Welcome to the Simulation

Advanced Improvable Pull System

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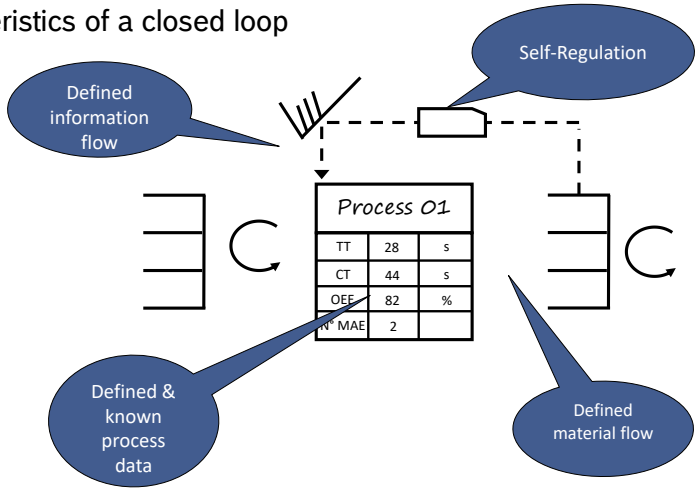
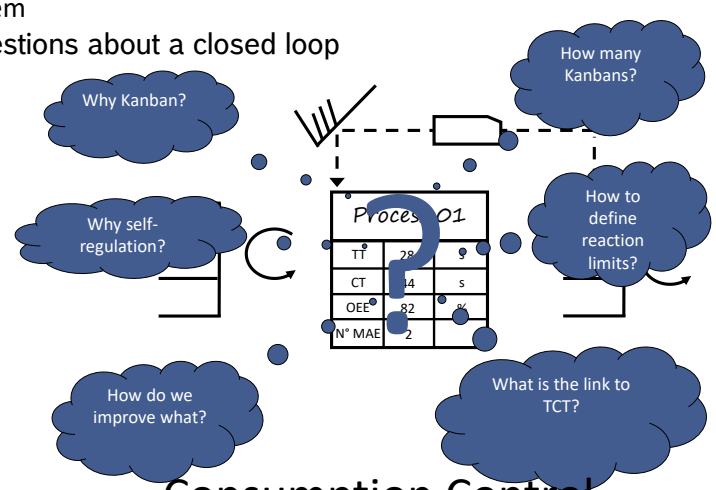
Pull System

Characteristics of a closed loop



Pull System

Key Questions about a closed loop



Consumption Control

Pull System

Consumption control: why ?

In a Pull system ..

There's no overproduction; kanban are calculated

Delivery Performance is ensured

Decoupling is managed by defined and calculated supermarket

Transparency and Standardized work is established

Production control, stocks control is managed with reduced efforts

Pull System
Why do we need decoupling?

- ➔Decoupling output fluctuations
- ➔Decoupling customer call-off fluctuations
- ➔Balancing differences of working hours and cycle times

What do we achieve by decoupling?

- ➔Reducing fire fighting by stabilizing the production system and increasing the problem solving abilities
- ➔Visualization of own process problems *(e.g. in the form of stock)*

Decoupling absorbs customer fluctuations and avoids bullwhip effect on the process

Pull System
How many types of decoupling?

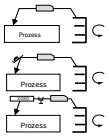
- ➔ Decoupling by material flow
  (FIFO lane, supermarket)
- ➔ Decoupling by information flow
  (lot size formation, leveling)
- ➔ Decoupling by staff
  (short term increase/reduction in capacity)
- ➔ Decoupling by POT (planned operation time)
  (decoupled shifts, running through breaks, shift models, special shifts

Pull System
FiFo, Supermarket, Stock

FIFO-Lane

- ▶ FIFO principle (fixed sequence)
- ▶ Maximum quantity (reference e.g. units, small load carrier etc.)
- ▶ Stop signal in both directions ("empty/full") – information flow
- ▶ Responsibility lies with the filling process

Supermarket



- ▶ Defined places for each part number (SNR)
- ▶ FIFO principle based on part number
- ▶ Defined stocks with min/max based on part number
- ▶ Clear control signal after withdrawal for delivery process – info flow
- ▶ Responsibility lies with the producing process
- ▶ Supermarket physically stands with the supplier

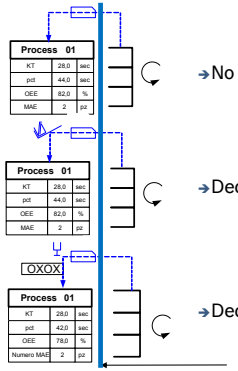
Defined

Stock

- ▶ Material/stock and/or information flow is not defined

Indefinito

Pull System
Decoupling of information flow



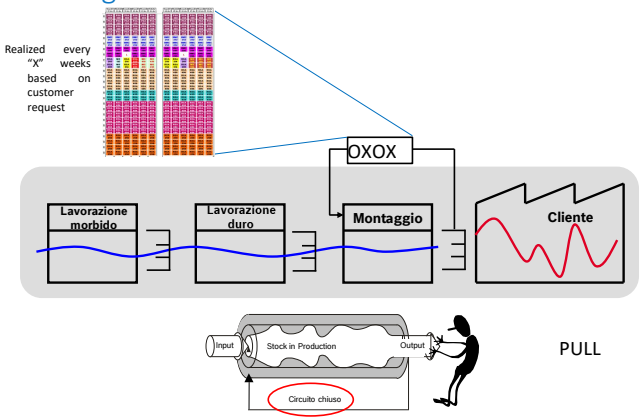
➔No decoupling in information flow

➔Decoupling in information flow by lot size formation

➔Decoupling in information flow by leveling

➔Production kanban from supermarket (pull system) or directly from logistics (build to order).

Pull System
Levelling



PULL

- Decoupling is realized by information flow (levelling plan) and material flow (supermarket with min/max calculated by Kanban formula)
- Order management and production «Takt» are supported by standardized processes:
  - Pacemaker
  - (Quick) Change over

Pull System
How we define the number of Kanban: The Kanban Formula

$$K = RE + LO + WI + SA1 + SA2 + \cancel{SA3}$$

RE → **RE**plenishmentTime coverage
Customer demand according to customer takt-time within replenishment time for 1 Kanban

LO → **Lo**t Size coverage
Lot size building

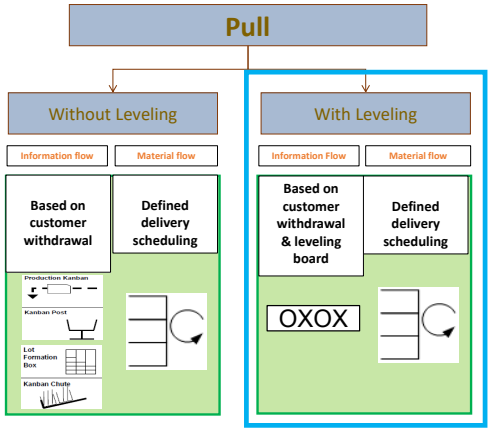
WI → **WI**thdrawalPeak coverage
Known customer demand fluctuations

SA1 → **SA***fety Time Coverage*.
Unknown fluctuations of internal process

SA2 → **SA***fety Time Coverage*.
Unknown fluctuations of the customer process

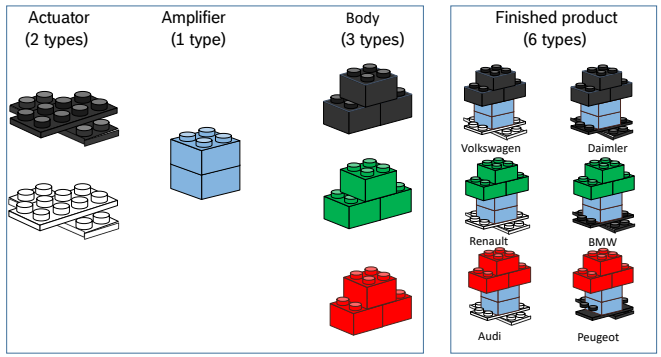
SA3 → **SA***fety Time Coverage*.
Extra quantity

Pull System
Production planning

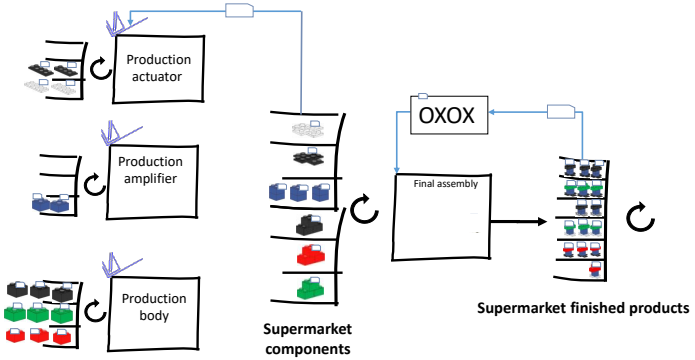


Pull System
Components and products

→ CRI3: production and final assembly



Pull System
Value Stream



Pull System
Steps to implement leveling:

1. Define pacemaker process (decided: final assembly)
2. Define **planning leveling period**
3. Define runner and exotics with ABC (volume) and XYZ (pick up regularity) (defined: all types are runners)
4. Analyze customer call-off behavior (done: customers prognosis quality is excellent)
5. Capacity analysis to define **number of maximal possible change overs (Step 5a) – verify supply ability of pre-processes (Step 5b)**
6. Definition of **EPEI** for each runner
7. Definition of **production lot size** per runner
8. Definition of **leveling production plan (8-a) and sequence (8-b)**
9. Calculation of **required decoupling (K-spot analysis and ReLoWiSa)**
10. Design of **heijunka board: distribution of lot sizes (10-a) and definition of daily setup of SA1 on overflow (10-b)**

Pull System

What is the pacemaker process?

- ➔ ... It is the one point in the complete value stream that controls the customer signal from the *external customer*
- ➔ ... It is the one point in the partial value stream that controls the customer signal from the *internal,* or *external customer*
- ➔ ... It controls the complete value stream (partial value stream)
- ➔ ... It sets the tact time for the complete value stream (partial value stream)
- ➔ ... It has nothing to do with the bottleneck process (can be the same, but does not have to be)

What are the requirements for the pacemaker process?

- ➔ ... Delivery capability and stability

Pull System
Customer Request

Step 2-3

customer pick-up per working day (number of kanbans)

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	sum	avg
VW	6	3	1	5	8	5	3	3	7	5	6	2	7	8	7	5	6	1	6	6	3	3	3	5	7	5	5	1	5	5	142	5
Renault	4	7	4	5	3	4	6	5	8	4	9	5	4	3	5	8	4	3	7	6	3	4	0	6	5	5	7	5	5	3	147	5
Daimler	2	2	2	2	1	2	2	2	2	2	3	3	1	1	2	2	1	2	1	2	3	1	2	3	1	3	1	2	2	2	57	2
BMW	2	3	1	2	1	2	2	3	2	2	3	2	3	2	2	2	1	2	2	2	2	2	2	1	2	3	2	1	3	1	60	2
Audi	0	1	1	1	1	2	1	2	0	1	1	1	1	1	1	1	1	1	1	0	1	2	1	1	1	1	1	1	1	1	30	1
Peugeot	1	1	2	1	1	1	1	1	1	1	1	1	2	0	1	1	1	2	0	1	1	1	1	1	1	1	1	1	1	0	30	1
total	**15**	**17**	**11**	**16**	**15**	**16**	**15**	**16**	**20**	**15**	**23**	**14**	**18**	**15**	**18**	**19**	**14**	**11**	**17**	**17**	**13**	**13**	**9**	**17**	**17**	**18**	**17**	**11**	**17**	**12**	**466**	**16**

customer demand in number of kanbans

Week	CW1	CW2	CW3	CW4	CW5	CW6	sum	avg
VW	23	23	30	24	21	21	142	24
Renault	23	27	26	28	18	25	147	25
Daimler	9	10	10	8	10	10	57	10
BMW	9	11	12	9	9	10	60	10
Audi	4	6	5	4	6	5	30	5
Peugeot	6	5	5	5	5	4	30	5
total	**74**	**82**	**88**	**78**	**69**	**75**	**466**	**78**

customer demand in pieces

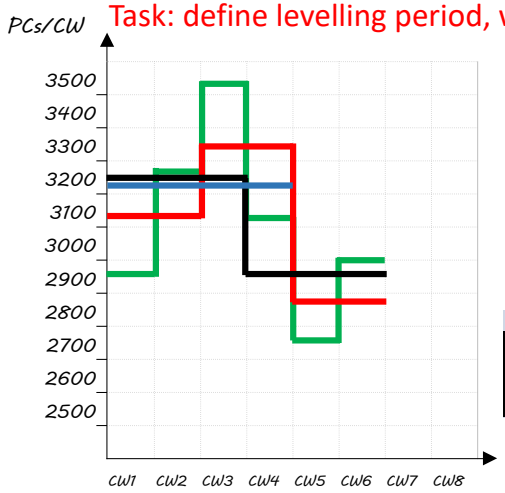
CW1	CW2	CW3	CW4	CW5	CW6	sum	avg/week
920	920	1200	960	840	840	5680	947
920	1080	1040	1120	720	1000	5880	980
360	400	400	320	400	400	2280	380
360	440	480	360	360	400	2400	400
160	240	200	160	240	200	1200	200
240	200	200	200	200	160	1200	200
2960	**3280**	**3520**	**3120**	**2760**	**3000**	**18640**	**3107**

1 box = 1 NPK = 40 pcs

Levelling period: ____ weeks

Step 2: Definition Leveling Period_File Excel

Task: define levelling period, why ? (Excel)



Day1: Round 1

- 1 week
- 2 weeks
- 3 weeks
- 4 weeks

	CW1	CW2	CW3	CW4	CW5	CW6
1 week	2960	3280	3520	3120	2760	3000
2 weeks (avg.)	3120	3120	3320	3320	2880	2880
3 weeks (avg.)	3253	3253	3253	2960	2960	2960
4 weeks (avg.)	3220	3220	3220	3220		

Step 3: Define runner and exotics

ABC (volume) vs XYZ (pick up frequency)

How to…

ABC (volume)

XYZ (Frequency)		High	Medium	Low
		A	B	C
Regular	X	VW Renault	BMW	
Periodic / Frequent	Y		Daimler Peugeot	Audi
Irregular	Z			

Step 4: Analyze customer call-off behavior

Done!!!

customers prognosis quality is excellent

Does the customer@ the end of leveling period pickup the same quantity that he ordered?

If NOT, it has to exist a strategy to react:
if customer takes more (ex· Overtime, other line…)
if customer takes less (ex· Shift cancel, flexibility MA in other lines, products…)

If YES, the customer order volume can be used to plan capacity (POT) and n°change-overs for the period·

Pull System

Dati

Task: calculate available time for production and Change Over (Excel)

- Data – **Average OEE of the previous period, without C/O**
  - Final assembly: 84 % (24h*84/100)=
  - Production actuator: 76 %
  - Production Amplifier: 68 %
  - Production Body: 80 %
- POT 24 h
- Change Over time 60 min
- Cycle time 1.5 min / pc
- NPK 40 pc

Pull System

Dati

Solution

- Capacity planning: **average OEE of the previous period, without C/O**
  - Final Assembly: 84 % = 20 h (24h*84/100)=
  - Production actuator: 76 % = 18,2 h
  - Production amplifier: 68 % = 16 h
  - Production body: 80 % = 19,2 h
- POT 24 h
- Change over time 60 min
- Cycle time 1.5 min / pc
- NPK (number per Kanban) 40 pcs = 1 h production
- Target OEE ≠ OEE used for capacity planning (reference: previous period)
- Nessuna fluttuazione del cliente non pianificata (???)

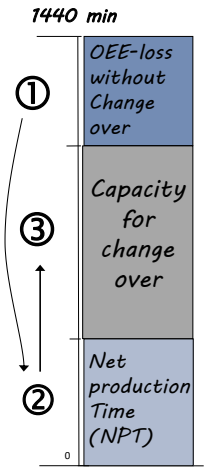
Step 5: Capacity analysis

Task: (Excel)

Step 5A: Define n° of change-overs (Per day)

	CW1	CW2	CW3	CW4	CW5	CW6
1 week	2960	3280	3520	3120	2760	3000
2 weeks (avg.)	3120	3120	3320	3320	2880	2880
3 weeks (avg.)	3253	3253	3253	2960	2960	2960
4 weeks (avg.)	3220	3220	3220	3220		

(3120+3120)/10= 624 Pz/g



1440 min	Final Assembly	
1)	OEE-loss w/o change over:	
	POT:	1440 min
	- POT * OEE:	1209 min
	= OEE-Loss	231 min
3)	POT:	1440 min
	- OEE-loss:	231 min
	- Net prod. Time	936 min
	= C/o capacity	273 min
	/ time per C/o	60 min
	= no. of max. C/O	4,5
2)	no. of parts to produce/day:	624 Pz
	* cycle time	1,5 min
	= NPT	936 min

Step 5: Capacity analysis

Step 5A: Define n° of change-overs (Per day)

+

- Smaller production batch
- Higher flexibility
- Reduced stock
- C/O time redcution becomes a key point

5

- Better POT utilization

4/5

- Higher Output (produttività +)
- Reduced number of C/O (OEE +)

4

-

- Capacity not sufficient for 5 C/O
- Higher losses due to C/0
- Lower Output
- OEE reduction

- High fluctuation (different output)
- Less stability ion the pre-processes

- Big production batches
- Less flexibility
- Higher stocks
- Longer waiting times (kanban in Heijunka)

Pull System

Capacity check

Task: complete with all data

Step 5b

How many change overs / day @Pacemaker ? Decision: _____ 4

Situation at the pacemaker (final assembly):	
Planned Operating Time (POT):	1440
- OEE-loss:	231
- Change Over Time:	240
= Net production time (NPT):	969
/ Cycle time per piece (in min/pc)	1.5
= max. number of pieces per day	646
= max. number of k per day	16,1

Capacity calculation [pcs / day] with a defined OEE loss and defined C/O number

Are the preprocesses able to produce the daily quantities of each type?	Amplifier module	Actuator module	Body Production
Number of types	1	2	3
(1) POT (min)	1440	1440	1440
OEE w/o change over losse	68%	76%	80%
(2) OEE-loss (min)	461	346	288
No. of C/o per day	0	2	3
Time per C/o (min)	60	60	60
(3) C/O-Capacity (min)	0	120	180
= NPT (1) - (2) - (3)	979	974	972
/ Cycle time	1.5	1.5	1.5
= pieces / day	652	649	648

Pull System

Data

Task: complete (Excel)

- Capacity planning: **average OEE of the previous period,**

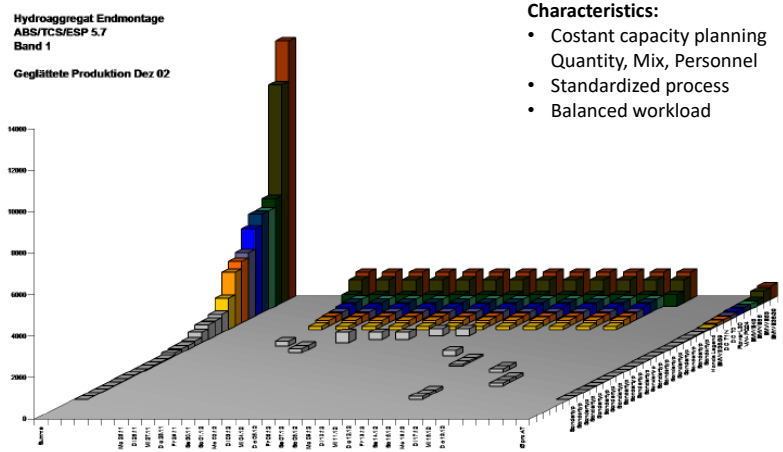
	without C/O	**with C/O (NPT/POT)**	
– Final assembly:	84 % = 20 h	16/24=66.6%	(4 C.O.)
– Production actuator:	76 % = 18,2 h	67.7 %	(2 C.O.)
– Production Amplifier:	68 % = 16 h	68 %	(0 C.O.)
– Production Housing:	80 % = 19,2 h	67.5 %	(3 C.O.)
– POT	24 h		

- Change Over time 60 min
- Cycle time 1.5 min / pc
- NPK 40 pcs = 1 h production
- Target OEE ≠ basis OEE for capacity planning (reference: previous period)
- No customer fluctuations
- Floating Runner considered only @pacemaker (not in the pre-processes)

Pull System

Customer request

Step 2-3



Characteristics:

- Costant capacity planning Quantity, Mix, Personnel
- Standardized process
- Balanced workload

Step 6: Definition of EPEI

Task: Renault? Daimler?

Customer	Average Daily customer Demand [pcs/day]	Change Over [Av./day]			EPEI	NPK
VW*	184	1	1	0,5	1	40
Renault	200	1	1	0,5	1	40
Daimler	76	1	0,5	0,5	2	40
BMW	80	1	0,5	0,5	2	40
Audi	40	1	0,5	0,5	2	40
Peugeot	44	1	0,5	0,5	2	40
Total	624	4				

*Example VW = (920+920)/10 =184

Step 6: Definition of EPEI

Task: Pattern Definition

Step 7: Average N° of cards/day

EPEI	Customer	Demand in cards/day	
1	VW*	4,6	5
1	Renault	5	5
2	Daimler	1,9	2
2	BMW	2	2
2	Audi	1	1
2	Peugeut	1,1	1
	Total		16

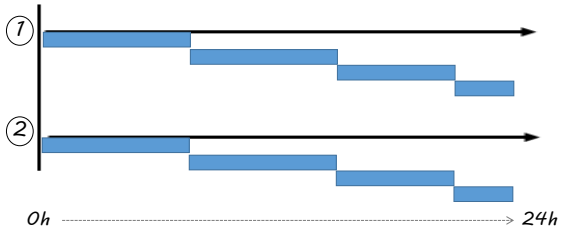
Step 8a: Leveling production Plan

Customer	Day 1	Day 2	Day 3	Day 4
VW	5	5	5	5
Renault	5	5	5	5
Daimler	4	0	4	0
BMW	0	4	0	4
Audi	2	0	2	0
Peugeut	0	2	0	2
Total	16	16	16	16

*Example VW = (184/40) =4,6

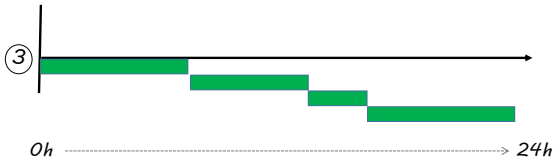
Step 8b: Definition of Leveling Sequence

How is normally the concept to organize the sequence in the leveling board?



How to set-up an optimized system which matches with the reality
(Negative & Positive fluctuation)?

Insert small production lots during the daily hours



Step 8b: Definition of Leveling Sequence for the round 1

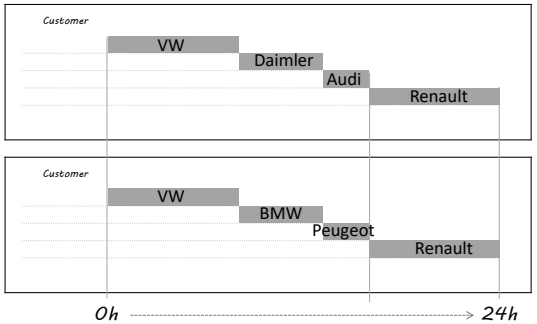
Out of the 3 concepts, which one should we use in the simulation to get closer to the reality ?

Reduce C.O. losses

Which one should be the Floating Runner type? Why?

Renault

How would looks like day1 & day2?



Leveling performance

Why do we measure the leveling quality?
The leveling quality is an indicator for the stability of the leveling process. It is not measured for any cross-comparison between lines or shop floors, due to its dependence on differentfactors.

How is the leveling quality measured?
Suggested base for the evaluation is planned vs. produced lots (≠Kanban)
[Exception: In case of a very high EPEI it could be better to use "Kanban" or "pieces" instead of "lots"]

$$\textbf{Leveling quality [\%]} = \frac{\text{Number of "OK"-lots in the evaluated interval}}{\text{Total number of lots in the evaluated interval}} \times 100$$

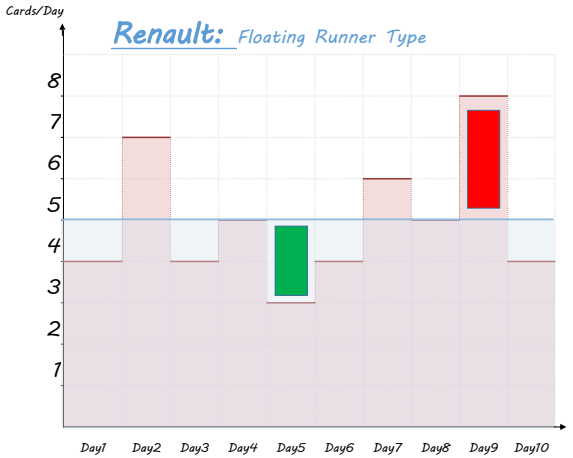
A production lot is "OK", if quantity and sequence are respected

- **Quantity:** The difference between planned and realized quantity per lot should be less than +/- 10%
- **Sequence:** The sequence of lots defined in the Leveling pattern is followed
- [Time: Adherence to the time is required only from Assessment Level 3 onwards]
- Hint: The production of Performance Kanban and the production of backlog are not measured as deviations

The evaluation of exotics is depending on the manufacturing principle and the target of leveling

- **Make-to-order:** Deviations are not considered in the leveling quality (unless the mayor target is the smoothing of preprocesses)
- **Make-to-stock**: Deviations are considered in the leveling quality (analogous to runner types)

Step 9: Calculation of required decoupling



What happens in this situation?

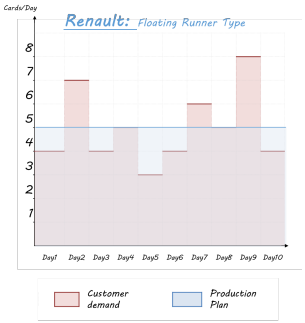
We need stock

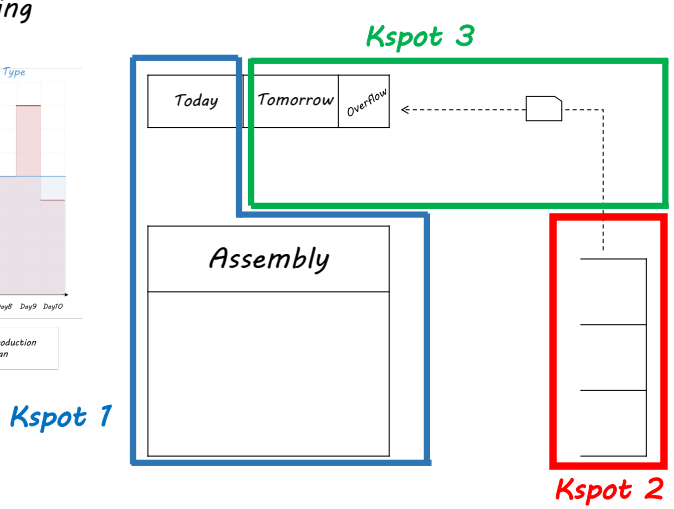
We need kanban

Customer demand

Production Plan

Step 9: Calculation of required decoupling





Step 9: Calculation of required decoupling

Kanbans in the PROCESS (Kspot 1) 5	Total Number of kanbans required for the planned set-up	Kanbans covering **Replenishment time (RE)**
Kanbans in the SUPERMARKET (Kspot 2) 6		Kanbans covering **Lot Size formation (LO)**
Kanbans in the OVERFLOW (Kspot 3) 8		Kanbans covering **Planned customer withdrawal peaks (WI)**

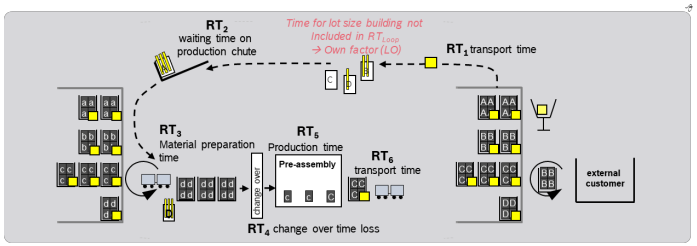
Step 9: Calculation of required decoupling

RE

$$RE = \frac{RTloop}{TT \times NPK} = n° \text{ kanban}$$

NPK = Number of parts per Kanban

RTloop = Replenishment time = Rt1 + Rt2 + Rt3 + Rt4 + Rt5 + Rt6



RT_1: time between withdrawal from the supermarket and arrival of Kanban on the production chute *(without lot size building!)*

RT_2: waiting time on production chute

RT_3: material preparation time (Milkrun)

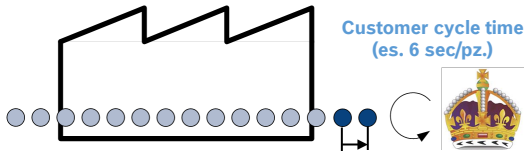
RT_4: change over time loss

RT_5: production time for 1 Kanban

RT_6: transport time in the supermarket

Step 9: Calculation of required decoupling

TT = Takt Time = Time Interval of customer withdrawal (1 pc)



POT= Planned Operation Time = Production time excluding planned breaks

PR= Period requirement

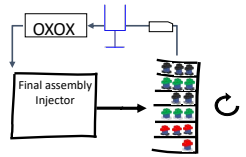
$$TT = \frac{POT}{PR} = (s/pc)$$

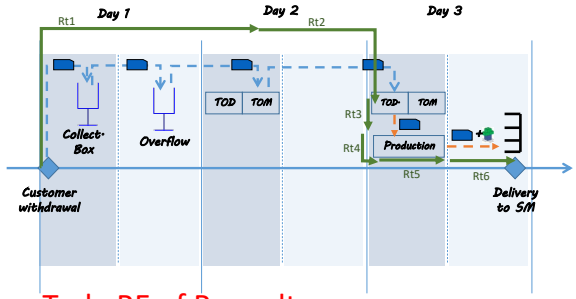
$$RE = \frac{RTloop}{TT \times NPK} = \frac{RTloop \times PR}{POT \times NPK} = (n°kanban)$$

Step 9: Calculation of required decoupling

Step A: Define RE (RELOWI)

(Nº of cards to cover the Replenishment Time → Rt loop





Rt loop= 3 Days

Rt1, Rt2, Rt3, Rt4, Rt5, Rt6

Task: RE of Renault

$$Re = \frac{RTLoop \times Pr}{POT \times NPK} \qquad Re = \frac{3 \times 200}{1 \times 40} = 15 \text{ Kanban}$$

Step 9: Calculation of required decoupling

Step B: Define LO (RELOWI)

(Nº of cards needed to complete lot size)

$$LO = \frac{\text{Lot Size}}{NPK} - 1$$

$$LO = 0$$

Step C: Define WI (RELOWI)

(Nº of cards needed to cover the planned customer peaks)

Process Kspot 1=5	Total Number of kanbans required for the planned set-up 19	Kanbans covering **Replenishment time (RE)**
SUPERMARKET Kspot 2=6		Kanbans covering **Lot Size formation (LO)**
OVERFLOW Kspot 3=8		Kanbans covering **Planned customer withdrawal peaks (WI)**

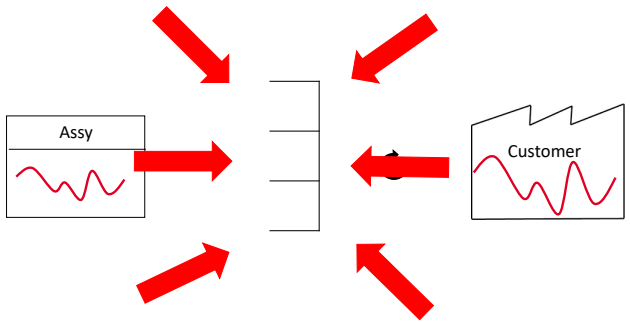
WI=Kspot tot-Re-Lo

Task: Calculate WI

WI= 19-15=4

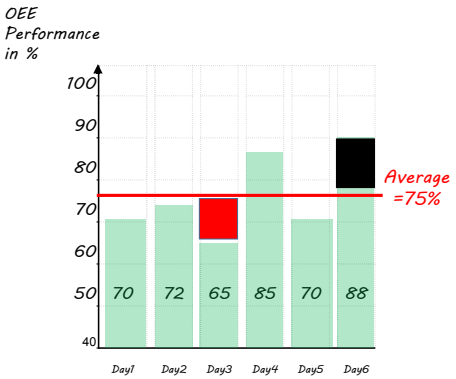
SA´s: Nº of cards to cover unplanned fluctuation

Why do we need SA?



SA_1: Nº of cards to cover unplanned process fluctuation

(Own Fluctuation)



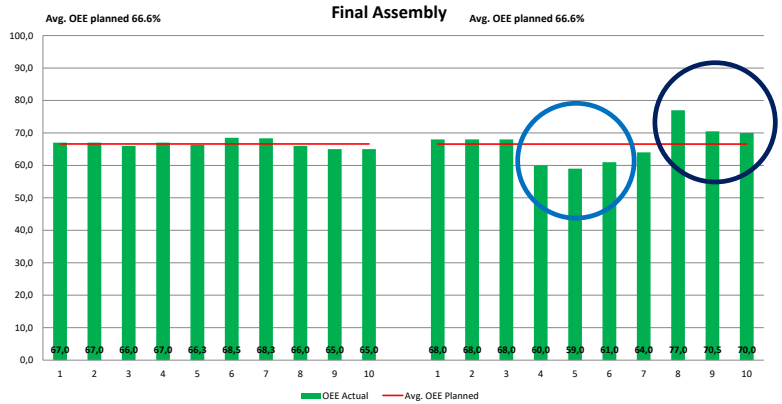
→ Where do we need SA1?

- Supermarket
- Overflow

→ What has to be considered additionally in the SA1 calculation?

SA1 needs to cover the unplanned fluctuations cumulated in reaction time

SA_1: Calcolo per SA1 pacemaker
(Own Fluctuation)

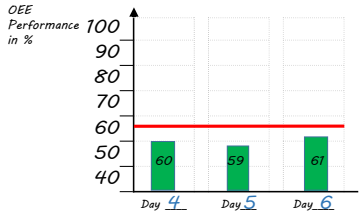


$SA_{1\ Supermarket}$: To cover negative fluctuation

Production deliver less than plan, to protect the customer, include safeties in the supermarket

$SA_{1\ Supermarket}$:

1) Calculate the biggest losses cummulated in the RT_{loop}



Day 4 : → 66,6% : 16K → 60 : X K | X= 14,4 → | Losses= 1,6 Cards

Day 5 : → 66,6% : 16K → 59 : Z K | Z= 14,2 → | Losses= 1,8 Cards

Day 6 : → 66,6% : 16K → 61 : W K | W= 14,7 → | Losses= 1,3 Cards

2) Calculate the number of cards to cover the biggest losses in the RT_{loop}

$SA_{1\ Supermarket}$= 4,7

Day1: Round 1

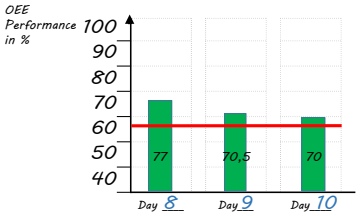
$SA_{1\ Overflow}$: To cover positive fluctuation

Number of cards tobe provide to the production when its perform better than average OEE, which was the basis to define the number of cards available daily (the aim is to support positive performance to the process)

Task: Calcolare Sa1 Overflow

$SA_{1\ Overflow}$:

1) Calculate the biggest performance increase cummulated in the RT_{loop}



Day 8 : → 66,6% : 16K → 77 : M K | M= 18,5 → | Increase= 2,5 Cards

Day 9 : → 66,6% : 16K → 70,5 : N K | N= 17 → | Increase= 1 Cards

Day 10 : → 66,6% : 16K → 70 : L K | L= 16,8 → | Increase= 0,8 Cards

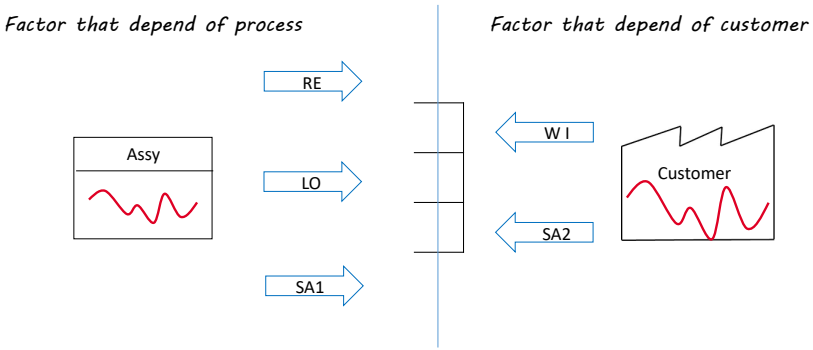
2) Calculate the number of cards for biggest positive performance in the RT_{loop}

$SA_{1\ Overflow}$= 4,3

Step 9: Calculation of required decoupling

	Renault
RE	15
LO	0
WI	4
SA1 (OEE)	
SA1 sup	5
SA1 overflow	4
SA2 (Customer)	
SA2 sup	
SA2 lev·board	
SA	9
Total	28

Kanban



Thanks a lot