TPPE74
Design and Development of Manufacturing Operations

Industrial Engineering and Management of European Higher Education

Seminar 4

Pitfalls and help in simulation

Fredrik Persson

2021

Co-funded by the Erasmus+ Programme of the European Union

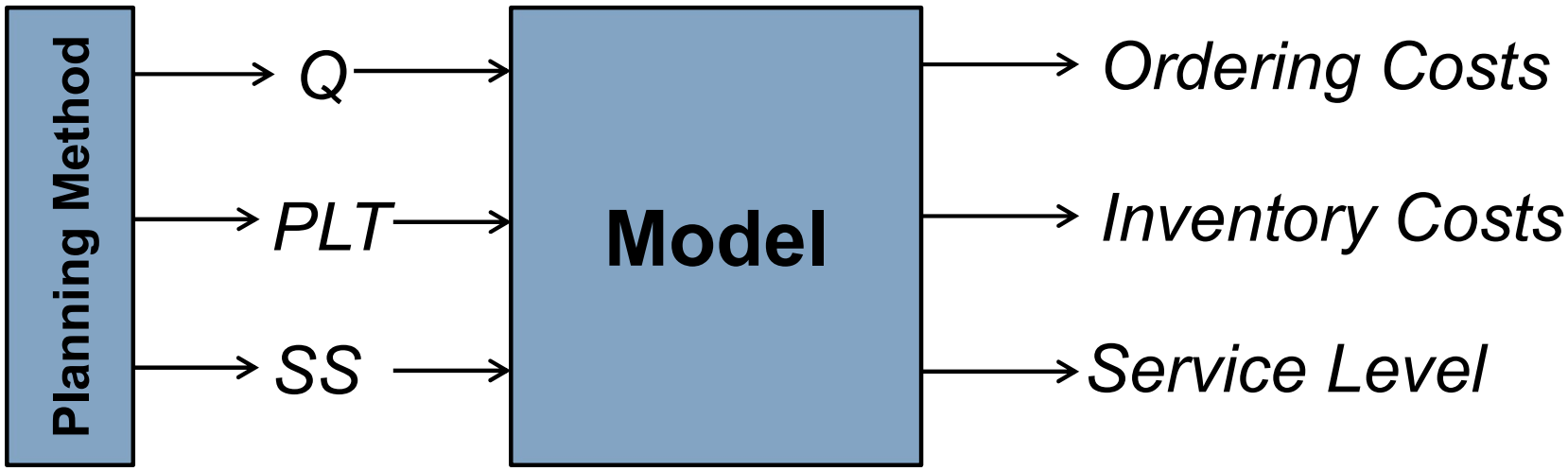
Seminar 4

Content

- Project Overview
  - Runs so far…
- A View on Safety Stock
- A View on Planned Lead Time
  - Static Analysis
  - Estimating Queue Time (alternative method)
- Flow Thinking Analysis

PicSim

- Production and Inventory Control Simulator (PicSim)
- From the Project Directive:
  "The markets all operate under the same **order winner, namely cost** (total cost in this case) and total service level (delivery) is seen as a market qualifier."



Four Tasks in the Project

- Task A
  - Create graphs over nine different relationships.
  - Lisam Quiz to test conceptual shape.
- Task B
  - Run 10 simulations (we run the model) with the target to reach:
    Inventory cost: 340 000 kr
    Service level: 95 %
    Total Cost: 680 000 kr
  - Test all different planning methods
  - Lisam Quiz before simulations (at least one in each group needs to pass)
- Task C
  - Carry out a setup time reduction and study the effects.
  - Run 3 simulations (we run the model) to study the effects.
- Task D
  - Formulate system specific guidelines and rules that apply to the design parameters.
  - Run 3 simulations (we run the model) to “optimize” the system.
  - Competition!

The Tasks

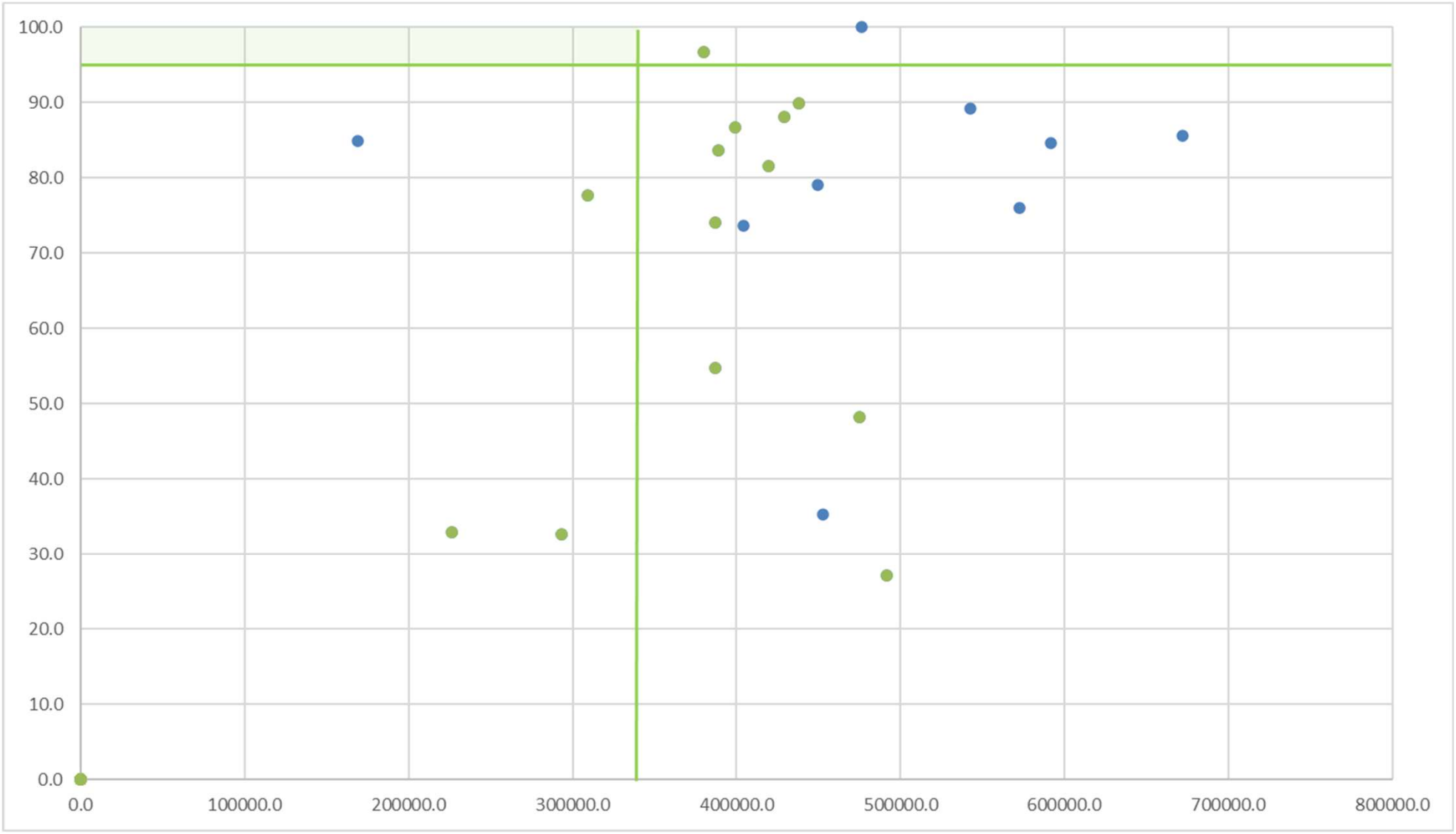
- Task B
  - Improve the system in maximum 10 simulation runs
  - Chose your runs carefully.
  - Give a suggestion for “optimal” planning and control for the company.
  - The evaluation…
    - **Service level more than 95%**
    - **Total inventory holding costs less than 340 000 SEK**
    - **Total costs less than 680 000 kr**
  - Reorder point systems, MRP, cyclic planning (base period, common cycle), and Lean production.
    - Motivate recommended values.
    - Note that, in order to dismiss a planning system, strong empirical evidence is needed as motivation.
  - Only control parameters may be changed in this task.
    - Planned Lead time, PLT
    - Order quantity, Q
    - Safety stock, SS

Examination – Grading Criteria

- Grade Pass requires the following:
- Active participation in the project group.

- For Task B:
  - Maximum of 10 simulation runs with at least 1 result is better or as good as the requirements (target values) for the total cost, total inventory cost and overall service level.
  - Theoretical motivation for all planning methods that show why or why not ROP, MRP, Cyclic planning and Cyclic planning with base period solution, or Lean Production is an appropriate planning method in this project.
  - Simulation results for all planning methods that show why or why not ROP, MRP, Cyclic planning and Cyclic planning with base period solution, or Lean Production is an appropriate planning method in this project.
  - Calculation and motivation for choice of Order quantities, Planned Lead Time, and Safety Stock and/or Safety Lead Time. For all runs.

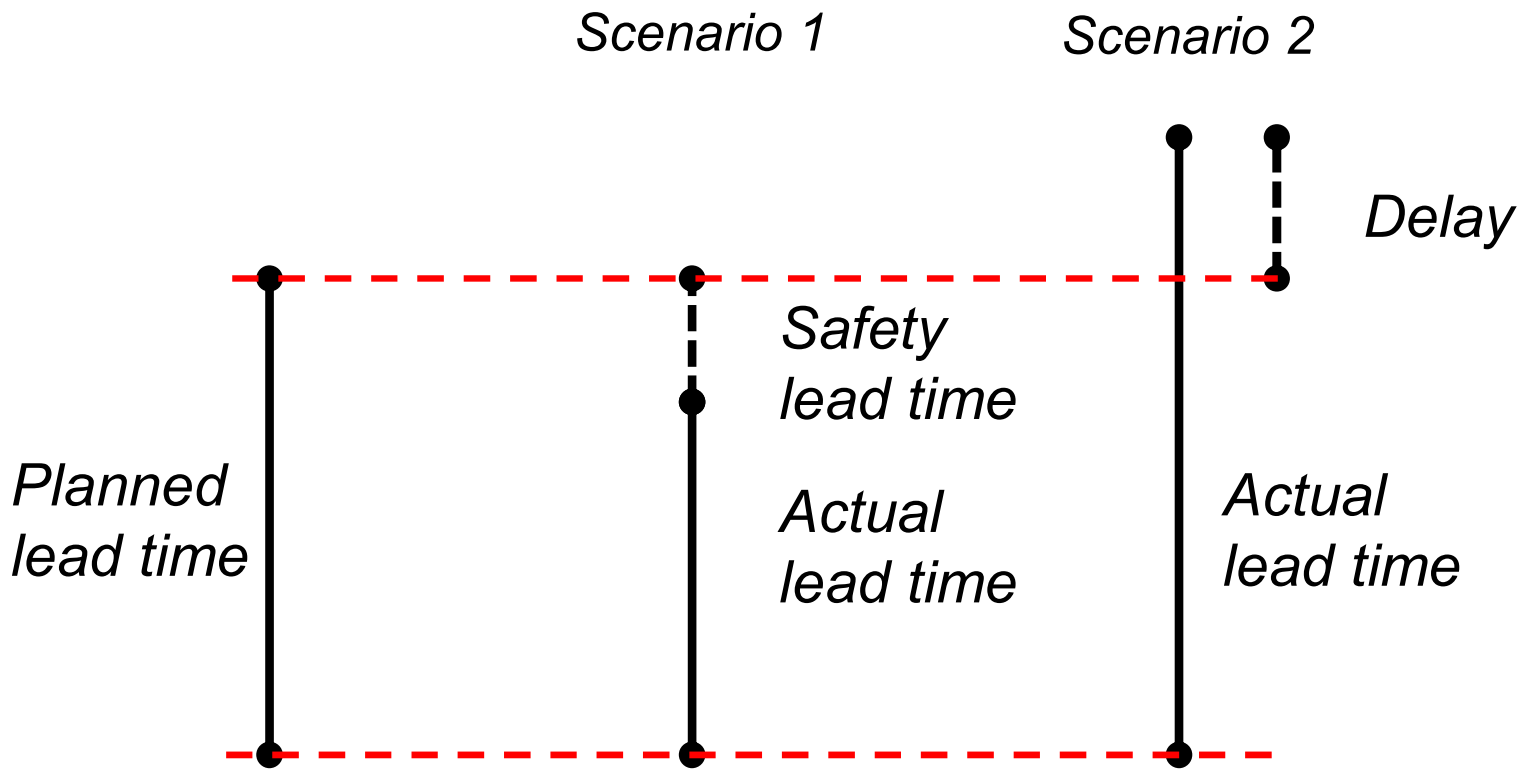
Runs so far (April 27), 22 runs



A View on Safety Stock

- Planned Lead Time and Safety Stock are interconnected
- Experiences from your runs:
  - Some use Safety Stock where it is unnecessary.
  - Some do not use the Actual Lead Time variations.
  - Some use only 95% SERV1.

Example: ROP #1

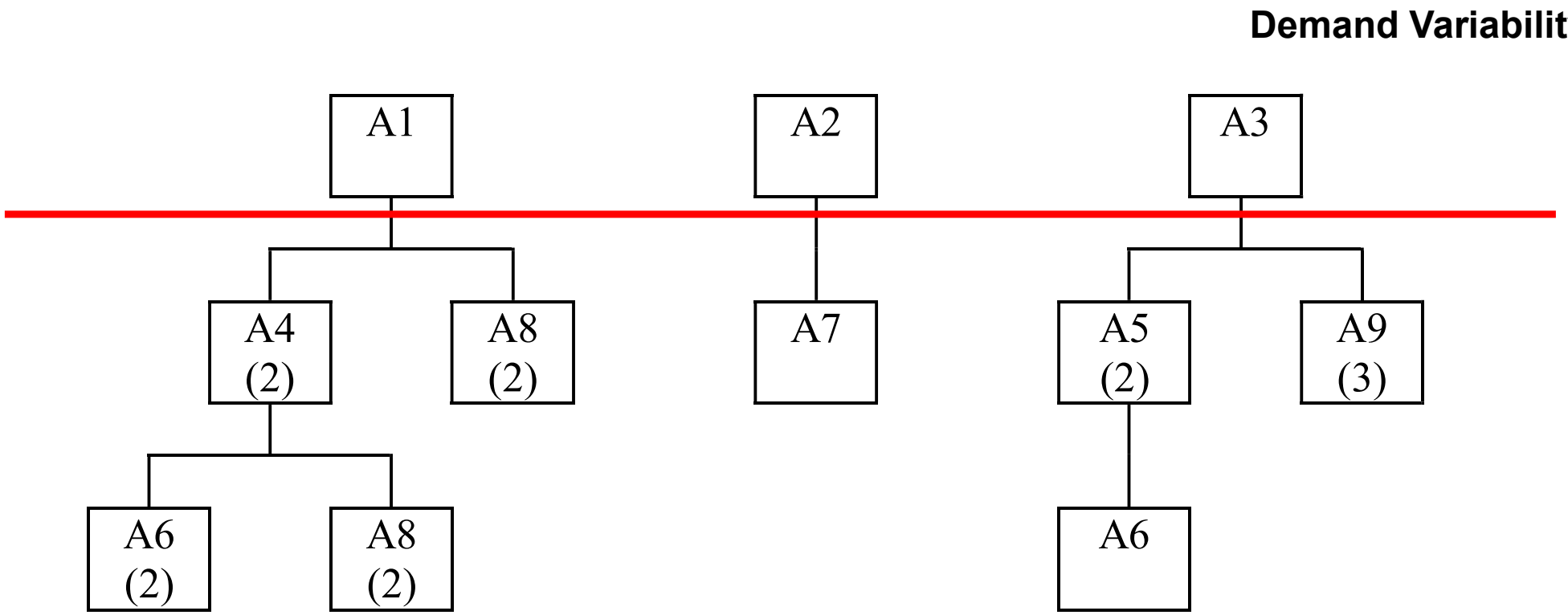


TPPE74 Seminar 3

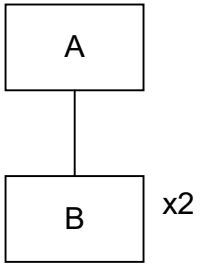
A View on Safety Stock

- Planned Lead Time and Safety Stock are interconnected
- Experiences from your runs:
  - Some use Safety Stock where it is unnecessary.
  - Some do not use the Actual Lead Time variations.
  - Some use only 95% SERV1.

Demand Variablity



MRP Decoupling from Demand to Production



Item: A		Lead time: 1 period							
Description: Final Item A		Safety mechanism: -							
		Lot sizing: FOQ = 100							
Time limits									
Period		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Item forecast		90	140	90	70	60	40	100	110
Production forecast									
Customer orders/Actual demand									
Projected Available Balance (PAB)	200	110	70	80	10	50	10	10	0
Available To Promise (ATP)									
Master Production Schedule (MPS)			100	100		100		100	100
Master Production Schedule (Order rel.)		100	100		100		100	100	

Standard dev. = 29

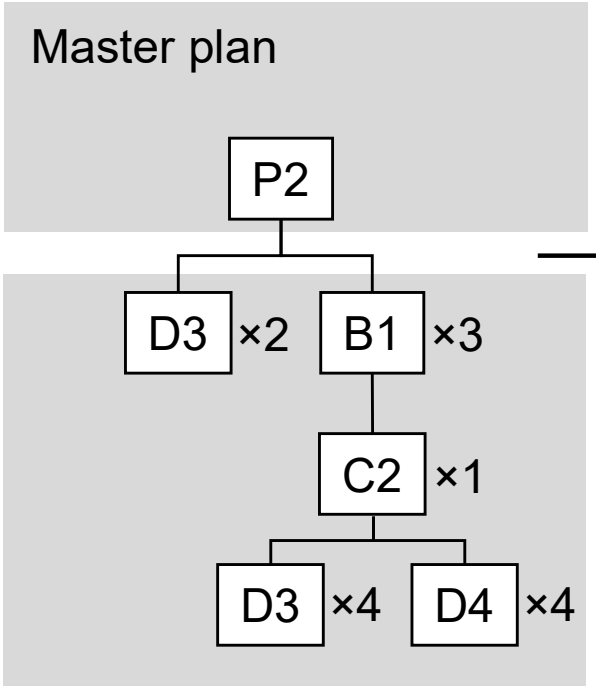
Demand Variability

Planning Variability

Item: B		Lead time: 1 period							
Description:		Safety mechanism: -							
		Lot sizing: FOQ = 300							
Period		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Gross requirements		200	200		200		200	200	
Scheduled receipts									
Inventory development	300	100	-100	-100	-300	-300	-500	-700	-700
Net requirements			100		200		200	200	
Lot sizing			300				300	300	
Planned order: ready			300				300	300	
Projected Available Balance (PAB)	300	100	200	200	0	0	100	200	200
Planned order: release		300				300	300		

Standard dev. = 0

Usage: Where is Safety Stock used?



Data	Is SS needed?
$Q_{P2} = 100$	Depends on Forecast or Demand
	Depends on BOM and uncertainties
$Q_{B1} = 300$	$SS_{B1} = \{3xQ_{P2}, 0\}$
$Q_{D3} = 900$	$SS_{D3} = \{2xQ_{P2}, 0\}$
$Q_{C2} = 400$	$SS_{C2} = \{Q_{B1}, 0\}$
$Q_{D4} = 900$	$SS_{D4} = \{4xQ_{C2}, 0\}$
$Q_{D3} = 600$	$SS_{D3} = \{4xQ_{C2}, 2xQ_{P2}, 0\}$

TPPE74 Lecture 3

A View on Safety Stock

- Planned Lead Time and Safety Stock are interconnected
- Experiences from your runs:
  - Some use Safety Stock where it is unnecessary.
  - Some do not use the Actual Lead Time variations.
  - Some use only 95% SERV1.

SERV1: Uncertainty in Demand and Lead Time

$$\sigma_{LTD}{}^2 = L\sigma_R{}^2 + R^2\sigma_L{}^2$$

σ_{LTD} = standard deviation for demand during the lead time
σ_R = standard deviation for demand per period (or forecast error)
σ_L = standard deviation for lead time
L = lead time (mean value)
R = demand rate (mean value)

$$I_s = z \times \sigma_{LTD}$$

TPPE74 Lecture 3

A View on Safety Stock

- Planned Lead Time and Safety Stock are interconnected
- Experiences from your runs:
  - Some use Safety Stock where it is unnecessary.
  - Some do not use the Actual Lead Time variations.
  - Some use only 95% SERV1.

SERV1: Safety Factor z

Safety factor, z, is derived from the Normal distribution

$$SERV1 = P(no\ shortage) = P(e \leq SS) =$$

$$= \{if\ e\ \in\ N(0, \sigma_{LTD}\} = \Phi\left(\frac{SS}{\sigma_{LTD}}\right)$$

$$SS = \Phi^{-1}(SERV1)\sigma_{LTD} = z\sigma_{LTD}$$

$$z = \Phi^{-1}(SERV1)$$

SERV1	***50%***	***95%***	***97.5%***	***99%***
z	0	1.65	1.96	2.33

$$I_s = z \times \sigma_e L^{\gamma}$$

TPPE74 Lecture 3

Seminar 4

Content

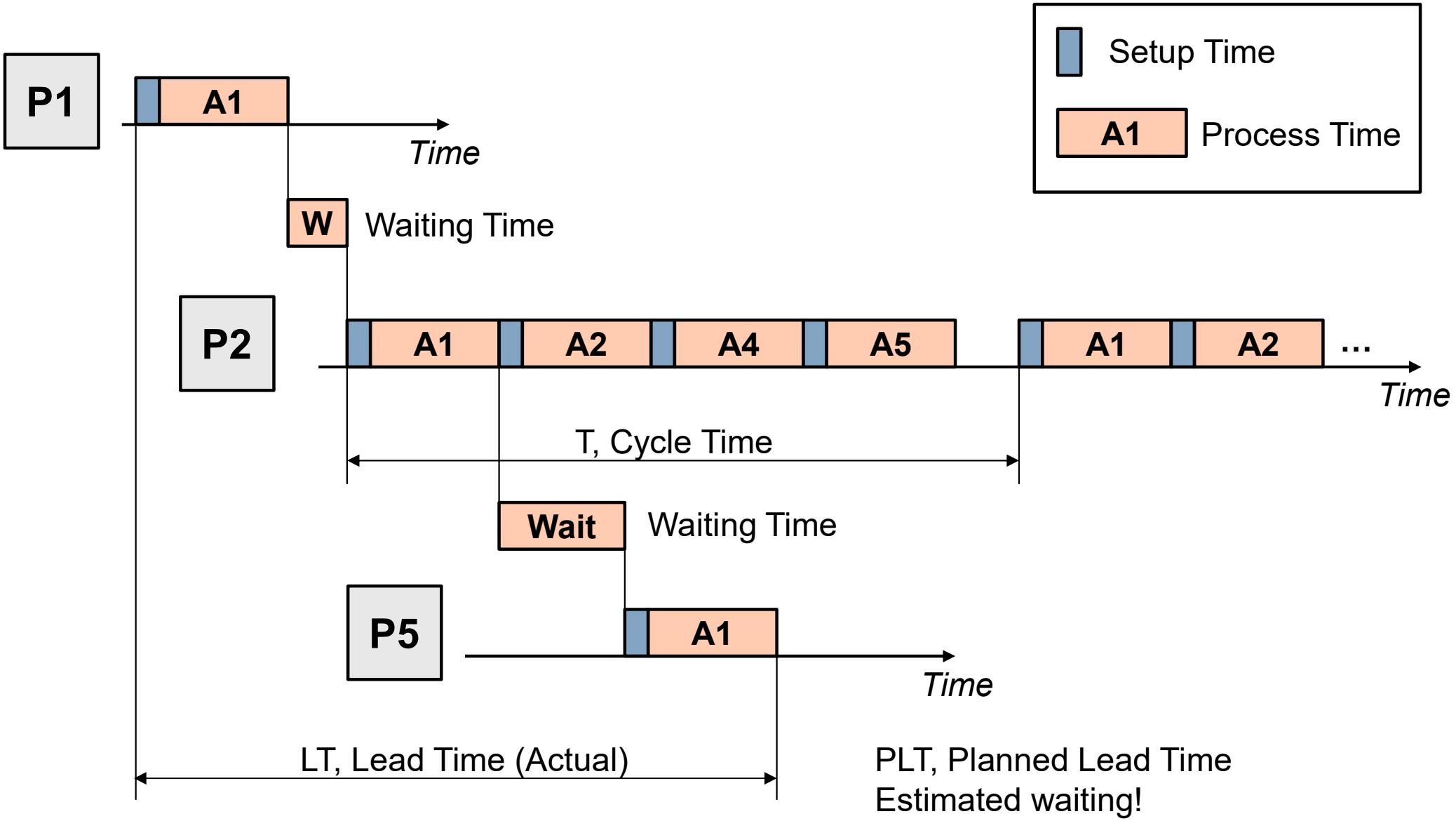
- Project Overview
  - Runs so far…
- A View on Safety Stock
- A View on Planned Lead Time
  - Static Analysis
  - Estimating Queue Time (alternative method)
- Flow Thinking Analysis

A View on Planned Lead Time

- Hard to estimate
- Experience:
  - Estimated with ”rule of thumb”
  - Guessing…?

- Remember: Lead Time in whole days; 3.4, 3.6, 3.8, … weeks
- Do not confuse Cycle Time and Lead Time

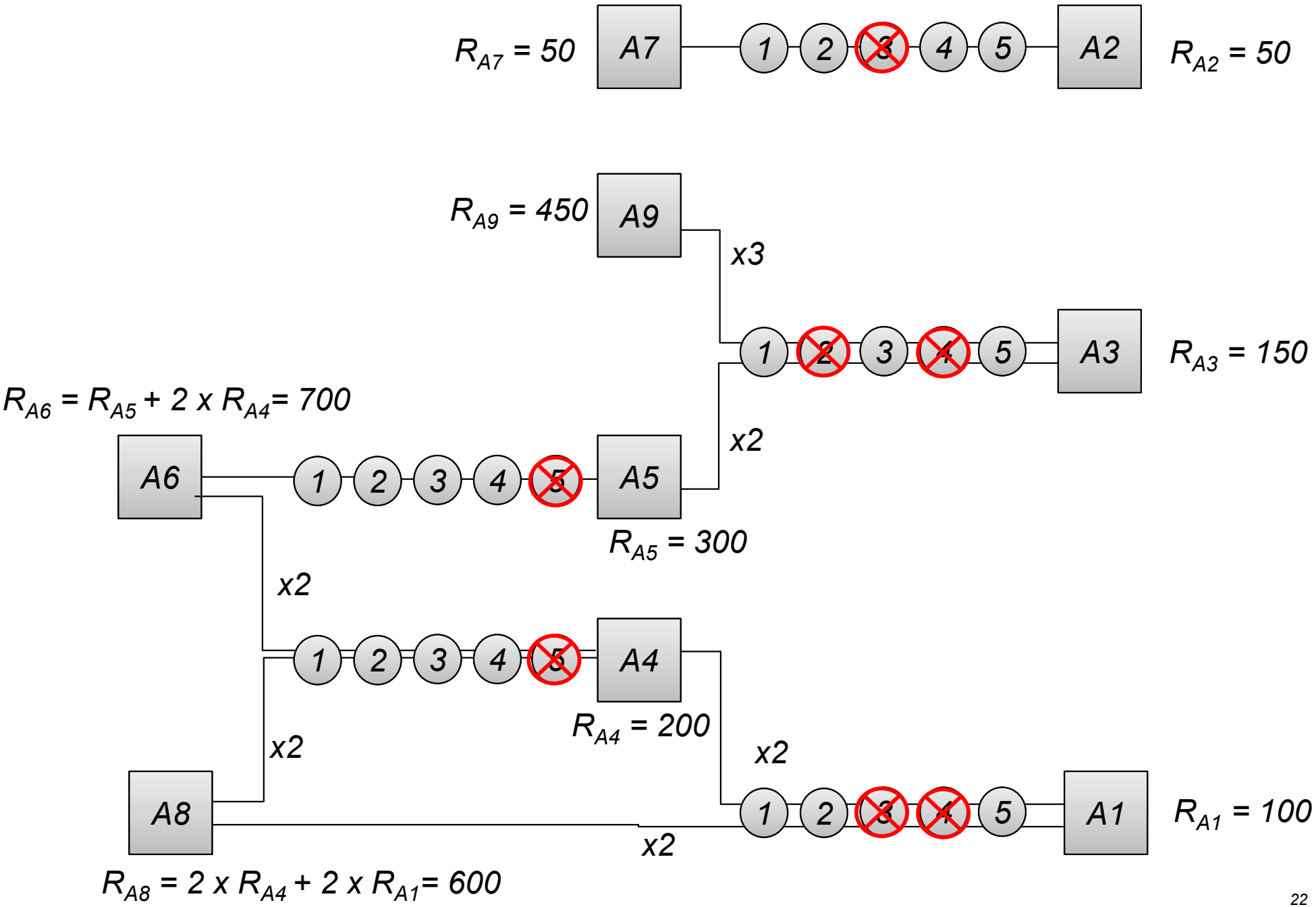
Difference between Cycle Time and Lead Time



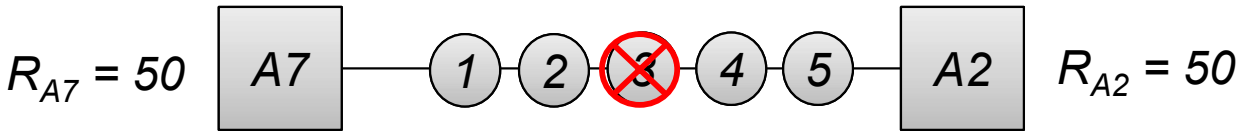
Simulation Result for the Case Company

Simulation Results			Simulation Results						
Group No.	1								
Run No.	0								
Input data									
Product/Item	A1	A2	A3	A4	A5	A6	A7	A8	A9
Lead time	3	4	3	4	4	3	3	3	3
Order quantity	495	632	692	1611	2619	2000	226	1732	1342
Safety stock	200	100	300	400	600	1400	100	1200	900
Costs									
Ordering cost	158400		Total Ordering Cost			158400			
Inventory of raw materials	94587		Total Inventory Cost			498498			
Work in process	347459								
Semi-finished and finished goods inventory	56452								
Total	656898								
Service levels (%)									
Product 1	28.3								
Product 2	72.8								
Product 3	20.8								
Overall	28.5								
Statistics									
Stockouts of finished products	3583.00	680.50	5940.00						
Average inventory level A1-A9	-434.00	186.00	-1149.00	721.50	975.00	2040.00	177.50	3103.00	4858.50
Average actual lead time A1-A5 (weeks)	7.09	8.69	7.36	11.20	15.25				
Average queueing time P1-P5 (hours)	51.34	37.77	44.98	88.66	53.36				
Average load P1-P5 (%)	82.46	67.13	66.21	78.77	73.03				
Inventory turnover rates									
Raw material inventory	8.54								
Work in process	5.89								
Semi-finished and finished goods inventory	36.23								
Total	5.72								

Static Flow Analysis



Static Flow Analysis



Static Flow Analysis

- One batch passing P1, P2, P4, P5
  632 * (0.05 + 0.08 + 0.05 + 0.06) + 2 + 2 + 3 + 1 = 3.99 weeks
- What about Queueing?
- Comparison:
  Lead Time A2 in simulation = 8.69 weeks
  Lead Time A2 in static analysis = 3.99 + Queueing time = ?

Queue Time Estimation

	A1	A2	A3	A4	A5		
P1							
Processing Time	0.03	0.05	0.07	0.02	0.04		
Order Quantity	495	632	692	1611	2619		
Setup Time	2	2	2	2	2	Average	Weeks
Operation Time	16.86	33.62	50.43	34.22	106.74	48.37	1.21
P2							
Processing Time	0.06	0.08		0.02	0.04		
Order Quantity	495	632	692	1611	2619		
Setup Time	2	2	2	2	2	Average	Weeks
Operation Time	31.72	52.60		34.22	106.74	56.32	1.41
P3							
Processing Time			0.05	0.03	0.04		
Order Quantity	495	632	692	1611	2619		
Setup Time	3	3	3	3	3	Average	Weeks
Operation Time			37.59	51.32	107.74	65.55	1.64
P4							
Processing Time		0.05		0.02	0.08		
Order Quantity	495	632	692	1611	2619		
Setup Time	3	3	3	3	3	Average	Weeks
Operation Time		34.62		35.22	212.49	94.11	2.35
P5							
Processing Time	0.11	0.06	0.1				
Order Quantity	495	632	692	1611	2619		
Setup Time	1	1	1	1	1	Average	Weeks
Operation Time	55.48	38.95	70.19			54.87	1.37

Calculate average processing time for each planning group

Assumption:

- Always one order before in queue
- Average queue time

Lead Time Estimation

		A1	A2	A3	
Processing Time		104.05	159.79	158.22	Hours
		2.60	3.99	3.96	Weeks
Queueing Time	P1	1.21	1.21	1.21	
	P2	1.41	1.41		
	P3			1.64	
	P4		2.35		
	P5	1.37	1.37	1.37	
		3.99	6.34	4.22	Weeks
Estimated LT		6.59	10.34	8.18	
Simulated LT		7.09	8.69	7.36	
	Error	-0.50	1.65	0.82	
		7.0%	18.9%	11.1%	

Assumption:

- Always one order before in queue
- Average queue time

Correct?

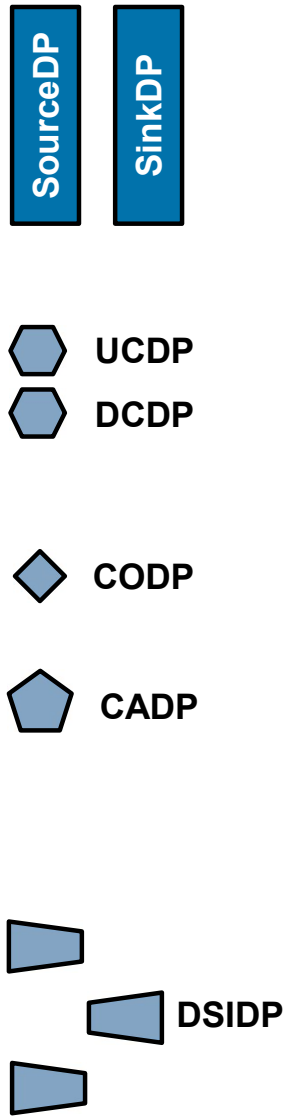
Seminar 4

Content

- Project Overview
  - Runs so far…
- A View on Safety Stock
- A View on Planned Lead Time
  - Static Analysis
  - Estimating Queue Time (alternative method)
- Flow Thinking Analysis

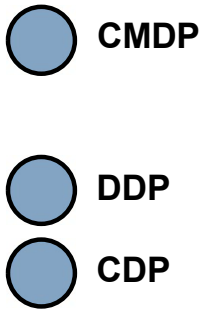
Flow Thinking Framework

- External boundaries of a flow system (B1a and B1b)
  - Source Decoupling Point
  - Sink Decoupling Point
- Controllable part of a flow system (B2a and B2b)
  - Upstream Controllability Decoupling Point (UCDP)
  - Downstream Controllability Decoupling Point (DCDP)
- Driver of a flow (B3)
  - Customer Order Decoupling Point (CODP)
- Differentiating a flow (B4b)
  - Customer Adaptaion Decoupling Point (CADP)
- Flow observability demand (B5a), Flow observability supply sink (B5b) and source (B5c).
  - Demand Information Decoupling Point (DIDP)
  - Downstream Supply Information Decoupling Point (DSIDP)
  - Upstream Supply Information Decoupling Point (USIDP)

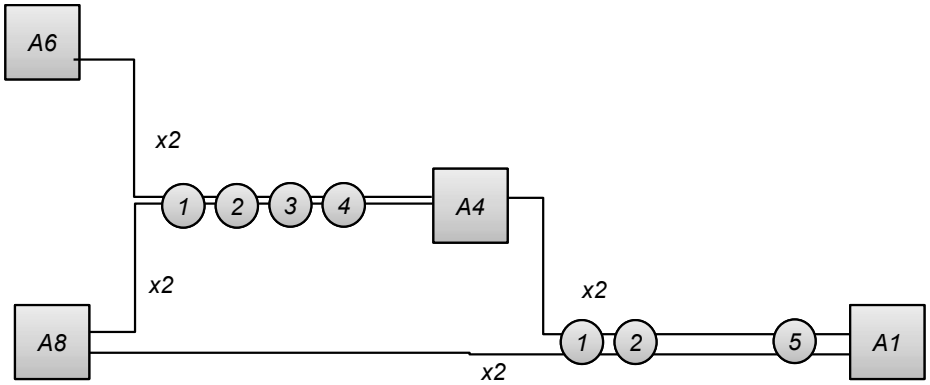


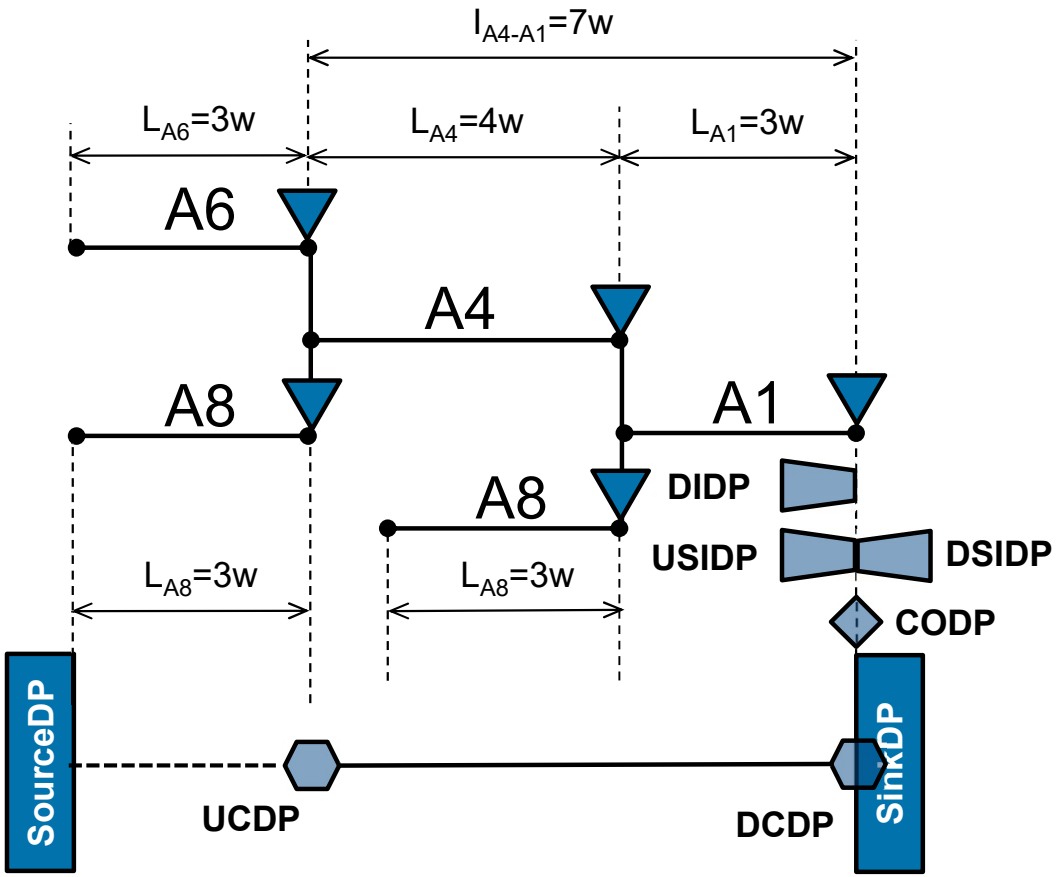
Flow Thinking Framework

- Control Mode (C1a, C1b, … C1f)
  - Control Mode Decouling Point (CMDP)
- Object Type (T1a and T1b)
  - Discretization Decouling Point (DDP)
  - Continuization Decouling Point (CDP)

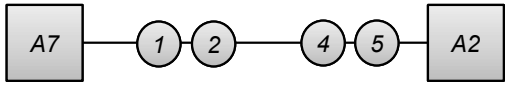


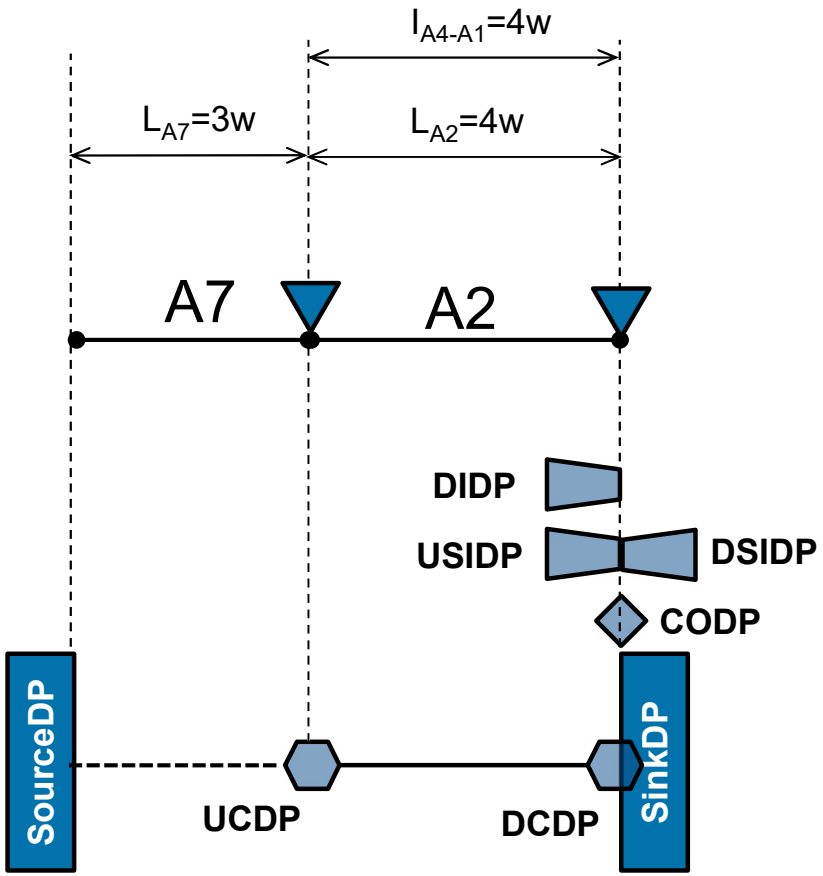
Static Flow Analysis



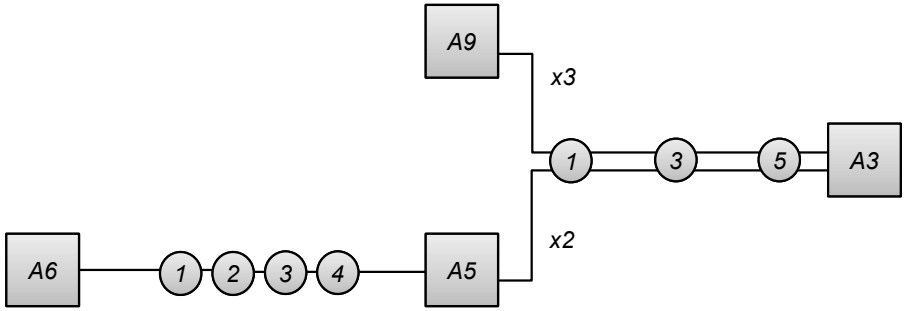


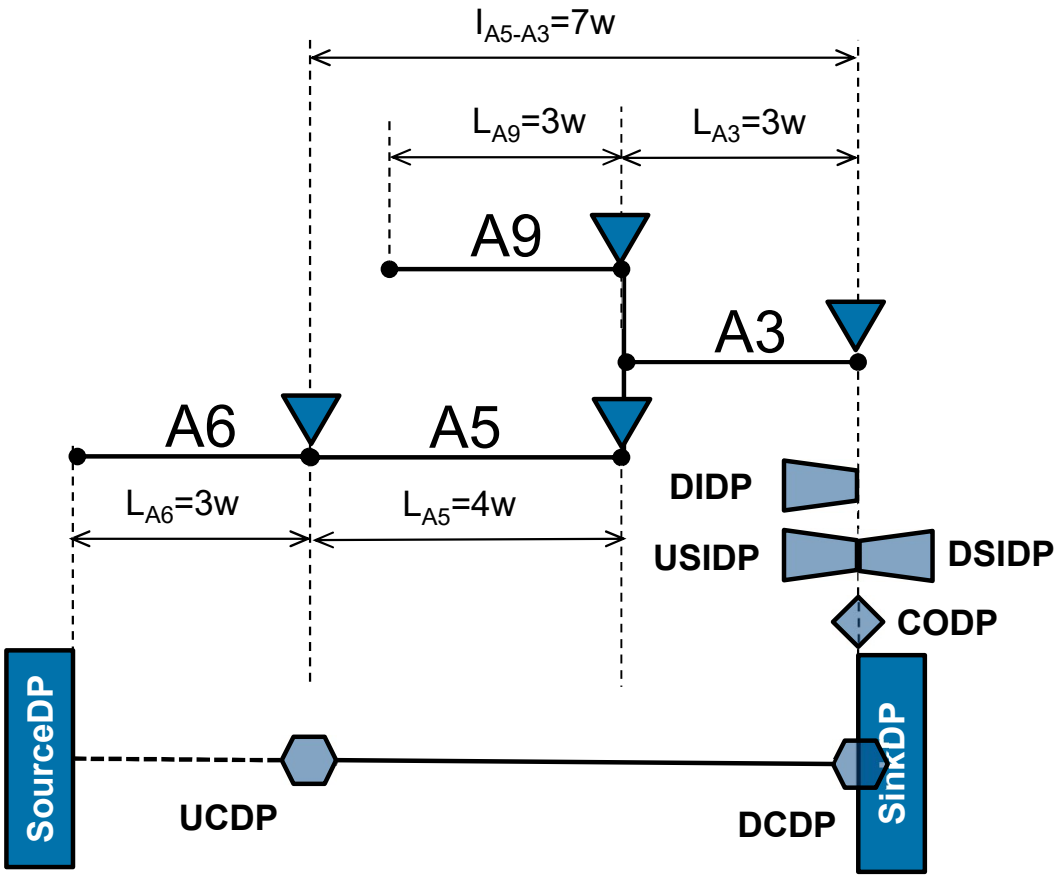
Static Flow Analysis





Static Flow Analysis





Static Flow Analysis

Conclusions

- Only controllable products and components: A1, A2, A3, A4, and A5
- Outside control: A6, A7, A8, and A9
  Meaning:
  Do not bother with PLT
  Order Quantity is handled by supplier
- CODP in FGI for A1, A2, and A3: Only these are affected by demand