GPI

Cycle time analysis game

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Lean Production Basics
Purpose of the Training

- Introduction to the **background** and the **basic principles** of Lean Production

- Understand **structured target derivation** as essential **basis for improvement work**

- Learn how to establish an **improvable system** by implementation **step by step**

- Learn the **structure** and the **success factors** of the **continuous improvement process**.

Lean Production Basics | **Introduction**

Why do we introduce Lean Production?

- Satisfied customers
  - High order fulfillment
  - High flexibility
  - High quality
- Satisfied associates
  - Ergonomic workplaces
  - Calm working environment
  - Less firefighting
- Efficient and lean processes both in manufacturing and in indirect areas

Lean production is the key to reach economic successf in a sustainable way

Lean Production Basics
Simulation Rules

- Questions are always OK
- Mistakes are allowed
- 100% attendance

Is that OK? Has anything been left out?

Lean Production Basics | **Manufacturing Round 1**

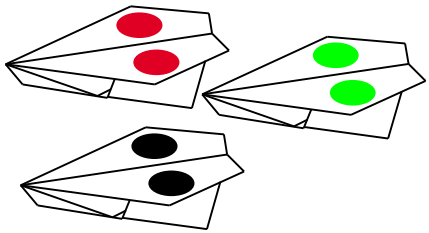
General Conditions

RoBo
Competitor 1

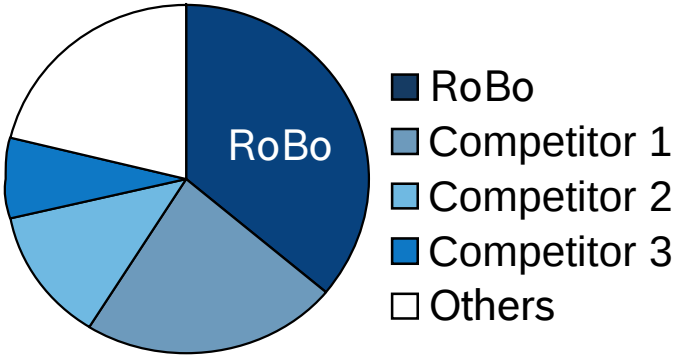
Product

Three variants of airplanes

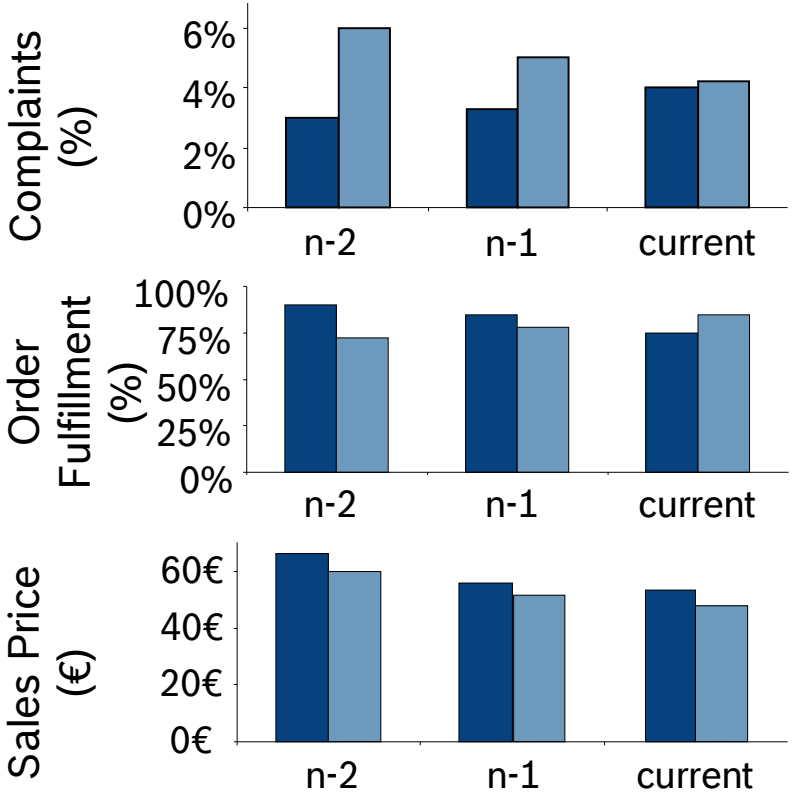
- Red
- Green
- Black



Market share



Customer perspective



Video 1: observation of the process steps

Video

Results of the observation

- What is your impression about the process ?
- What is your impression about the delivery ?
- What is your impression about the supply ?
- .....

Lean Production Basics | **Airplane Production**

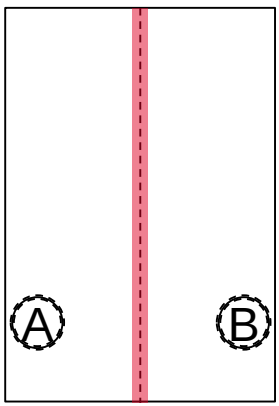
Instructions for Cockpit Assembly

8 sec

Step 1.1

Folding 1:

Fold centerfold, smooth out with finger and reopen it. Fold exactly centered!



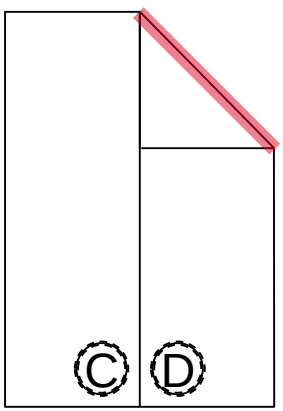
7 sec

Step 1.2

Turn sheet

Folding 2:

Fold edge to centerfold, smooth out with finger

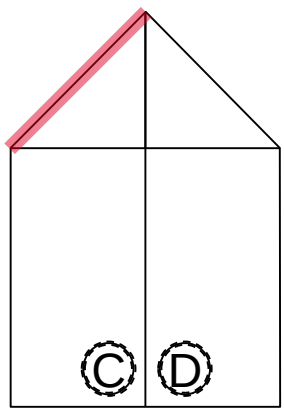


7 sec

Step 1.3

Folding 3:

Fold edge to centerfold, smooth out with finger. Symmetry with folding 2 important!



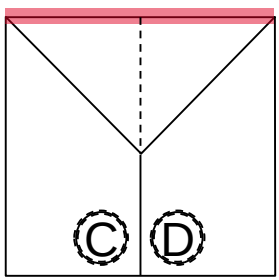
7 sec

Step 1.4

Folding 4:

Fold according to folding 4 and smooth out

Set aside assembled part and, if material available, continue with next one. Send-ahead quantity 3



It is more important to have symmetry than to fold along the printed lines!

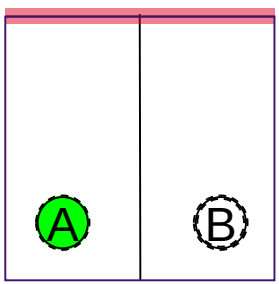
Lean Production Basics | **Airplane Production**

Instructions for Painting

19 sec

Step 2.1

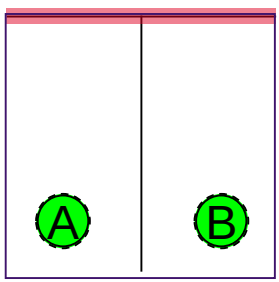
Fill out circle A with color. Surface of inner circle has to be filled 100%. Coloring must not exceed outer circle



19 sec

Step 2.2

Paint circle B like A

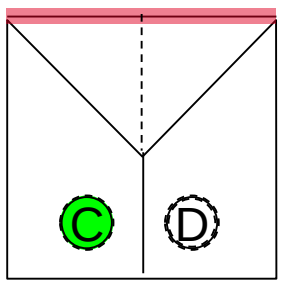


19 sec

Step 2.3

Turn sheet

Paint circle C like A

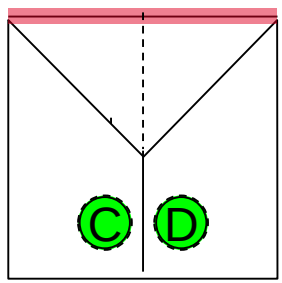


19 sec

Step 2.4

Paint circle D like A

Set aside painted part and, if material available, continue with next one. Send-ahead quantity 3



Lean Production Basics | **Airplane Production**

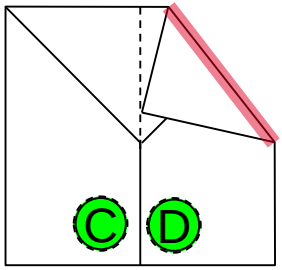
Instructions for Body Assembly

5 sec

Step 3.1

Folding 5:

Fold corner to centerfold at the target point, smooth out with finger

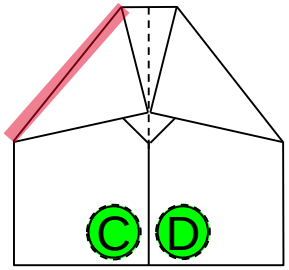


5 sec

Step 3.2

Folding 6:

Fold corner to centerfold at the target point, smooth out with finger. Symmetry with folding 5 important!

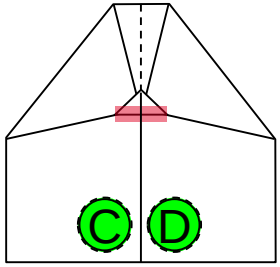


4 sec

Step 3.3

Folding 7:

Fold up triangle, smooth out with finger



5 sec

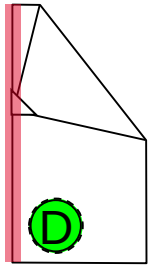
Step 3.4

Turn sheet

Folding 8:

Fold centerfold, smooth out with finger

Set aside assembled part and, if material available, continue with next one. Send-ahead quantity 3

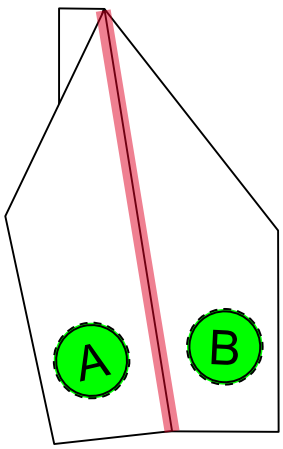


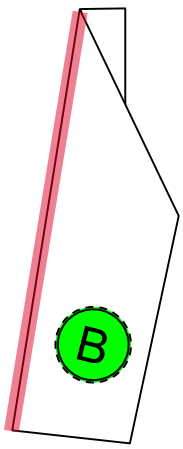
It is more important to have symmetry than to fold along the printed lines!

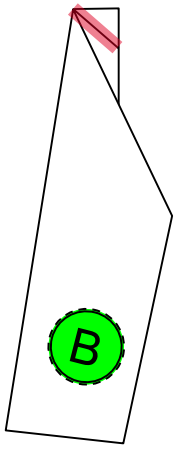
Lean Production Basics | **Airplane Production**

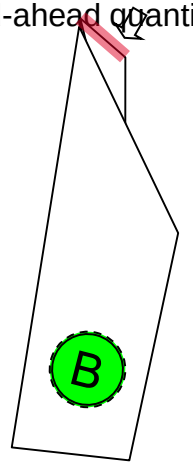
Instructions for Wings Assembly

6 sec	6 sec	7 sec	5 sec
Step 4.1	**Step 4.2**	**Step 4.3**	**Step 4.4**
Folding 9: Fold and smooth out with fingers	Turn sheet Folding 10: Fold and smooth out with fingers. Symmetry with folding 9 important!	Folding 11: Fold in both directions and smooth out with fingers	Finishing folding 11: Fold in edge Set aside assembled part and, if material available, continue with next one. Send-ahead quantity 3









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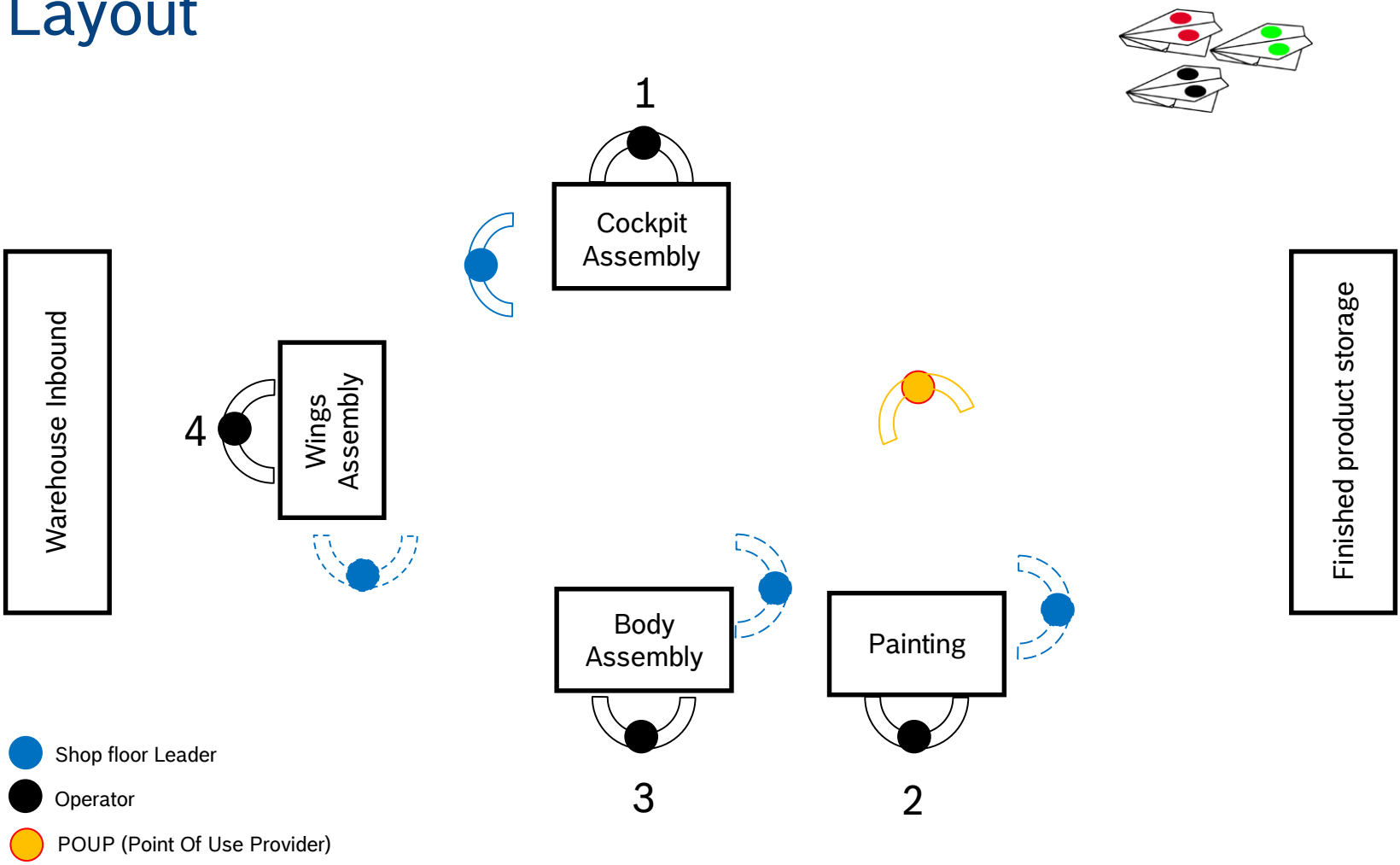
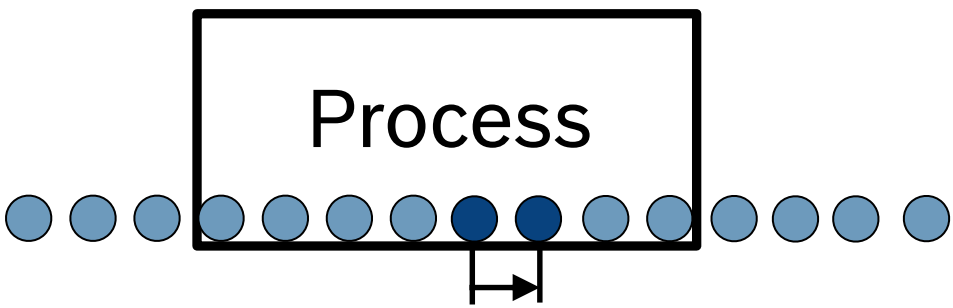
Lean Production Basics
Layout



Lean Production Basics | **Balancing**

Cycle **T**ime (CT)

- Time interval between two parts (without malfunction)



Cycle time
(e.g. 2s / unit)

Lean Production Basics | **Balancing**

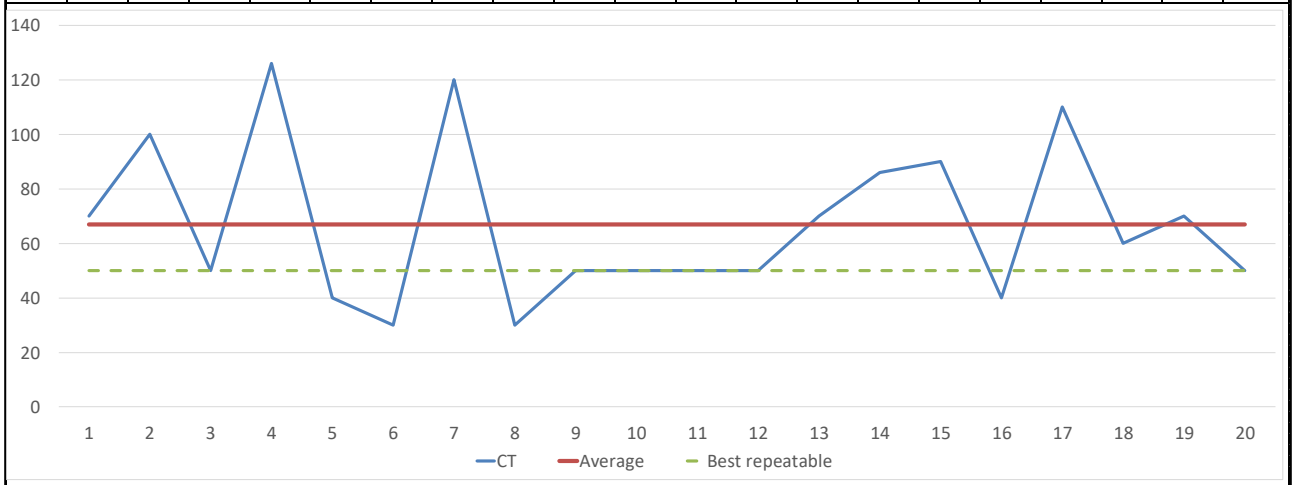
Cycle Time (CT)

Process Analysis of Cycle Time

Workshop	Date

Line	Type	Cycle	Min. cycle time	Max. cycle time	Cycle time duration
			30	126	67

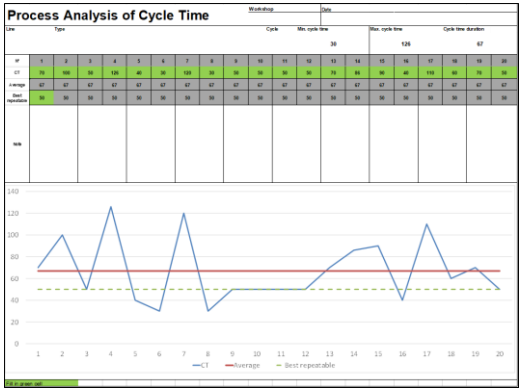
N°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CT	70	100	50	126	40	30	120	30	50	50	50	50	70	86	90	40	110	60	70	50
Average	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67
Best repeatable	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Note																				



Fill in green cell

Lean Production Basics | **Balancing**

Cycle **T**ime (CT): exercise



- Measure the cycle time
- Comment in case of malfunctions / waiting times
- Check whether the operator is working according to the standard (Process confirmation)
- Present the results in a graph
- Identify the shortest (best) repeatable cycle time
- Calculate the average cycle time (without malfunctions/waiting times)
- Identify the longest cycle time (without malfunctions/waiting times)

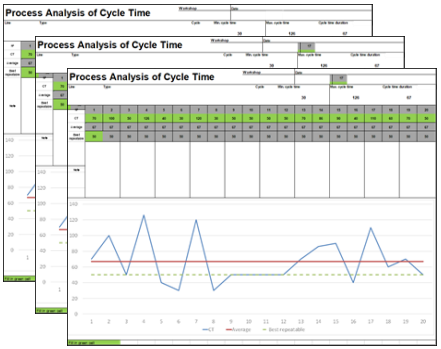
Lean Production Basics | **Manufacturing Round 1**

Video 1: observe the 4 production steps

Video 1

Lean Production Basics | **Manufacturing Round 1**

Discussion: measurements results from the students



Lean Production Basics | **Manufacturing Round 1**

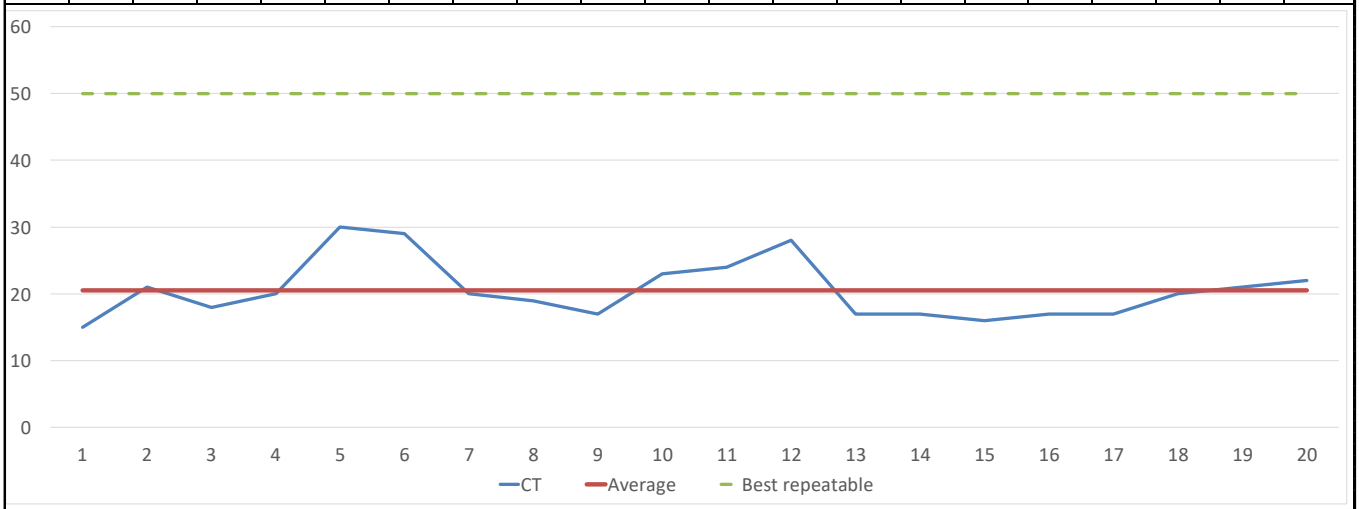
Measurements results from Trainer

Process Analysis of Cycle Time

Workshop	Date

Line	Type	Cycle	Min. cycle time	Max. cycle time	Cycle time duration
Airplane	RED; Black; Green;	Station 1	15	30	21

N°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CT	15	21	18	20	30	29	20	19	17	23	24	28	17	17	16	17	17	20	21	22
Average	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
Best repeatable	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Note																				



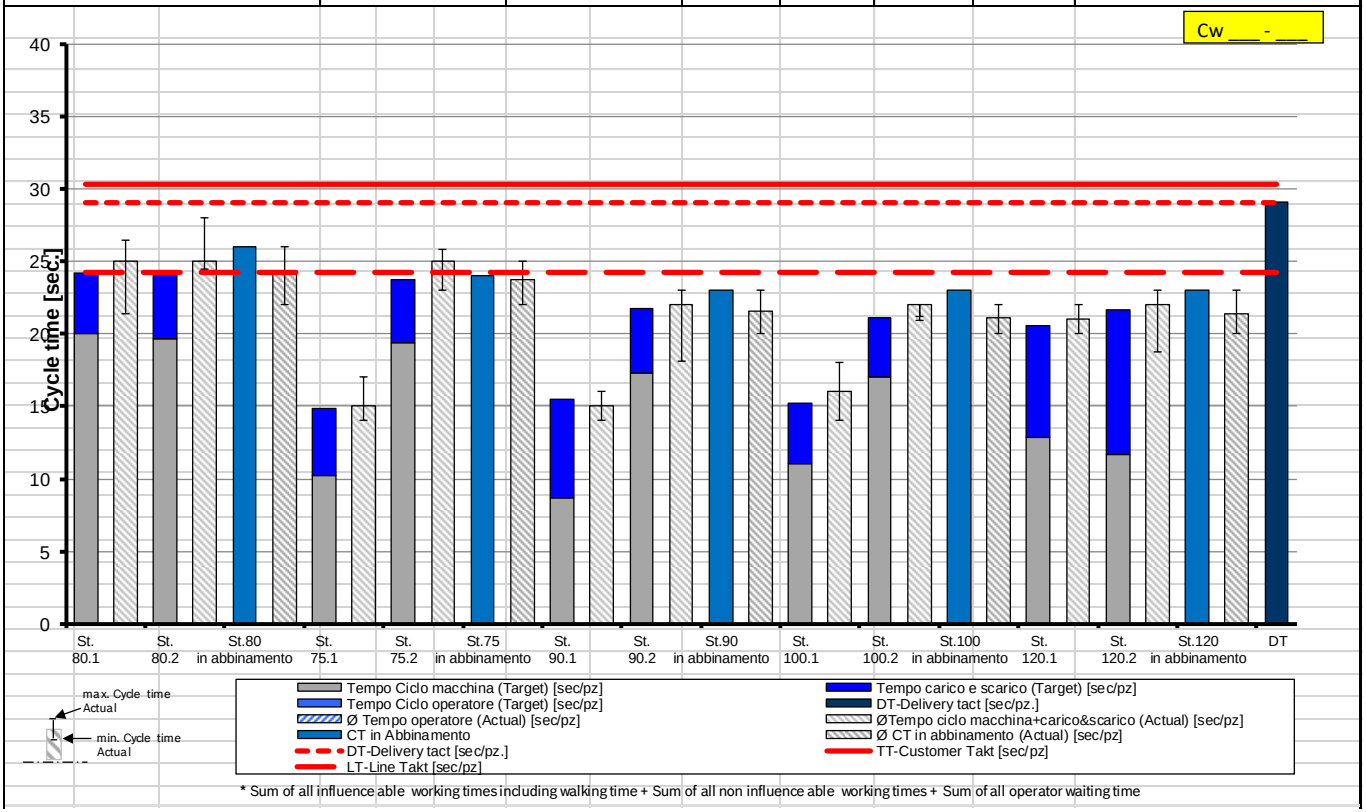
Fill in green cell

Lean Production Basics | **Manufacturing Round 1**

Balance Diagram

10.1 Takt time chart: MAE xxx

Tipo:	TeCO	Planer	TT [sec./pce.]	LT [sec./pce.]	DT [sec./pce.]	OEE actual	aggiornato al
xxxxx	CBA	ABC	30,3	24,3	29,09	83,4%	01/11/2017



* Sum of all influence able working times including walking time + Sum of all non influence able working times + Sum of all operator waiting time

Lean Production Basics | **Balancing**

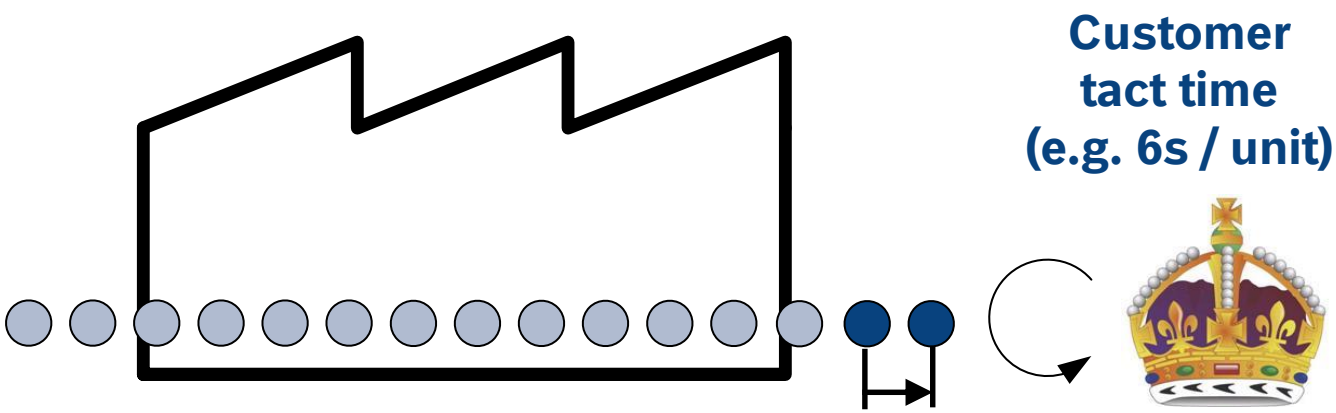
Customer **T**act **T**ime (TT) (ritmo di prelievo)

- It's the withdrawal rhythm of the customer

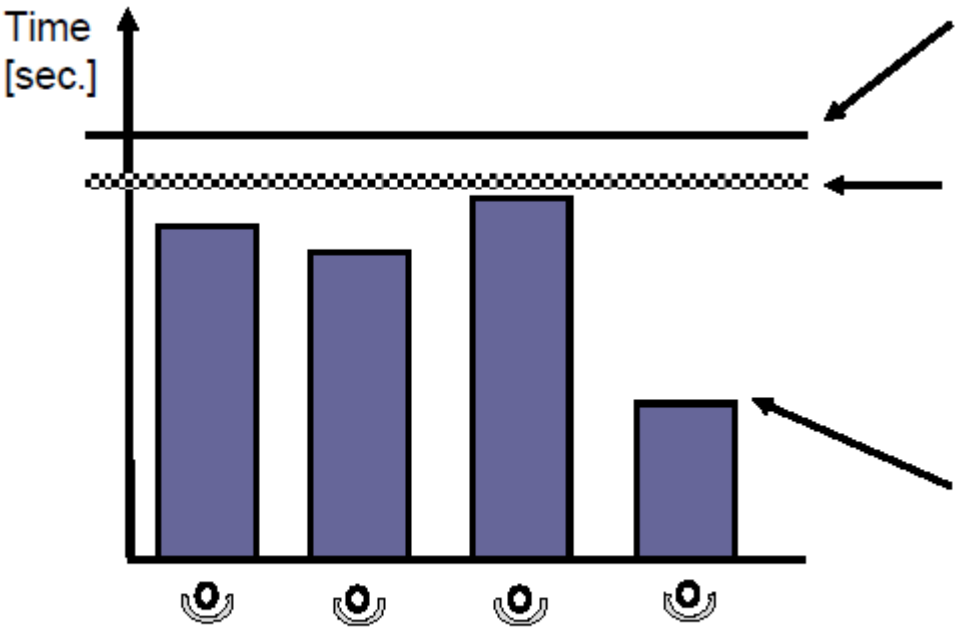
it's an average time considering that real delivery (shipment) is based on lotsize and order quantity.

- Customer tact time = $\dfrac{\text{planned operation time* / period}}{\text{customer demand / period}}$

* available time without planned breaks and planned maintenance



Lean Production Basics | **Balancing**
Target **C**ycle **T**ime (TCT)



Takt Time (TT):
The customer demand rate, also known as "Customer Takt"

Target Cycle Time (TCT)
A production rate that is different from the customer demand rate. (Has to be faster than TT since it includes changeover time and/or downtime.)

Operator Cycle Time (CT):
Time for work content of one operator (standard work procedure)

source: Mike Rother

Lean Production Basics | **Balancing**

Calculation of Customer Tact Time

- Time to meet customer demand:
  - Production time is 492 seconds,
  - No breaks or planned maintenance while production ongoing

- Customer demand is 10 airplanes

$$\text{Customer takt time} = \frac{492 \text{ seconds}}{10 \text{ airplanes}} = 49.2 \quad \text{Sec./Pz}$$

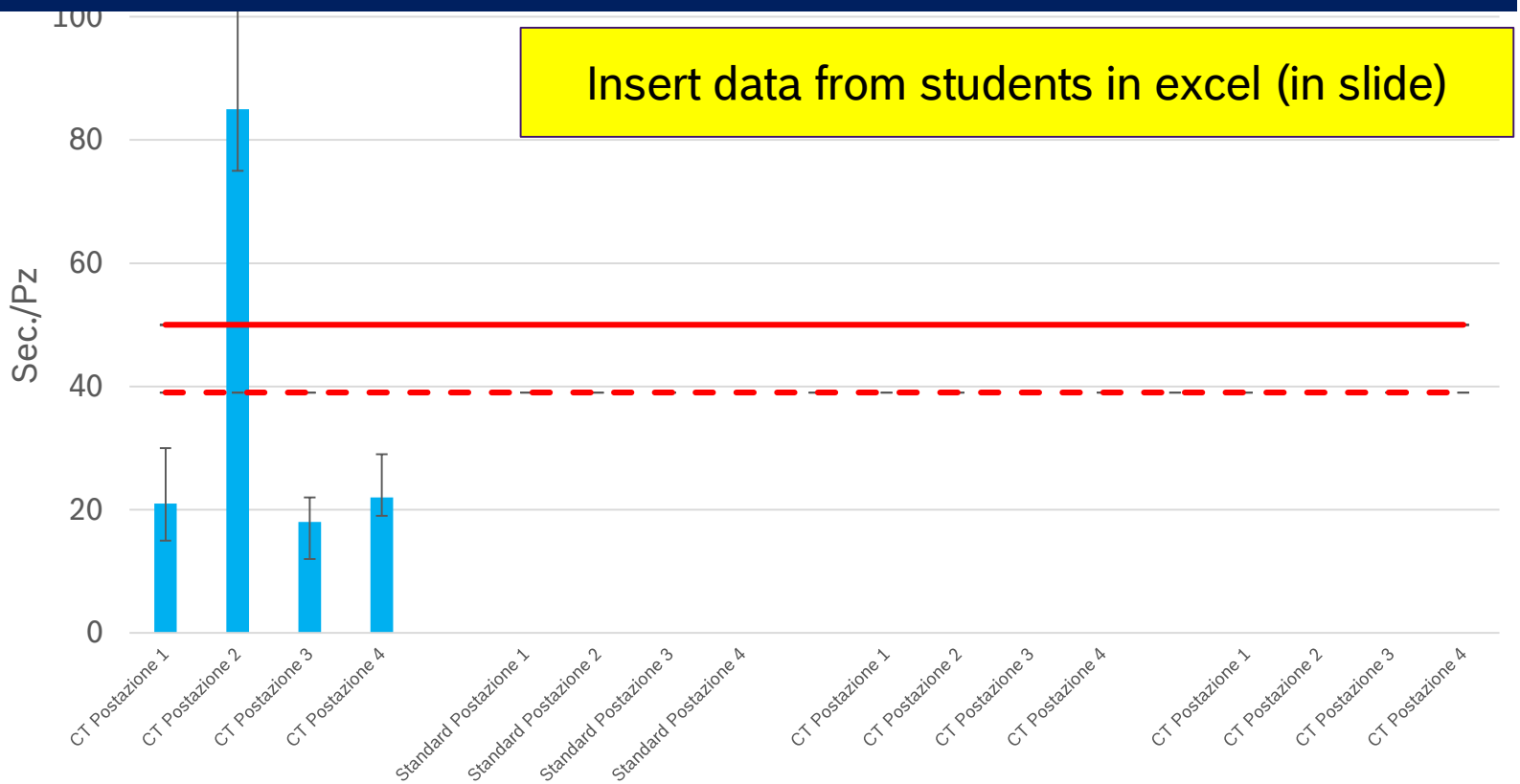
$$\text{Target Cycle Time} = \text{TT} \times \text{OEE}^* = 49.2 \times 80\% = 39.3 \quad \text{Sec./Pz}$$

* OEE = 80%

Lean Production Basics | **Manufacturing Round 1**

Balance Diagram: new standard

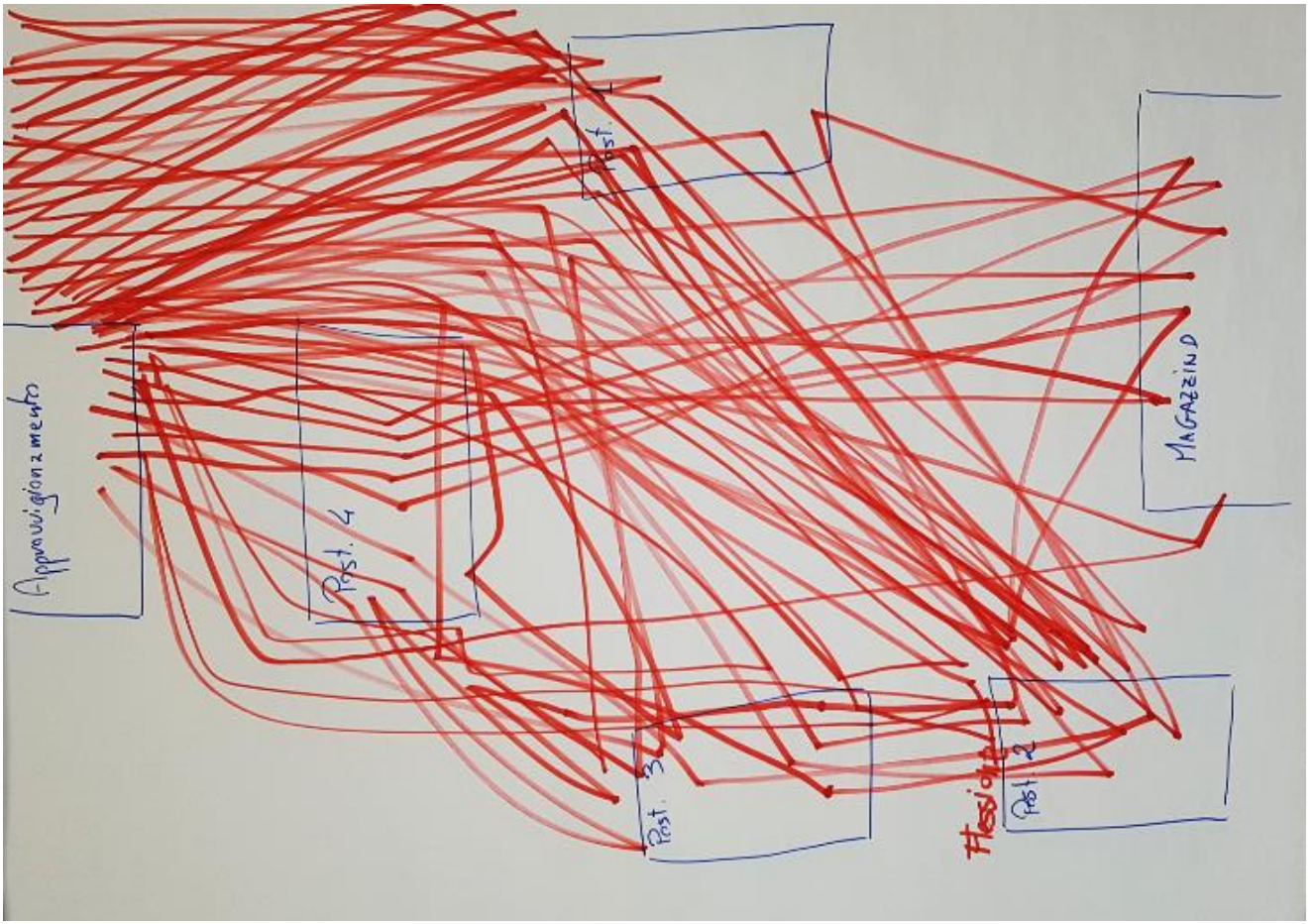
Sharing results of the exercise (students)



Round 1 New Standard Round 2 Round 3

Lean Production Basics | **Manufacturing Round 1**

POUP Results



Lean Production Basics | **Manufacturing Round 1**

Question

Discussion (chat)

What is our biggest problem in achieving our targets?

Lean Production Basics | **Manufacturing Round 1**

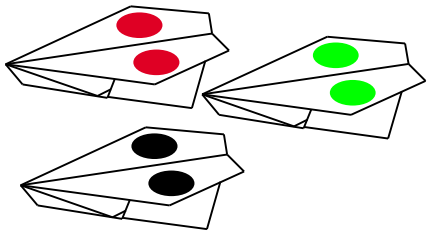
General Conditions

RoBo
Competitor 1

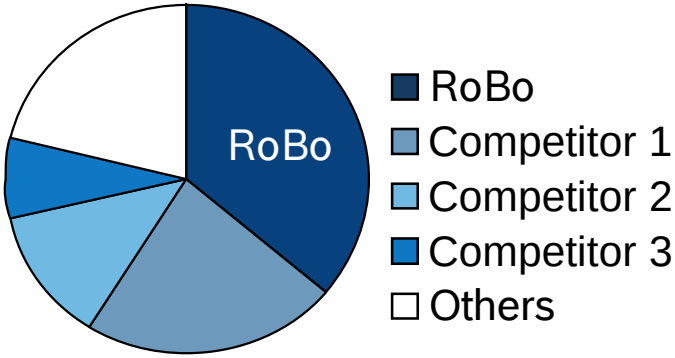
Product

Three variants of airplanes

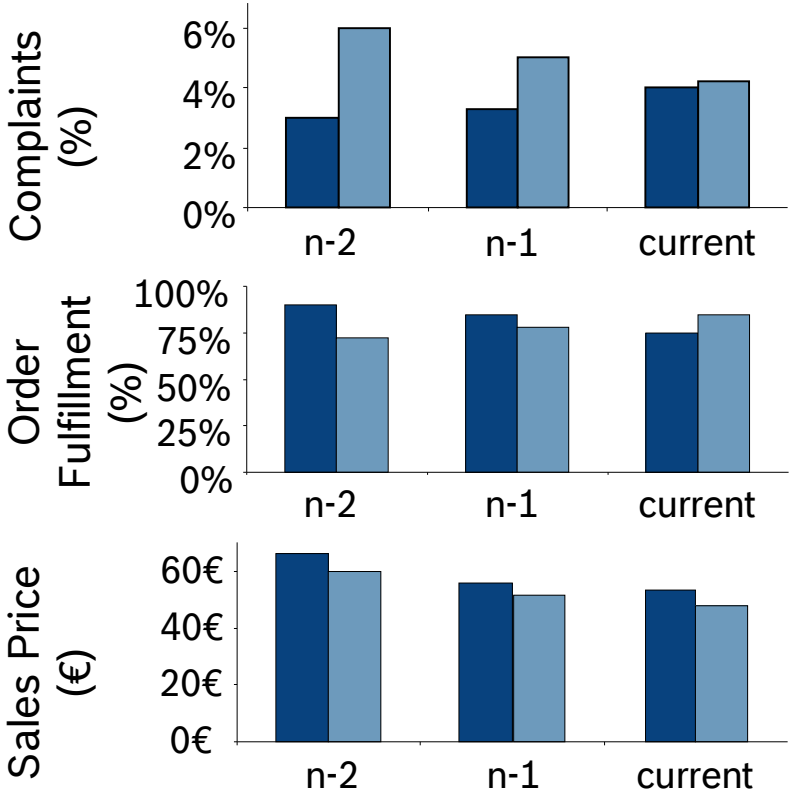
- Red
- Green
- Black



Market share



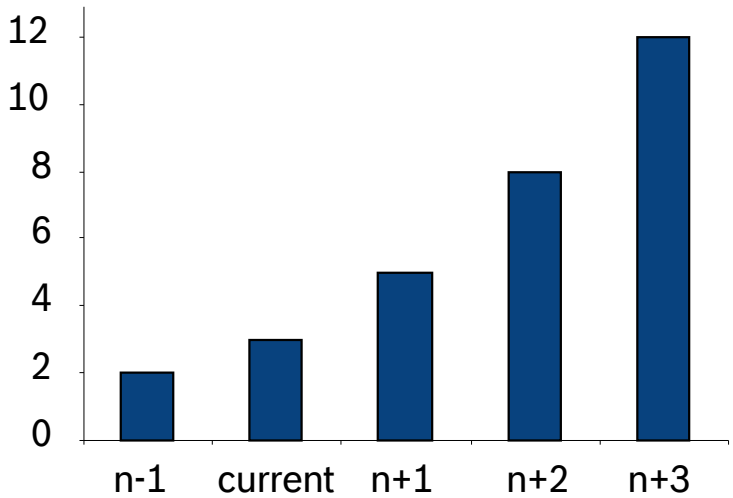
Customer perspective



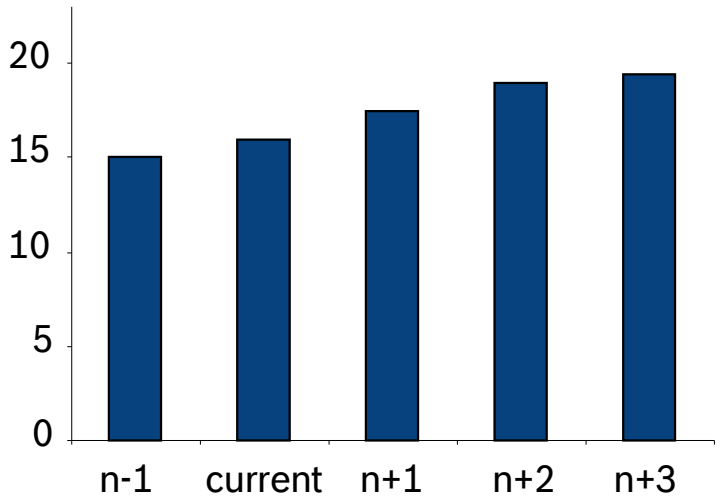
Lean Production Basics | **Manufacturing Round 1**

Current Trends

Number of variants (unit)



Costs (EUR)



Customer requires a maximum delivery time of 2 minutes from call off order fulfillment is measured accordingly

Lean Production Basics | **Manufacturing Round 1**

Question

What are our targets?

How do we need to produce to meet customer demand?

Lean Production Basics | **Balancing**

Question

The customer tact time is 49.2 seconds per airplane.

How fast do we have to design our cycle time to meet customer demand?

Lean Production Basics | **Standardized Work**

Question

How can we ensure that a process runs as consistently as possible and always takes the same time?

Lean Production Basics | **Standardized Work**

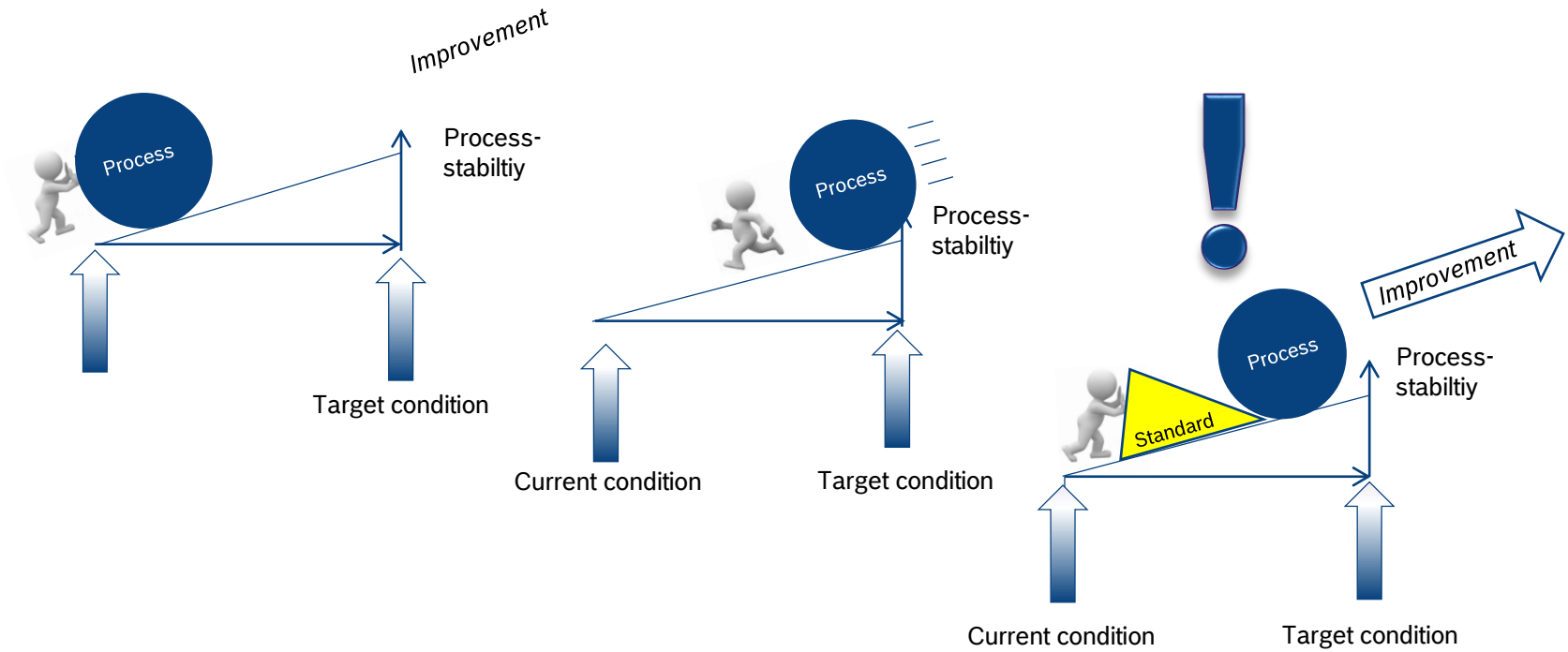
What is standardized work?

- Current best procedure for a process, that happens regularly in the same way
- Description of the method
- It needs:
  - Training of the associates in the method
  - Confirmation of the accomplishment to the method
  - Management in the event of deviation from the method.

Standards are not static, but are constantly improved

Lean Production Basics | **Standardized Work**

Why are standards important?



No systematic improvement without standardization!

Lean Production Basics | **Standardized Work**

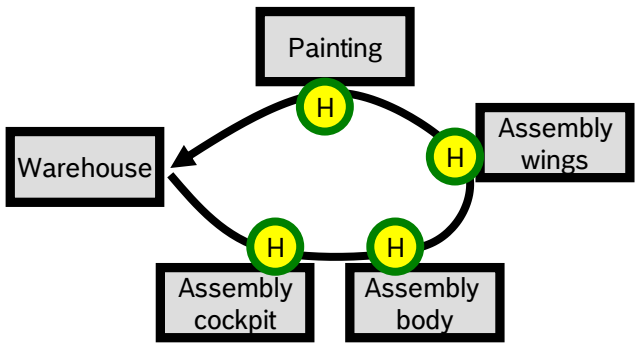
Question

What can we do to standardize the work of the material supplier?

Lean Production Basics | **Standardized Work**

Material Supplier

- The material provider covers all processes in turn, replenishes consumed material and takes away empties (empty boxes).
- Example:



- When establishing a standard for material supply:
  - Determine clear rules for replenishment of material
  - Create transparency storing positions, pick-up and drop-off stations by clear marking

Lean Production Basics | **Standardized Work**

Question

What can we do to standardize the work of the painter?

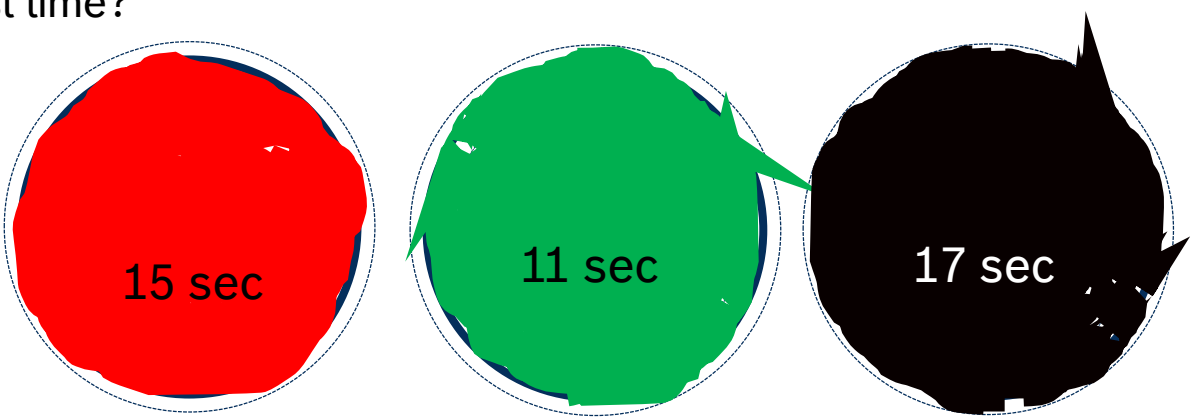
Lean Production Basics | **Standardized Work**

Example Airplane Painting

- Try out which tool fits best. Define the right marker:
  Width, form, hardness, …

Example: Tip of the marker

- Try out different work sequences. Which sequence requires the lowest time?



Lean Production Basics | **Balancing**

Question

The customer takt time is 49.2 seconds per airplane.

How fast do we have to design our cycle time to meet customer demand?

Lean Production Basics | **Manufacturing Round 2**
Implementation Balancing

All other groups – Balancing (**Home work**)

- Split up the work contents among the various work stations with consideration of the target cycle time (based on existing printouts of the standard, times specified in standards)
- No relocation of work stations; maintain send-ahead quantity 3 and lot size 3
- Do not change the position of the work stations or screwdrivers
- Design standard
- Put the planned cycle time in the cycle times diagram

  (Round 1 + Round 2 to be displayed)

- **Presentation in the next lesson**

Lean Production Basics | **Manufacturing Round 2**

Solution from Partecipants

Proposta Paolo:
Dopo la discussion inserire nel grafico anche il risultato del bilanciamento proposto dagli student (un sempio) nel diagramma

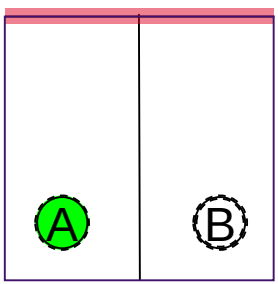
BPS-Basics | **Airplane Production**

Instructions for Station 1 -Solution

19 sec

Step 2.1

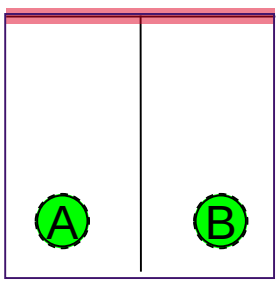
Fill out circle A with color. Surface of inner circle has to be filled 100%. Coloring must not exceed outer circle



19 sec

Step 2.2

Paint circle B like A



BPS-Basics | **Airplane Production**

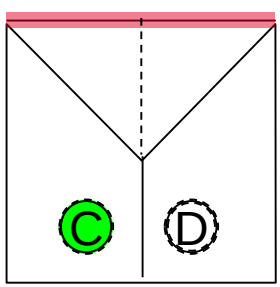
Instructions for Station 2 -Solution

19 sec

Step 2.3

Turn sheet

Paint circle C like A

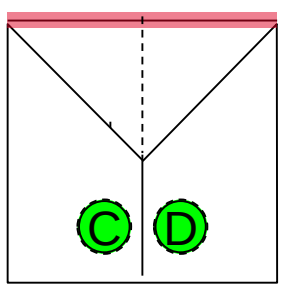


19 sec

Step 2.4

Paint circle D like A

Set aside painted part and, if material available, continue with next one. Send-ahead quantity 3



BPS-Basics | **Airplane Production**

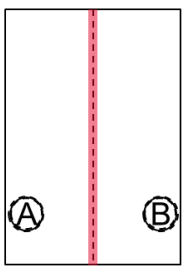
Instructions for Station 3 - Solution

8 sec

Step 1.1

Folding 1:

Fold centerfold, smooth out with finger and reopen it. Fold exactly centered!



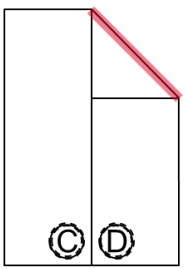
7 sec

Step 1.2

Turn sheet

Folding 2:

Fold edge to centerfold, smooth out with finger

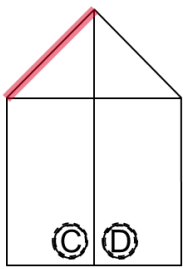


7 sec

Step 1.3

Folding 3:

Fold edge to centerfold, smooth out with finger. Symmetry with folding 2 important!



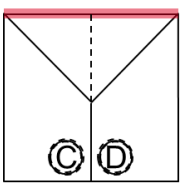
7 sec

Step 1.4

Folding 4:

Fold according to folding 4 and smooth out

Set aside assembled part and, if material available, continue with next one. Send-ahead quantity 3

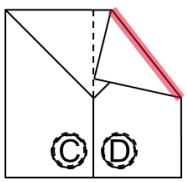


5 sec

Step 3.1

Folding 5:

Fold corner to centerfold at the target point, smooth out with finger

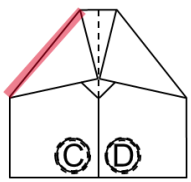


5 sec

Step 3.2

Folding 6:

Fold corner to centerfold at the target point, smooth out with finger. Symmetry with folding 5 important!



It is more important to have symmetry than to fold along the printed lines!

BPS-Basics | **Airplane Production**

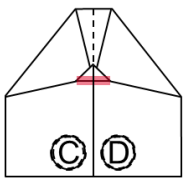
Instructions for Station 4 Solution

4 sec

Step 3.3

Folding 7:

Fold up triangle, smooth out with finger



5 sec

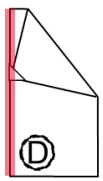
Step 3.4

Turn sheet

Folding 8:

Fold centerfold, smooth out with finger

Set aside assembled part and, if material available, continue with next one. Send-ahead quantity 3

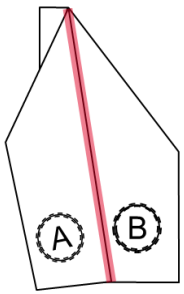


6 sec

Step 4.1

Folding 9:

Fold and smooth out with fingers



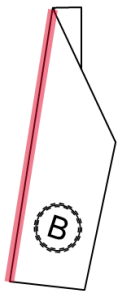
6 sec

Step 4.2

Turn sheet

Folding 10:

Fold and smooth out with fingers. Symmetry with folding 9 important!



7 sec

Step 4.3

Folding 11:

Fold in both directions and smooth out with fingers

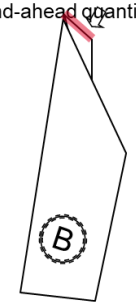
5 sec

Step 4.4

Finishing folding 11:

Fold in edge

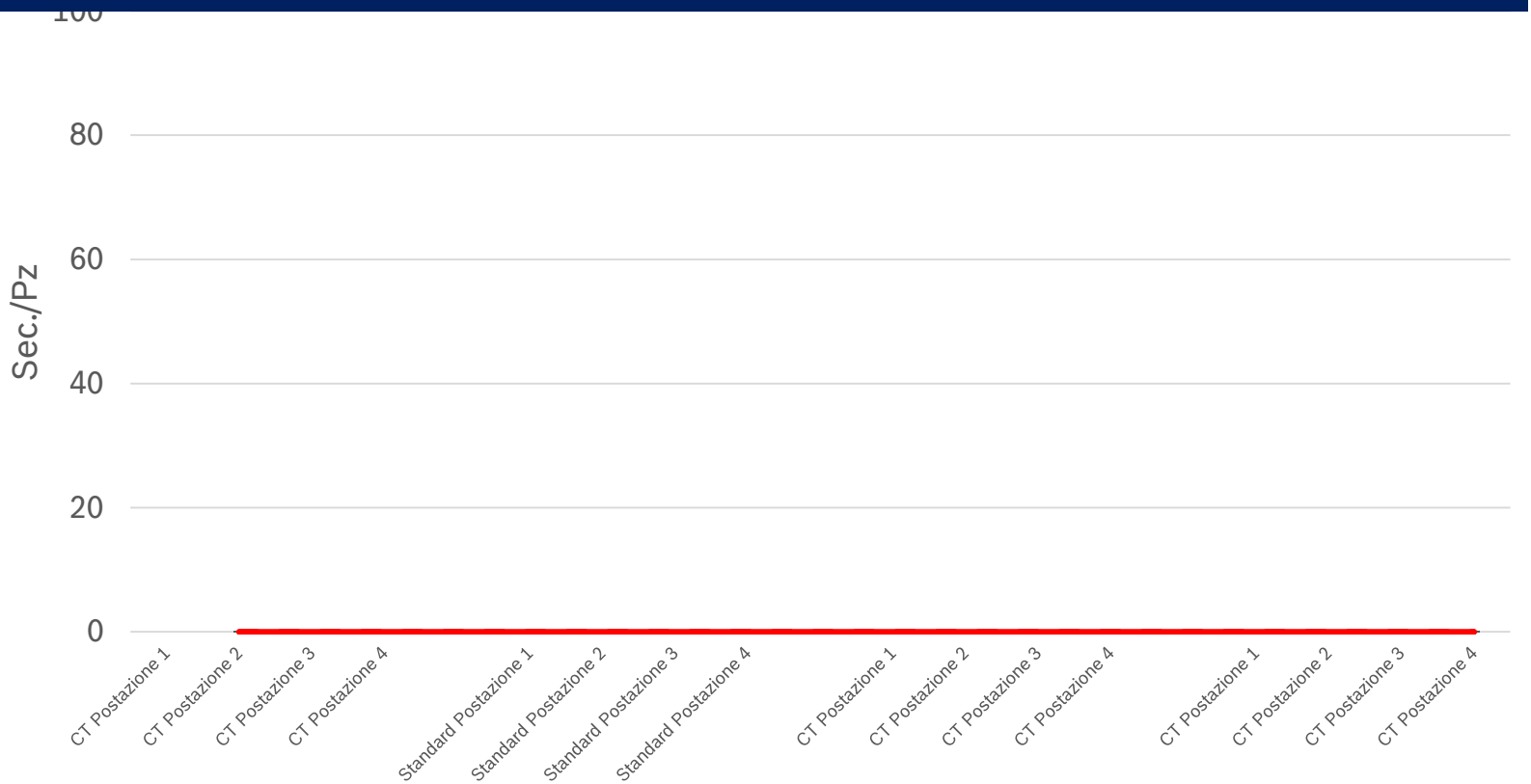
Set aside assembled part and, if material available, continue with next one. Send-ahead quantity 3



It is more important to have symmetry than to fold along the printed lines!

Balance Diagram: new standard

Show balancing diagram (round 1 + New Standard from the students)



Round 1 | New Standard | Round 2 | Round 3

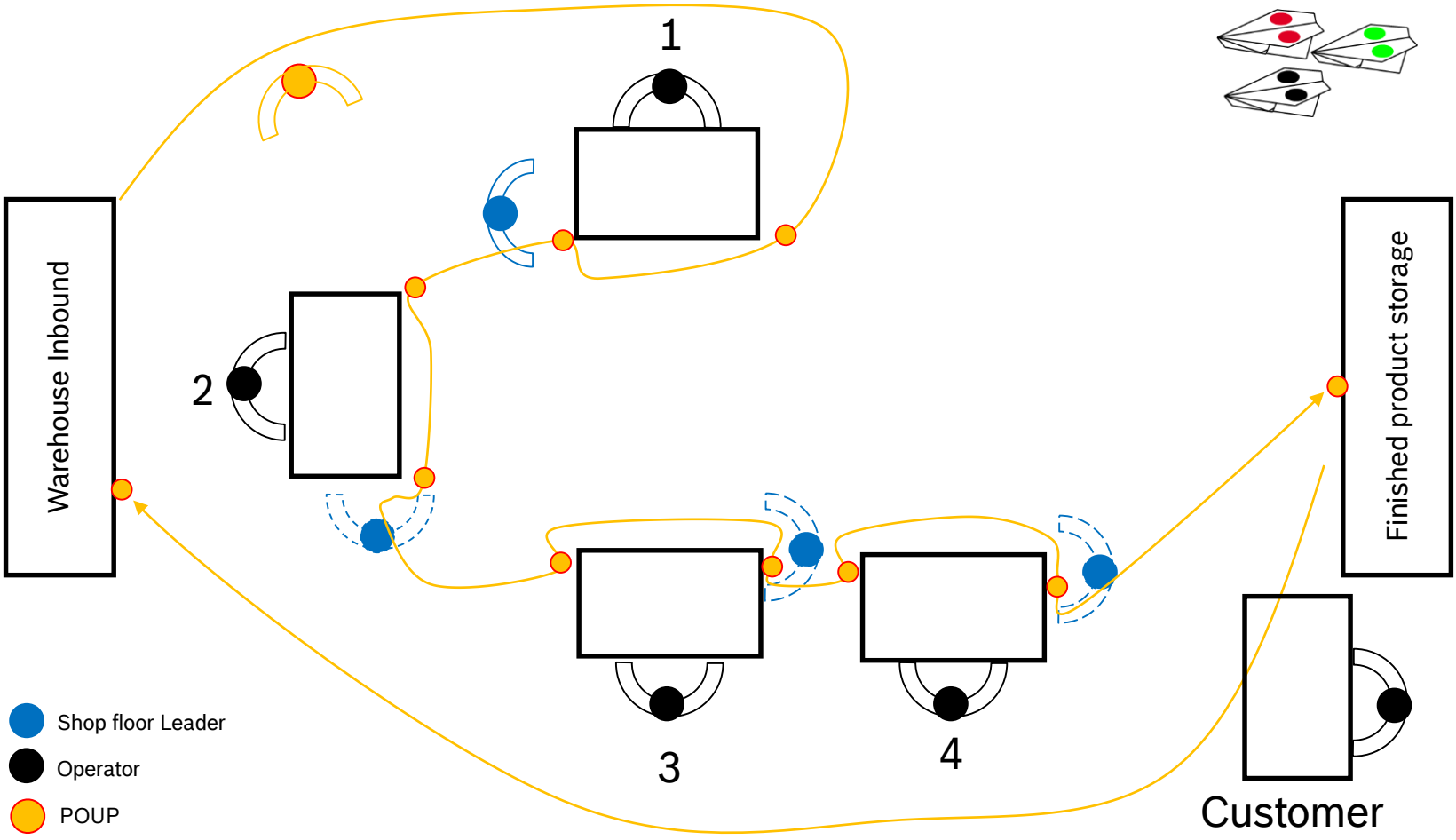
Lean Production | **Manufacturing Round 2**
Implementation Material Supplier

Material supply group – Material supplier development

- Design a cyclic route for the material supplier
- Adapt the pick-up and drop-off stations at the work stations to your requirements
- No relocation of work stations
- Maintain send-ahead quantity 3 and lot size 3
- Ensure that each station has material at all times (connection between material supplier speed and material stock)
- Design standard

Lean Production | **Manufacturing Round 2**

Implementation Material Supplier Result



Lean Production Basics | **Manufacturing Round 2**

Round 2 in the Training Workshop

- **Manufacturing round 2 (after implementation of station balancing)**

Video 2

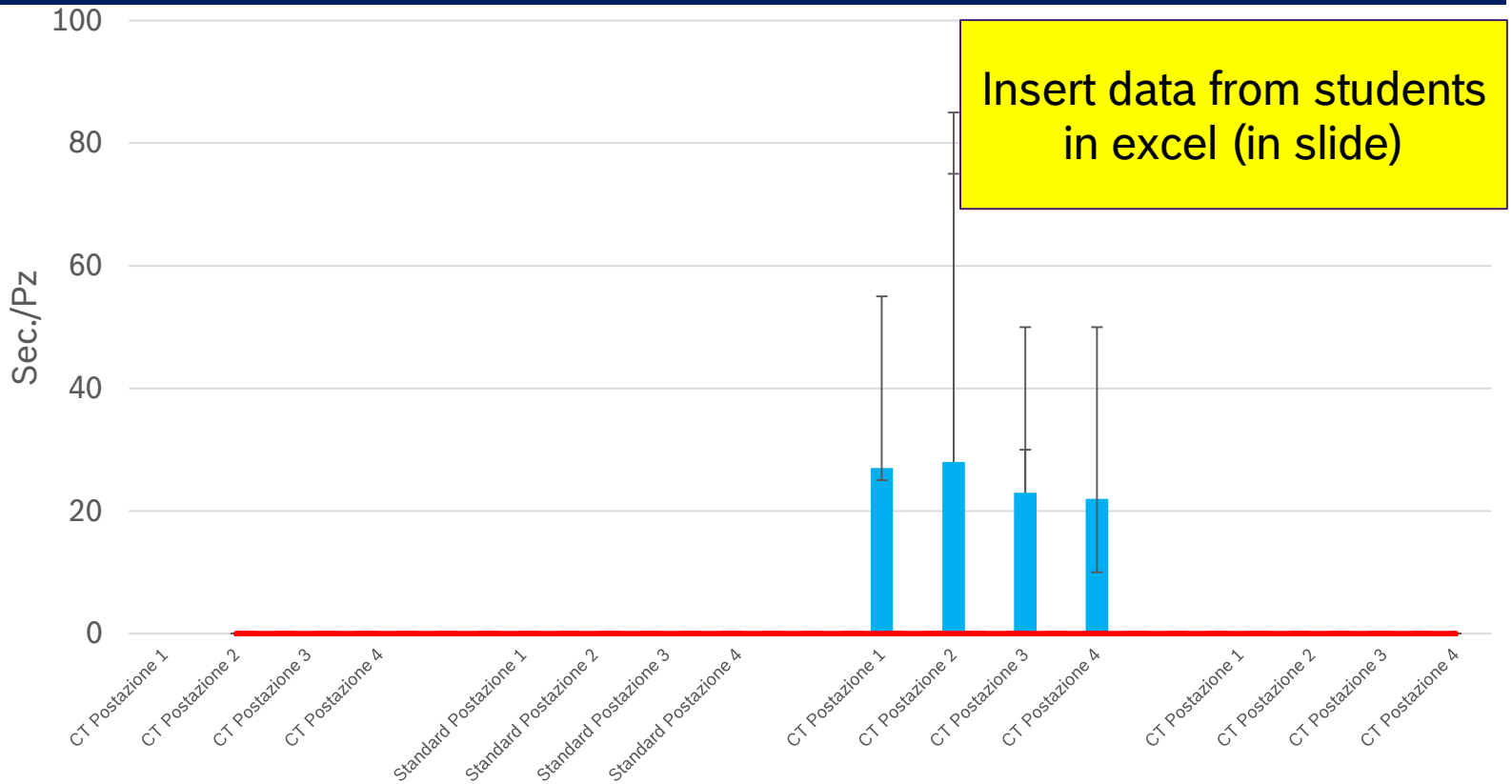
EXERCISE:

- **observe and measure cycle time of each station**
- **Report measurements in excel**

Lean Production Basics | **Manufacturing Round 2**

Balance Diagram: new standard

Discussion balancing diagram (round 1 + New Standard + round 2 measurement from the students)



Round 1 New Standard Round 2 Round 3

Lean Production Basics | **Manufacturing Round 2**

Question

What is our biggest problem in achieving our targets?

Question

How long do we actually need until a part is produced ?

What is Value Stream Planning?

- **Value Stream Mapping (VSM)** and **Value Stream Design (VSD)** are tools that allow the development of an overall concept of low-waste material and information flows. The target is to develop a vision for a lean production system and to derive the required implementation measures

Visualization of the Value Stream

- Structured visualization of actual or planned value stream processes with following content
  - Visualization from customer to supplier (extended value stream)
  - Visualization of material flow
  - Visualization of information flow in order to control the system
  - Visualization of value stream key data

- Use of standardized symbols
  - All persons, working on the value stream, have the same understanding of the symbols
  - This understanding is the base of target oriented improvement work

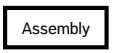
How to map a Value Stream

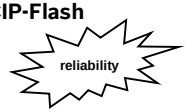
Record and map the initial situation

- Equipment
  - Clipboard, paper
  - Pencil, eraser
  - If applicable calculator, stopwatch
- Go along the flow from “dock to dock" in person
- Always go in the opposite direction of the material stream (e.g. from dispatch to incoming goods)
- Map material and information streams with standardized symbols
- Record actual process data (no standard times!)
- Map of the actual state forms the basis for the next step

Lean Production Basics | **Value Stream Mapping**

Value Stream Symbols for VSM*

External process	Symbol for processes outside RB (e.g. supplier, extended workbench, customer etc.) ➔Clear designation (e.g. name etc.) ➔Record additional details in the "data field". (Supplier, customer, extended workbench etc.)
Process box 	Used for production processes (also several grouped individual steps, e.g. "assembly"), for production planning and dispatch.
Data field	Give typical key figures of a process (customer, supplier, manufacturing process etc.): CT; SLT; OEE or availability; EPEI; number of product variants; finished product container size; working hours available; scrap; rework; etc. ➔Allocation under the respective process box.
Stock	Stock between two process steps. Record quantity in each case (e.g. 300 units). Note: The coverage is calculated on the basis of the customer cycle.
Material transfer by <u>PUSH</u>	Material that is produced and transported before the next process requires it. Generally when controlling through production planning. ➔Only use the symbol internally

Manual flow of information	Information in the form of lists (e.g. handwritten, computer printout etc.). Enter coverage (forecast <u>and</u> fixed) and regular updating cycle as text within the rectangle [e.g. 6 month forecast, 2 weeks fixed; weekly].
„Go see"-Production Control	Employee goes to shop floor frequently but not regularly to influence actual state of production based on inventory. Necessity forced by low transparency.
CIP-Flash 	CIP flash visualizes problems. CIP flash are opportunities for improvement of process.

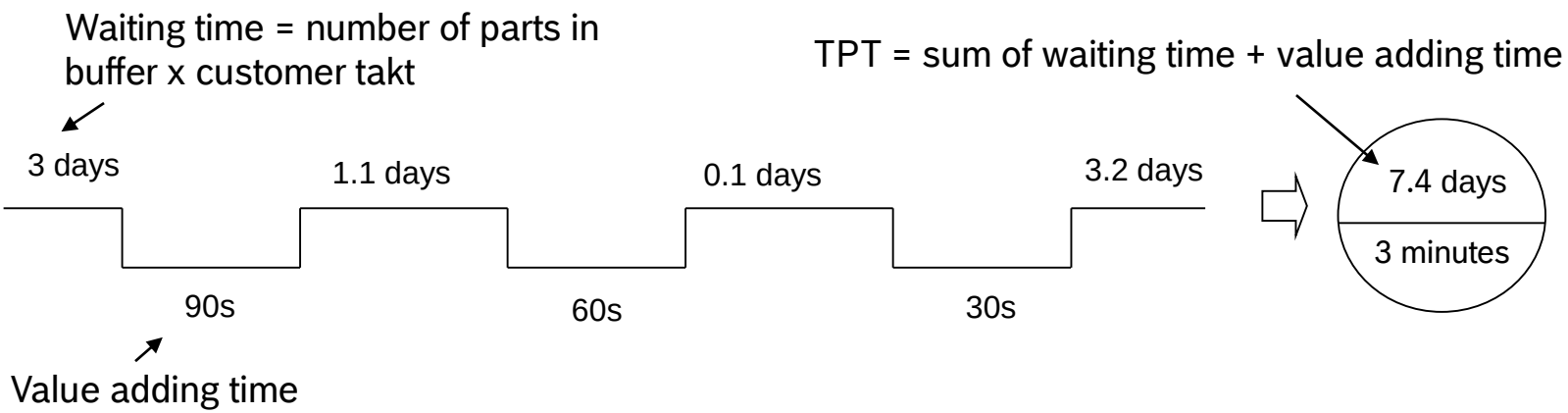
* Shown are only the symbols necessary for group work VSM of round 2

Lean Production Basics | **Value Stream Mapping**

Throughput Time TPT (**T**hrough**P**ut **T**ime)

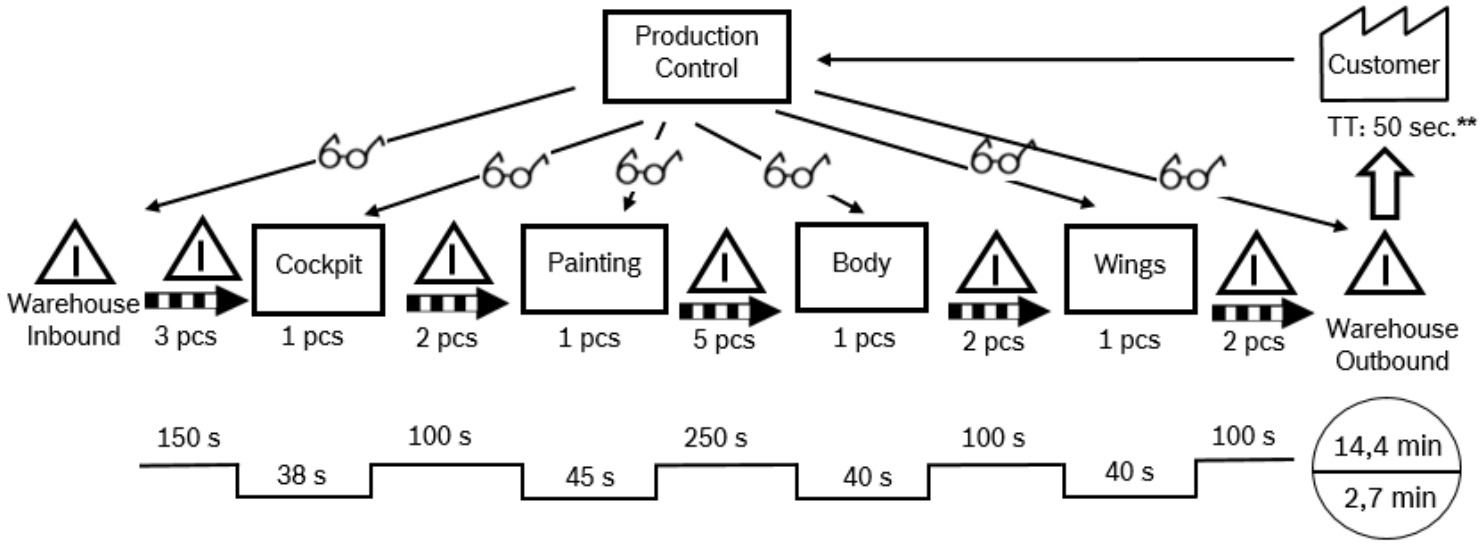
How long do we actually need until a part is produced?

- Time necessary for a production part to move through the value stream, from the start to the end, including all waiting times
- TPT = Process time + transportation time + waiting time
- Displayed as timeline below the value stream



Lean Production Basics | **Value Stream Mapping**

How long do we need to fulfill an Order?



- TPT (material) at the moment of recording approx. 14 minutes
- TPT fluctuates due to undefined stocks
- Time requirement for information flow unknown due to missing standard.

System is not clearly defined!

Lean Production Basics | **Consumption Control**

How do you buy Milk?

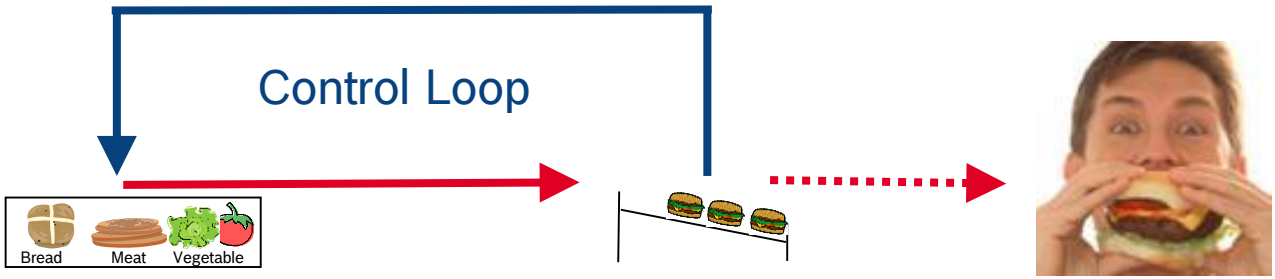
A: Determine weekly quantity based on previous year's average and initiate regular delivery

B: As required

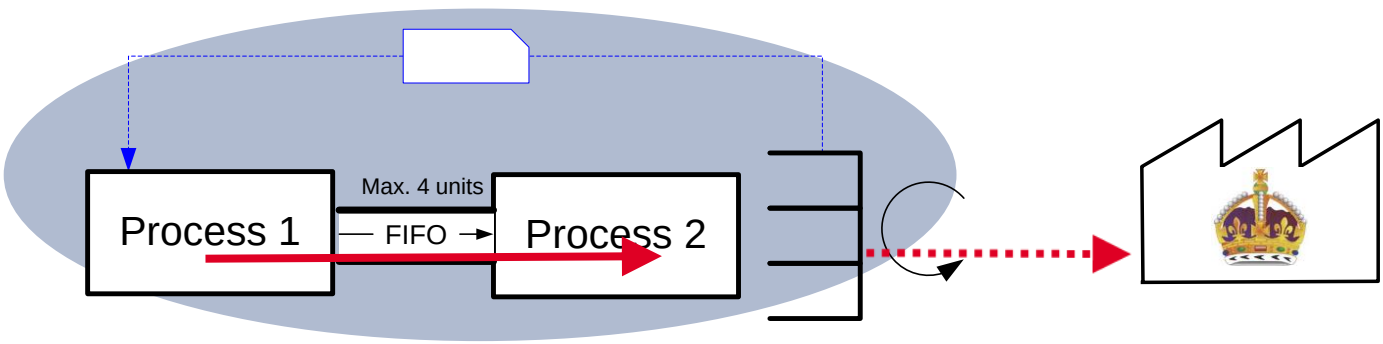
Lean Production Basics | **Consumption Control**

Consumption Control Loop

- It's a closed cycle of information and material flow



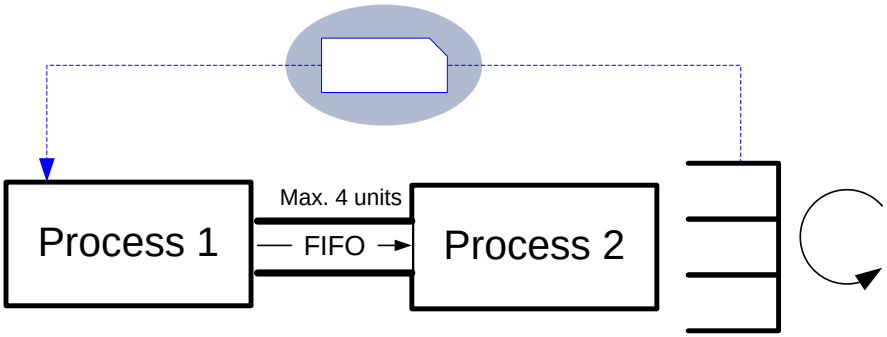
- Value stream visualization



Lean Production Basics | **Consumption Control**
Kanban (= Signal)

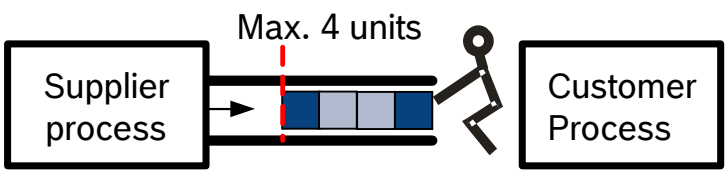
- Control element that limits the quantity of circulating goods

- Value stream visualization

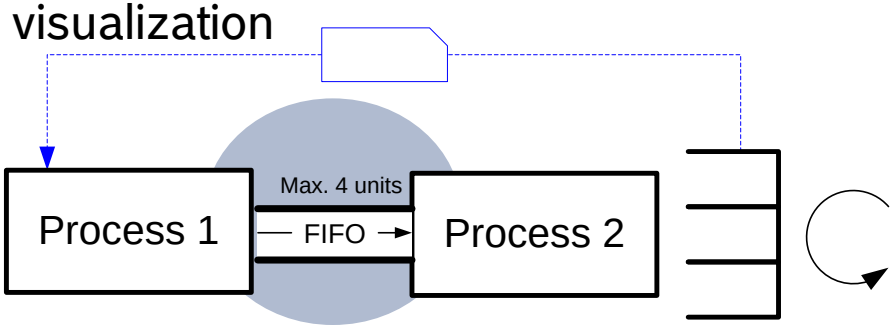


Lean Production Basics | **Consumption Control**
First **i**n **F**irst **o**ut (FIFO) Lane

- Different processes within a consumption control loop are connected by FiFo-lanes. Points for feeding and withdrawal are clearly defined and separated. When defined max. quantity is reached the supplier process has to stop



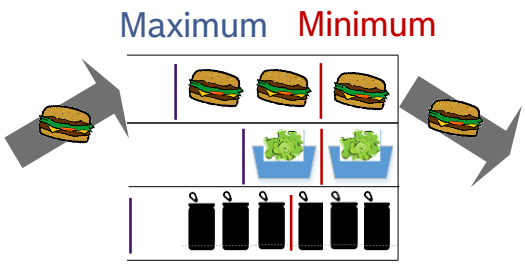
- Value stream visualization



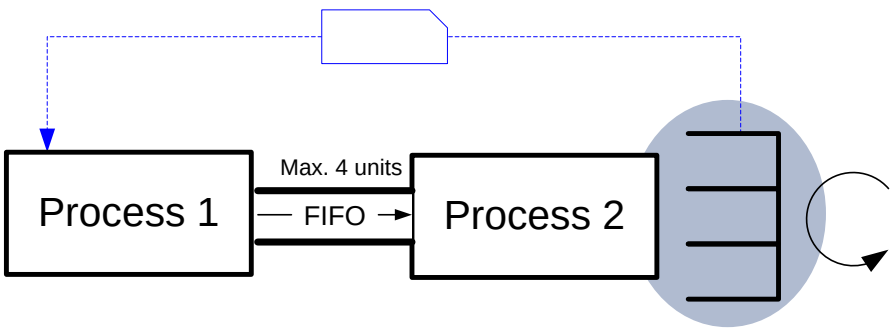
Lean Production Basics | **Consumption Control**

Supermarket

- Defined stock, which ensures supply of the customer (decoupling). For each part number the max. and min. content is defined. A clear signal triggers reproduction according to consumption



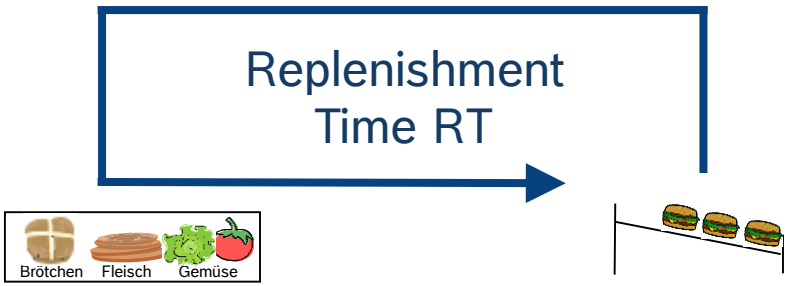
- Value stream visualization



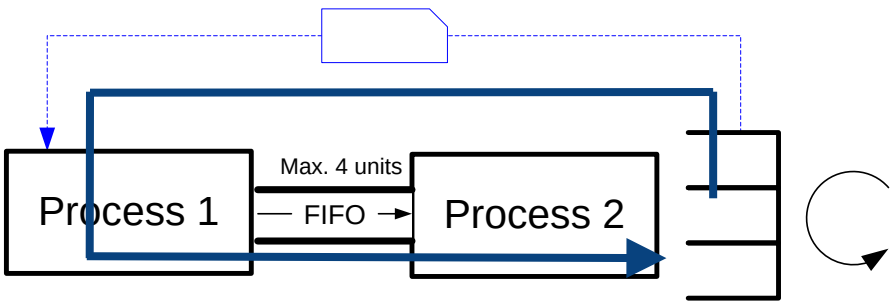
Lean Production Basics | **Consumption Control**

Replenishment Time RT (**R**eplenishment **T**ime)

- Period of time between withdrawal from and refilling of the supermarket. It consist of required time for information flow and material flow



- Value stream visualization

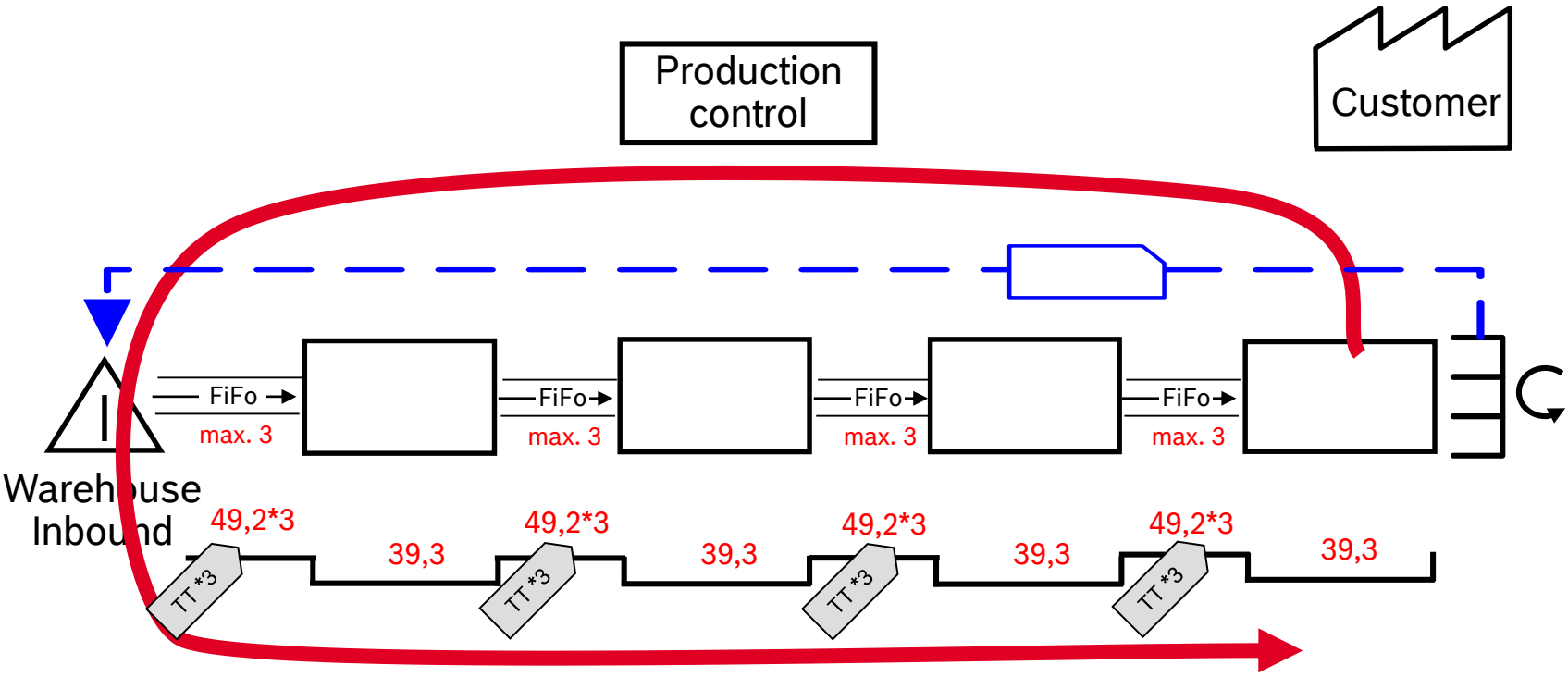


Question

How should our value stream look like in future?

Lean Production Basics | **Value Stream Design**

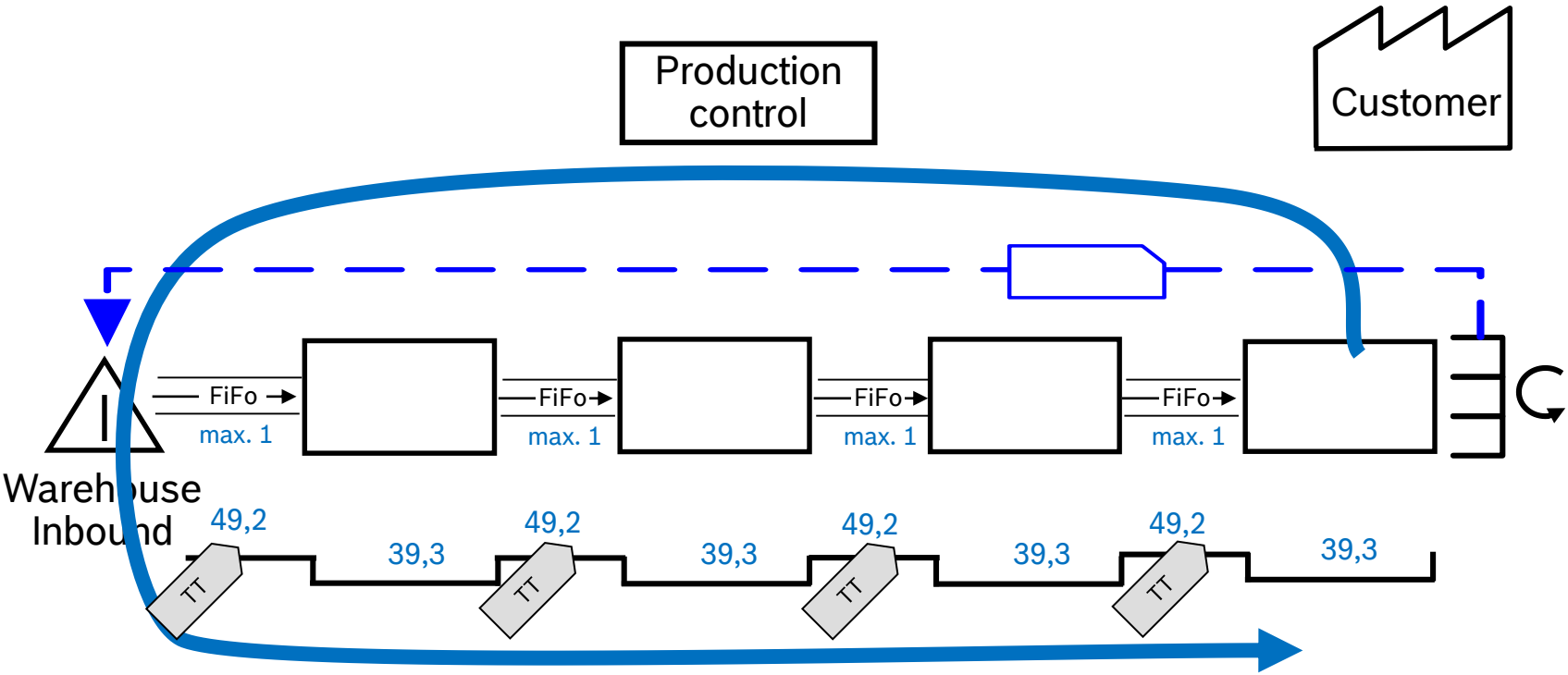
Value Stream Design Airplane Production 1st Step



Time for **material flow** (worst case): 12 * 49,2s = 590,4s
Time for **information flow** worst case: 2 * 39,3s (cycle of material provider) = 78,6s
In **total**: 590,4s + 78,6s = 769s → **11,15 min.**

Lean Production Basics | **Value Stream Design**

Value Stream Design Airplane Production 2nd Step



Time for **material flow** (worst case): 4 * 49,2s = 196,8s
Time for **information flow** worst case: 2 * 39,3s (cycle of material provider) = 78,6s
In **total**: 196,8s + 78,6s = 275,4s → **4,59 min.**

Question

The replenishment time influences our number of Kanban.

How many Kanban do we need?

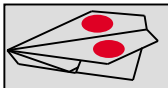
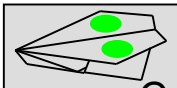
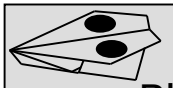
Lean Production Basics | **Manufacturing Round 3**

Number of Kanban

- The required number of Kanbans for covering the replenishment time RT is calculated with a Kanban formula

$$K = RE + LO + WI + SA$$

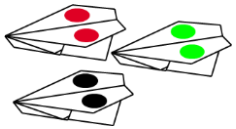
- The Kanban formula considers different factors such as the replenishment time (RE), lot size (LO), customer demand fluctuation (WI) and a safety factor (SA)
- For our purposes we shall use the following number of Kanban*

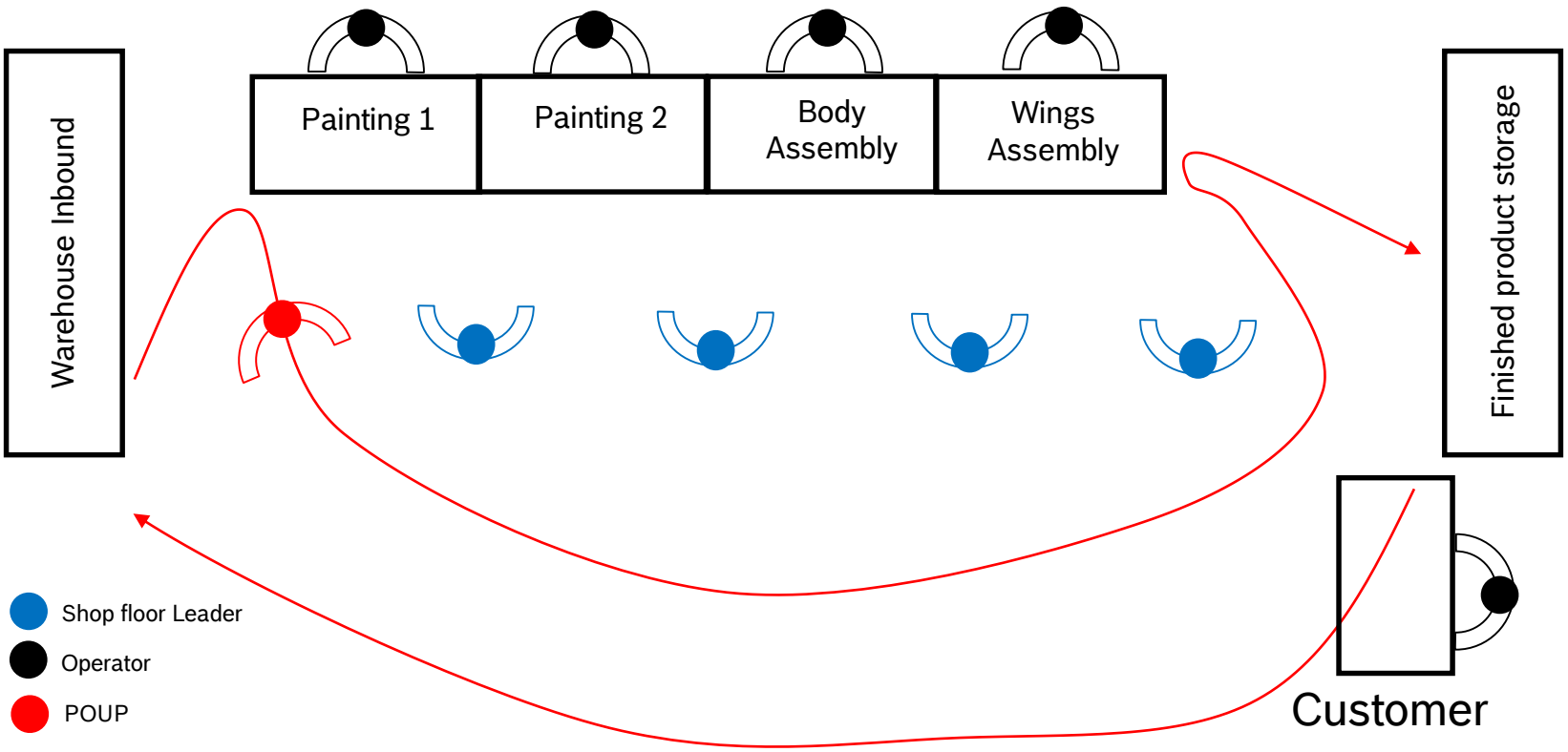
	 Red	 Green	 Black
Number of kanbans	4	4	2

* Exact announcement from the trainer

Lean Production Basics | **Manufacturing Round 3**

Layout





Lean Production Basics | **Manufacturing Round 3**

Round 3 in the Training Workshop

- **Manufacturing round 3**

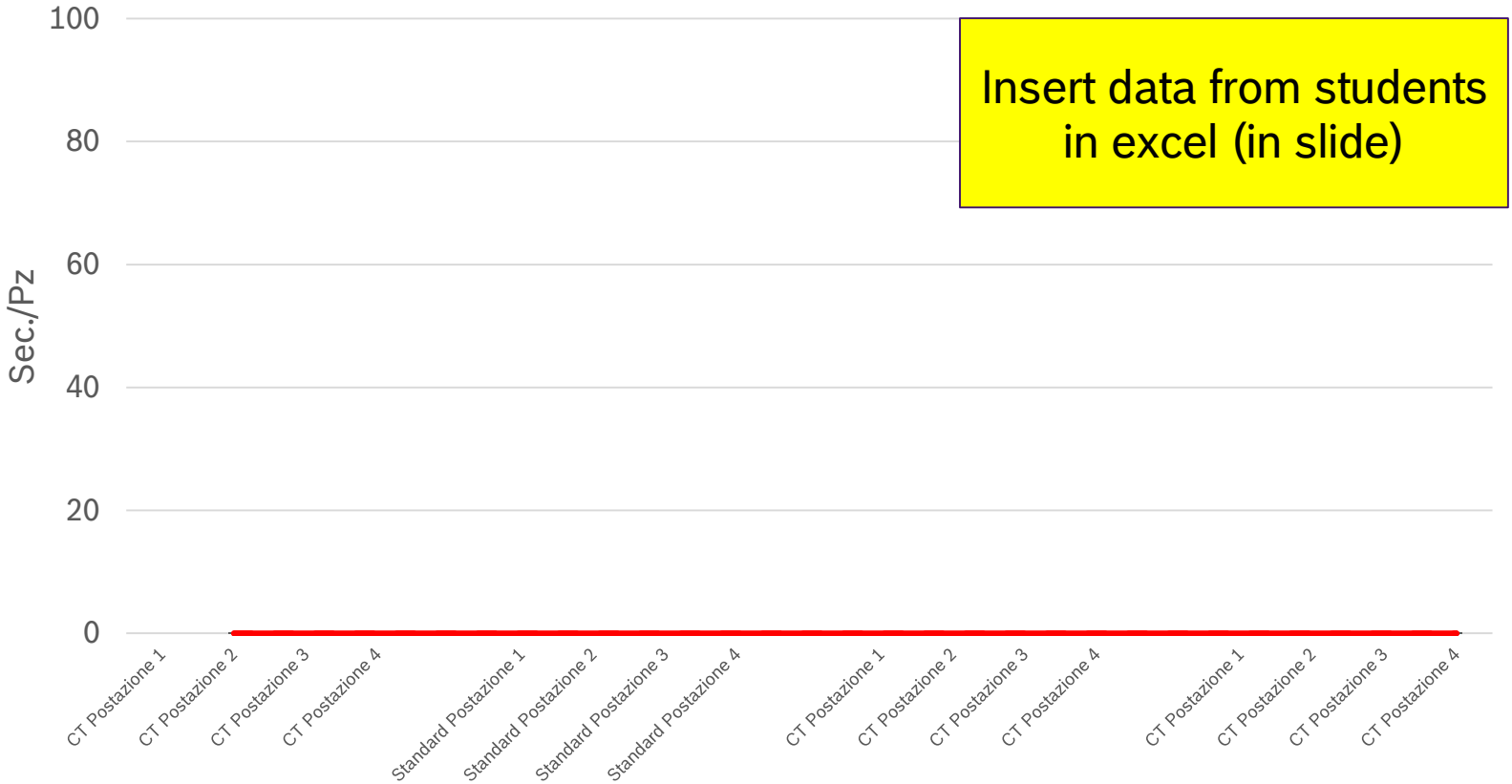
Video 3

- **EXERCISE: measure cycle time of each stations and report data in excel**

Lean Production Basics | **Manufacturing Round 3**

Balance Diagram: new standard

Show balancing diagram (round 1 + New Standard + round 2 + round 3 from students)



Insert data from students in excel (in slide)

Round 1 | New Standard | Round 2 | Round 3

Lean Production Basics | **Manufacturing Round 3**

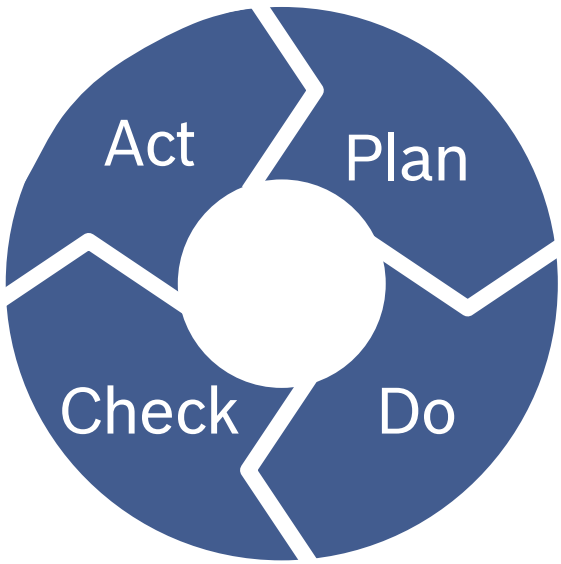
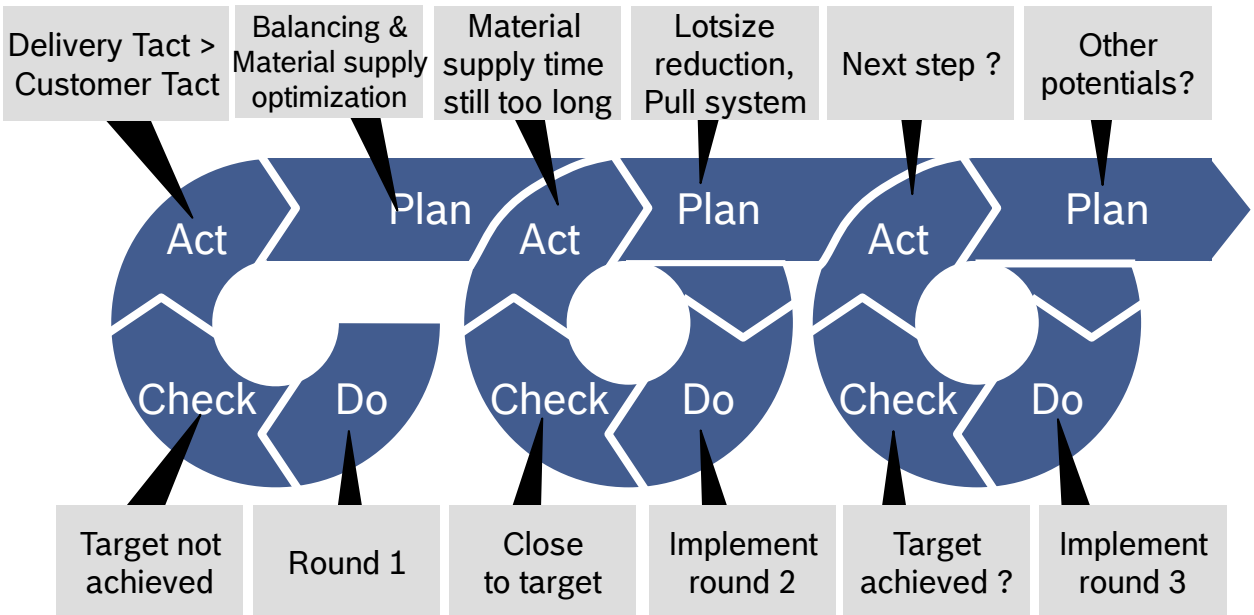
Question

What is our biggest problem in achieving our targets?

Lean Production Basics | **Continuous Improvement**

PDCA – Plan–Do–Check–Act

- PDCA is a problem-solving method
- PDCA stands for Plan–Do–Check–Act
  - Plan: Analyze the problem and plan improvement measure
  - Do: Implement the plan
  - Check: Check whether the plan/implementation has achieved the target
  - Act: If the target has not been achieved, why not? Otherwise, address the next problem
- Important: Check and Act are especially likely to be forgotten



Continuous Improvement – PDCA Cycle