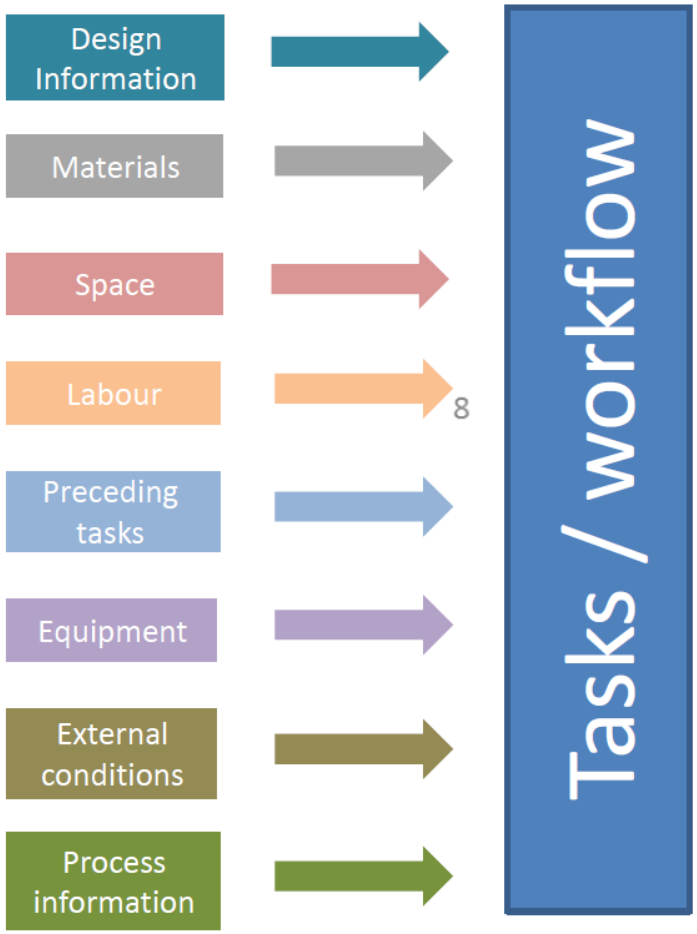
Where are our tools and materials?

2

How and when the work should be done?

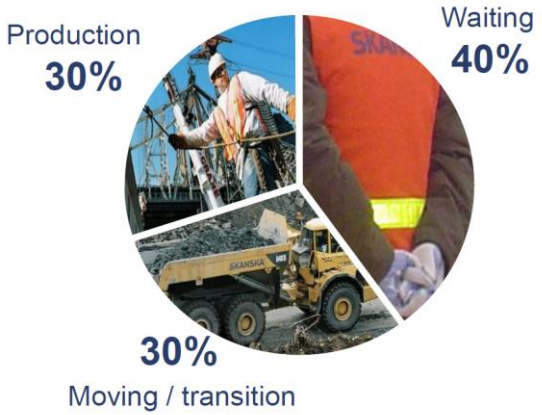
Adapted from: Fira/Otto Alhava 2017

8 Flows of production



Wasted time causes low productivity

- **Only 30% of work time is value-adding production work**



Original(?) source:
Skanska / Jan Elfving

Research on plumbers in Finland:

- Plumbing work 30%
- Material logistics 35%
- Waiting / interference / breaks: 30%
- Meetings, cleaning, misc 5%

International research using stopwatch

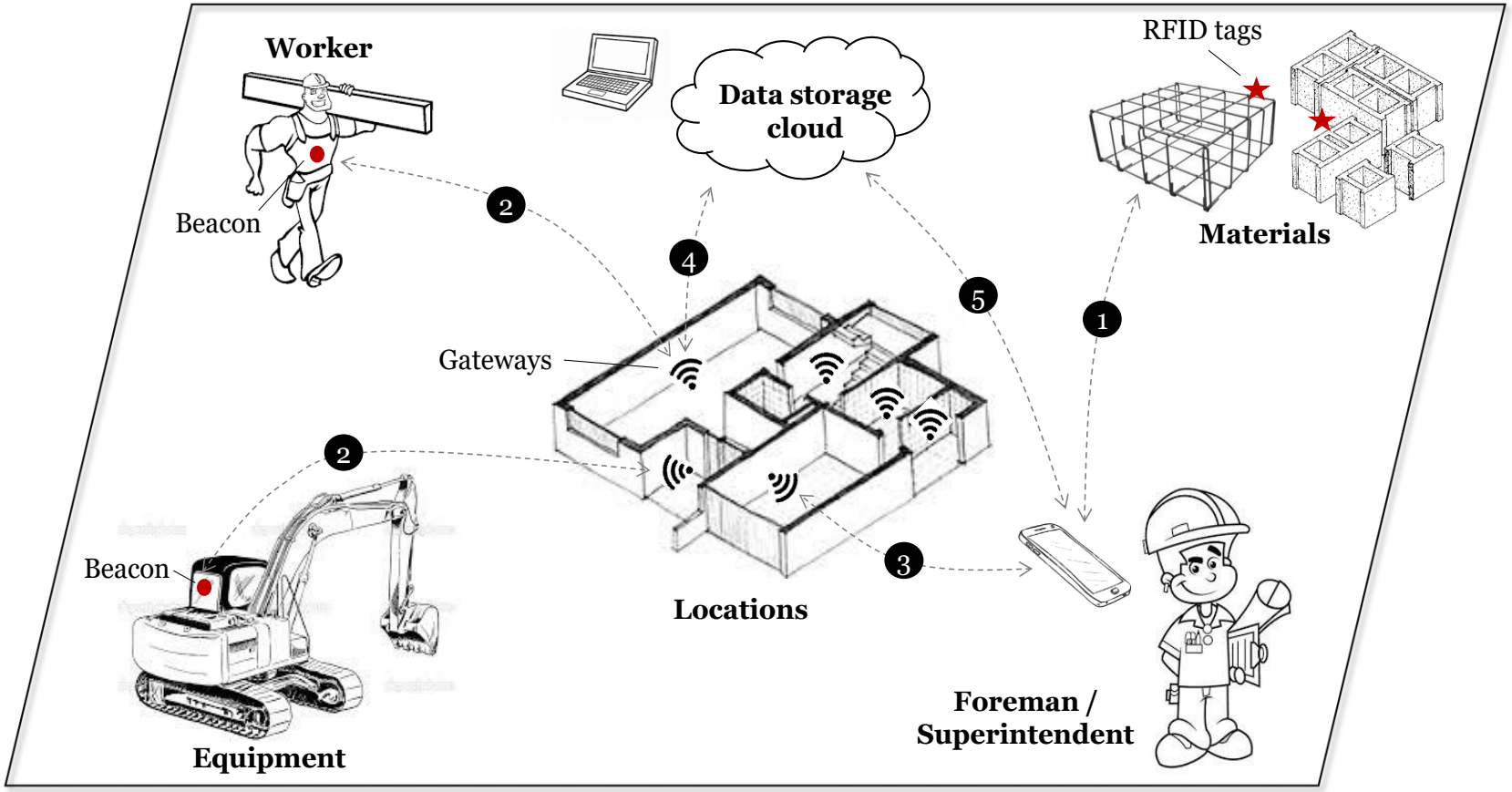
- 30-40% value-adding depending on study

What is waste in construction

	Transformation	*Flow*	*Value*
Production resource	Materials, machinery, energy and labour	Time	
Type of waste	Material loss	Time loss	Value loss
Wastes	1. Material waste 2. Non-optimal use of material 3. Non-optimal use of machinery, energy or labour	*In the work flow* 1. Unnecessary movement (of people) 2. Unnecessary work 3. Inefficient work 4. Waiting *In the product flow* 5. Space not being worked in 6. Materials not being processed 7. Unnecessary transportation (of material)	*Main product* 1. Lack of quality 2. Lack of intended use *By-product* 3. Harmful emissions 4. Injuries and work related sickness

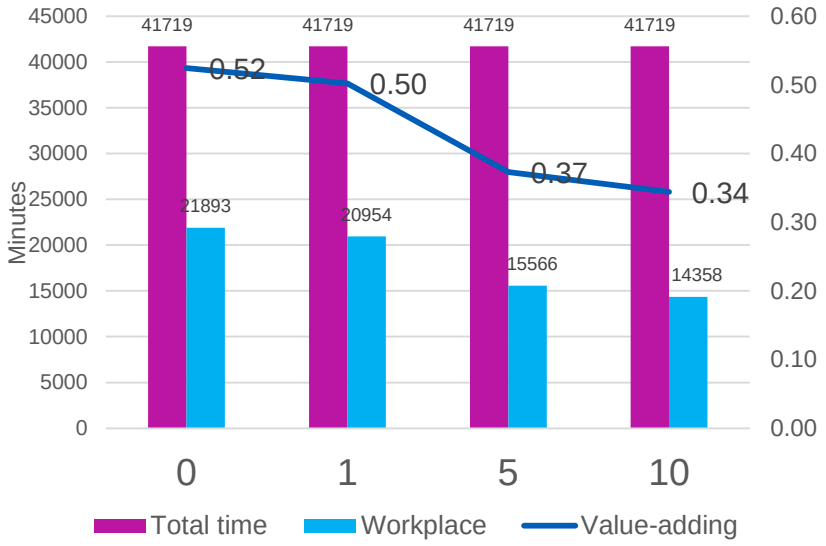
Bolviken, Rooke & Koskela 2014

Measurement of work flow (indoor positioning)

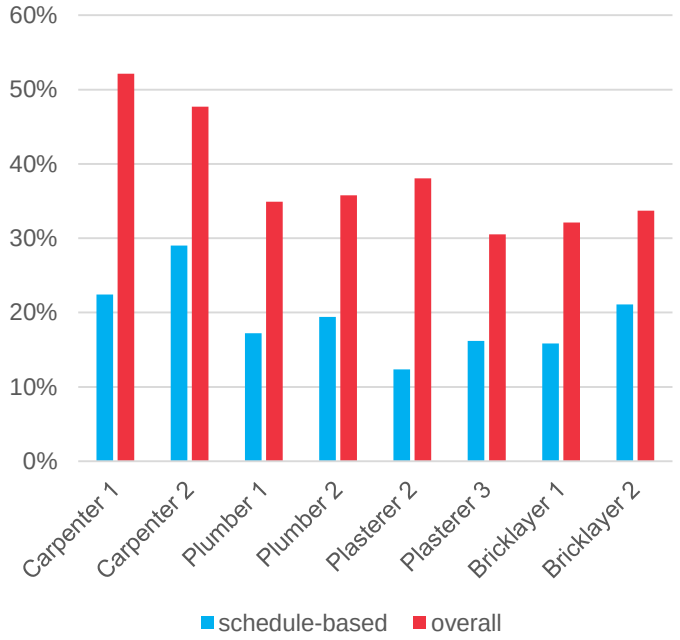


Indoor positioning results

- **Workers in the location longer than x minutes at the time**



- **Workers in the correct location**



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Overall results

- **7 projects analyzed**

- **Assuming 10+ minutes is value adding:**
  - Value adding % is 25-35% depending on project
  - 25-40% depending on trade (carpenters 40%, MEP lower)

- **Only 50% of value adding time is in the correct location**
- **In reality, a small portion of the time in locations in value adding (half?)**

Helmet camera study

MSc thesis Hans Pasila

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Distribution of time

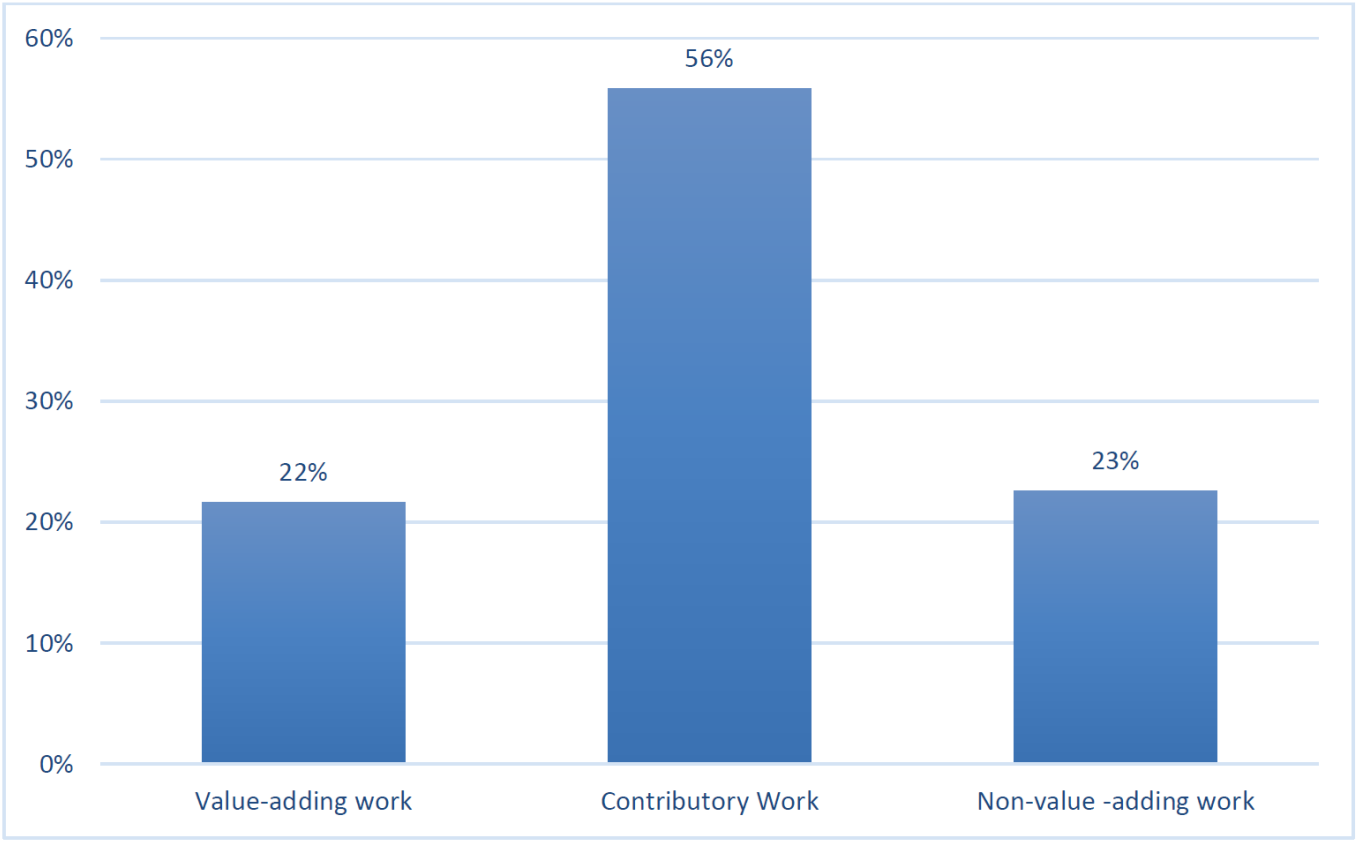

Figure 14: Distribution of work time (not including non-work -related time)

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More detailed distribution of time

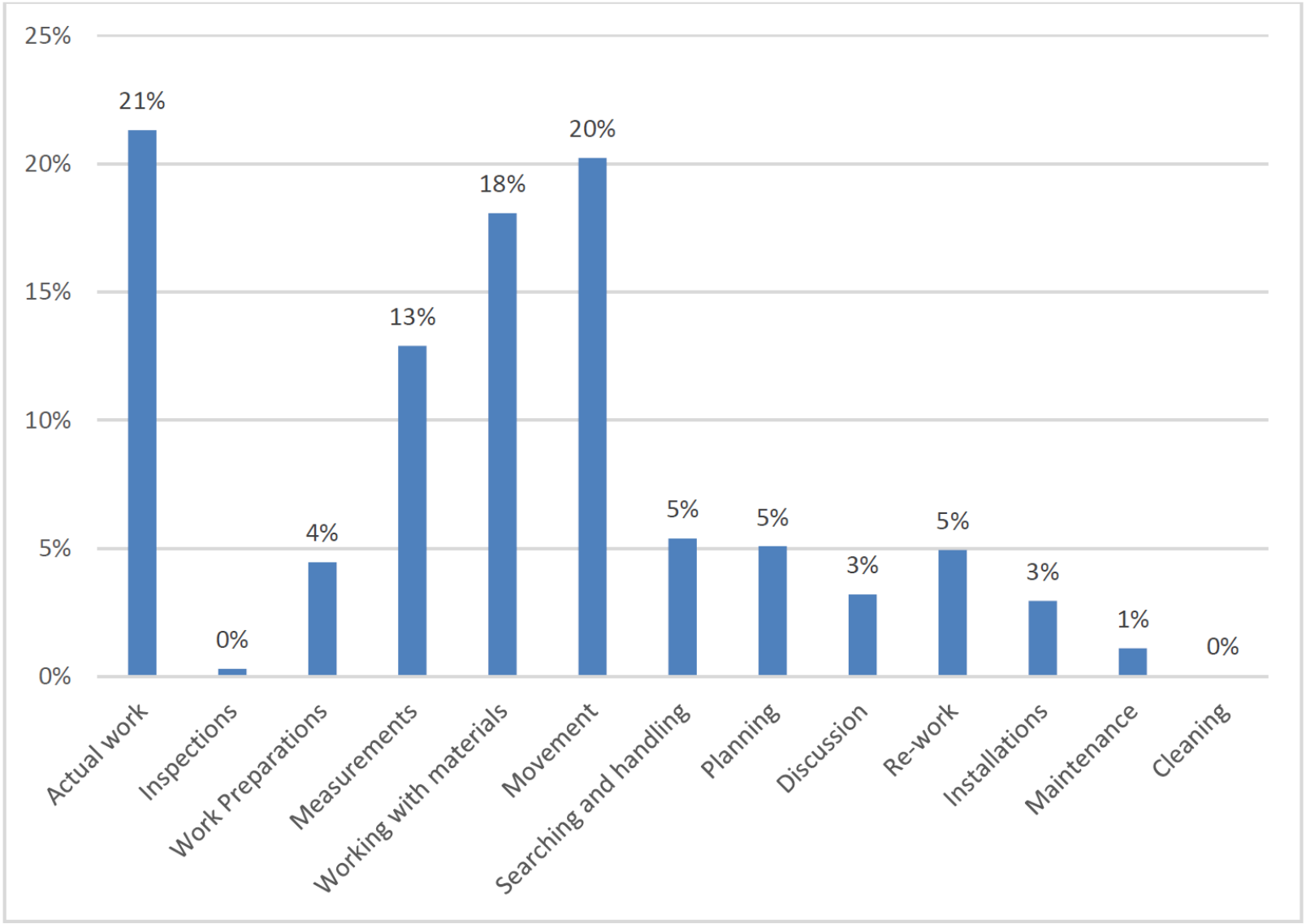

Figure 15: Division of data gathered in the first measurement

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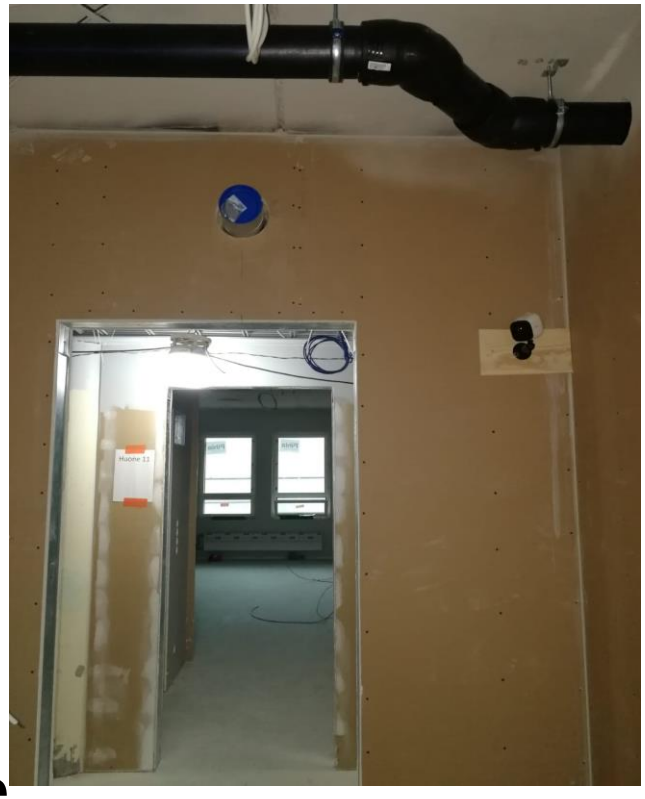
Measurement of flow efficiency

- MSc thesis project of Anton Ruohomäki (ongoing)
- Hotel renovation using takt of 1 day per hotel room
- Just 37% utilization rate of hotel rooms and achieved takt schedule
- 80 visits in a room during one day (average 2 min 26 seconds)
- There is room for improvement



Thank you
Questions & Comments