Aalto University
School of Science

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PRODUCTION PROCESSES AND PRODUCTION CONTROL

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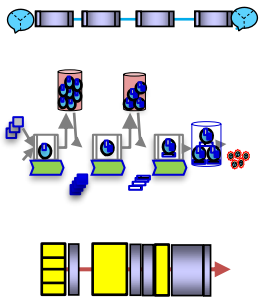
HOW TO CREATE KNOWLEDGE ABOUT PROCESSES

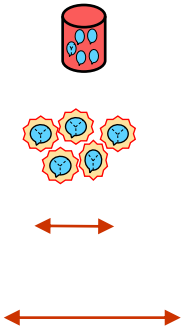
What is it? *Ontology*	What can be known? *Epistemology*	How does it work? *Dynamics*	What can be done? *Technology*
Conceptual model	**Measures**	**Dynamic model**	**Interventions**

Process definition

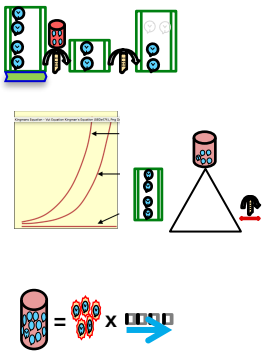


Process types

Key indicators



Process dynamics

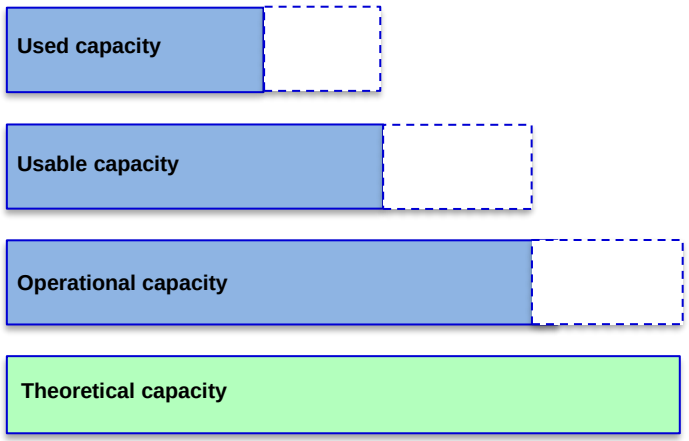


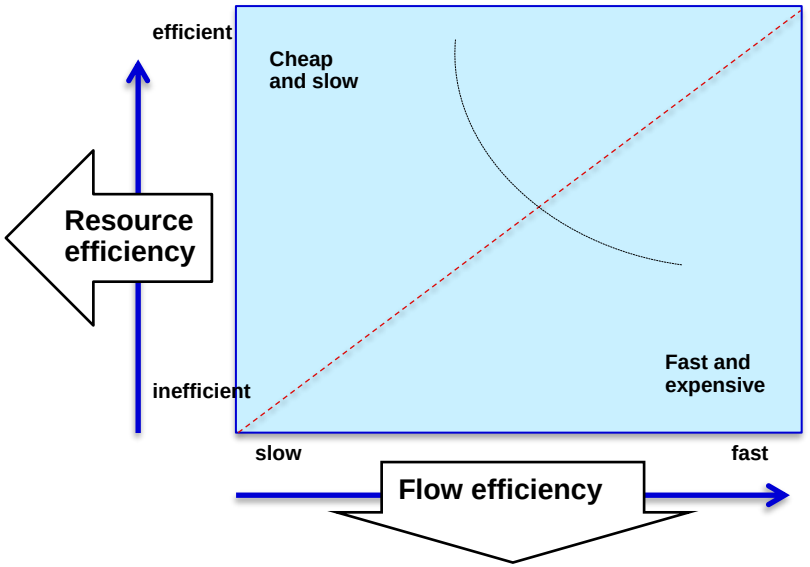
Process planning, control, and improvement

Quality Assurance & Improvement

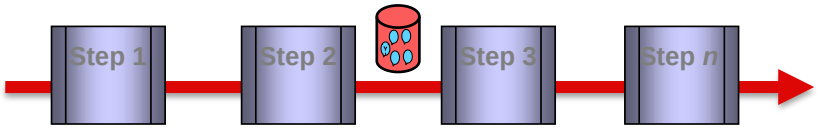
RESOURCE- AND FLOW EFFICIENCY

Management of production unit

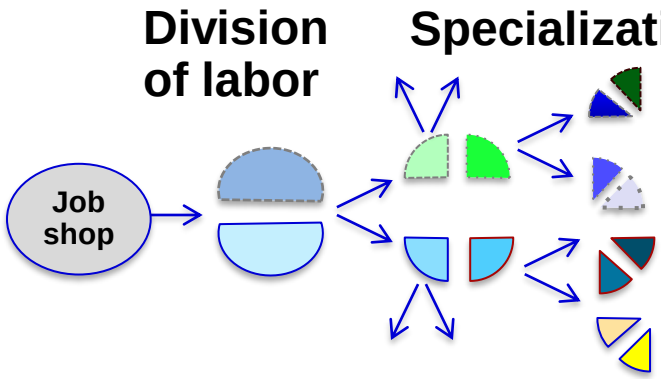


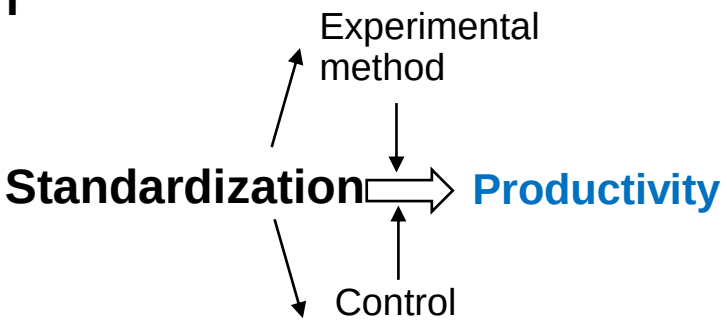


Management of process



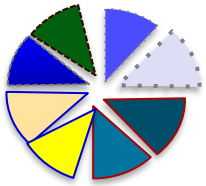
PROCESS IS A CONSEQUENCE OF SPECIALIZATION



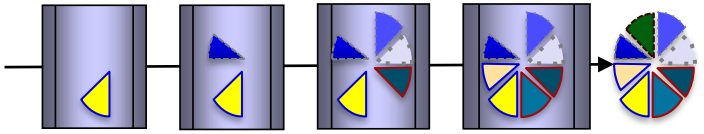


Fragmentation

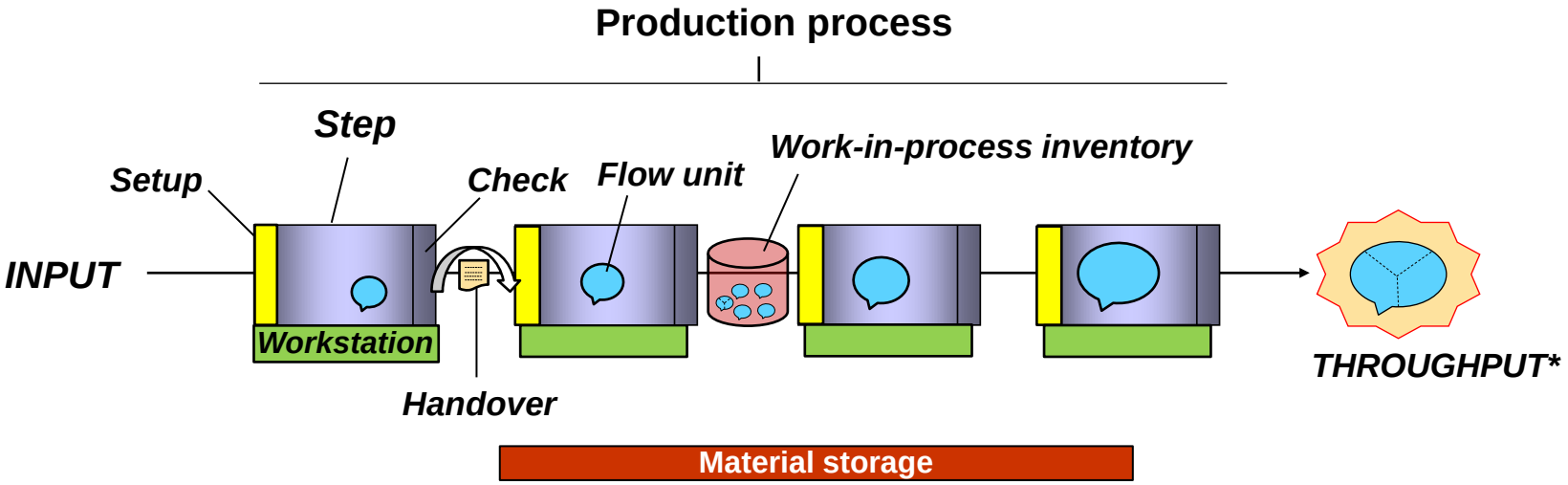
Integration of a multi-component product or service
Product planning, Design



Coordination of a multi-step process
Control, staffing, scheduling, quality



A PROCESS IS A COORDINATION DEVICE



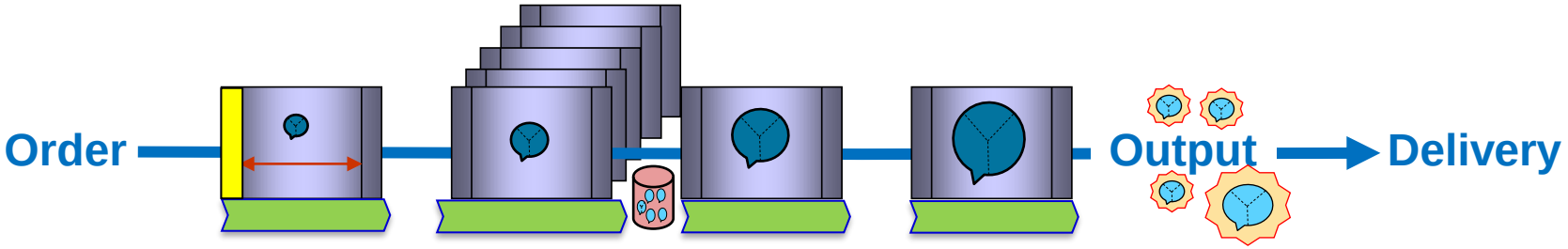
- Sequential coordination of steps, that change the state of a flow-unit (transformation)
- Division of labor: two or more distinct but complementary steps
- Specialization: workstations with dedicated resources for a specific output
- Handovers and inventory between tasks
- Identical or similar repetition: same process – same output
- Subject to variability – management required

*) Throughput in industry is (strictly speaking) output that has been sold.

BOTH REPETITION AND FLOW

Identical repetition of steps with one setup

- Variability
- Quality
- Standardization
- Capacity

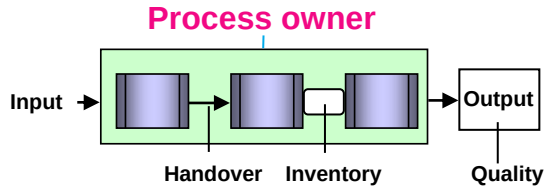


The journey of a flow unit from order to delivery
Supply chain

- Throughput time
- Work-in-Process inventory
- Flow / layout
- Handovers

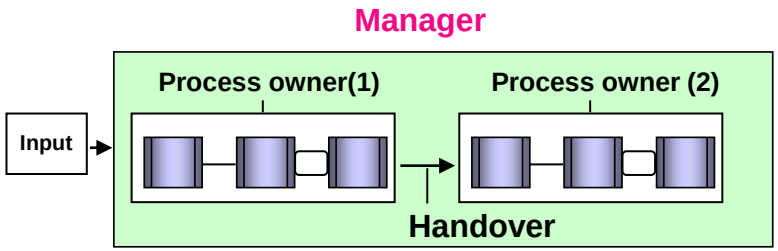
PRODUCTION SYSTEMS ARE ASSEMBLED FROM PROCESSES

Process



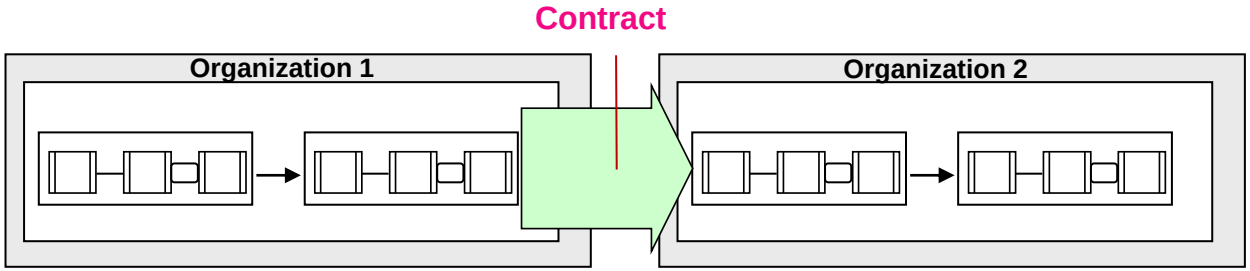
Direct, hands-on management

Multi-functional process



Management through administrative fiat

Production system
Supply chain



Management through legally binding contracts

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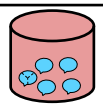
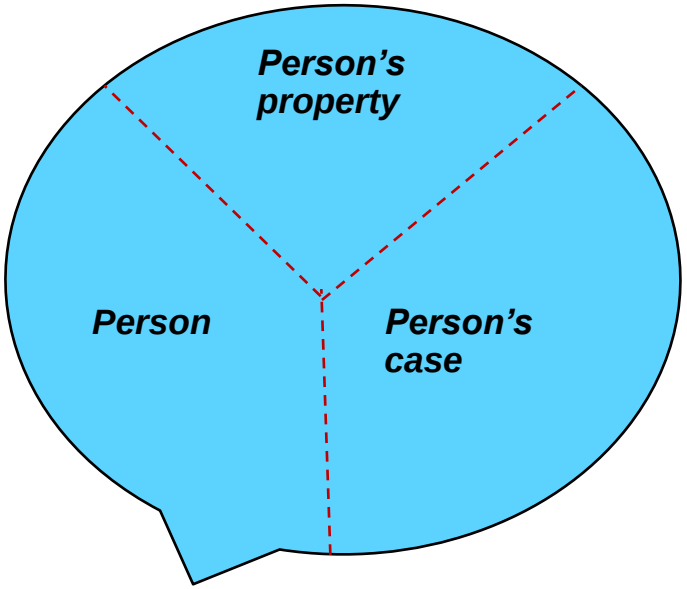
THE ELEMENTS OF PRODUCTION PROCESSES

ELEMENT	WHAT IS IT (ONTOLOGY)	WHAT CAN BE KNOWN? MEASUREMENT (EPISTEMOLOGY)
TASK PROCESSING 	Transformation, State change Requires technology and skill	Duration, Resource consumption (variable cost) Quality (conformance)
FLOW UNIT 	Object to be processed (goods, person, property, case, data)	State (arriving, processed, waiting) Movement / Experience
WORKSTATION 	Resource unit / location doing processing Stationary or mobile	Capacity Fixed cost
SETUP 	Prepare flow unit and workstation for processing	Duration, risk, format, Bargaining space Setup to repetition -ratio
STEP 	A setup+task connected to other steps, In / out –interfaces	*Step time, Takt time*
HANDOVER 	Moving a flow unit from one step to the next	Type, duration Accompanying information
FLOW 	The route / journey of a flow unit Planned or explorative	Beginning, end, duration Alternative routes
WORK-IN-PROCESS INVENTORY (WIP) 	Flow units processed or waiting to be processed	Inventory volume, Inventory turnover Queues
BATCH 	A set of flow units moving together	Batch size
CYCLE TIME 	The time for a flow unit to move through a certain number of steps	Time
THROUGHPUT 	Number of finished flow units per time-unit	Production volume per time unit Capacity

FLOW UNIT IN SERVICES

Patient as property:
Diseases
Organs and organ systems
Genome

Patient as person:
Personal and medical history, Social relations, Preferences, values….

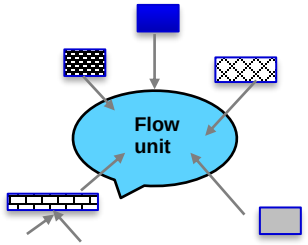


Patient as a case:
Clinical information
Applicable rules and legislation

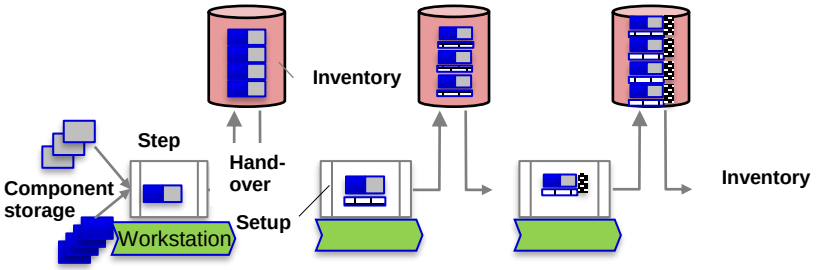
The entity that is processed / undergoes state changes in production.

PROCESS TYPES (1)
by movements of the flow unit

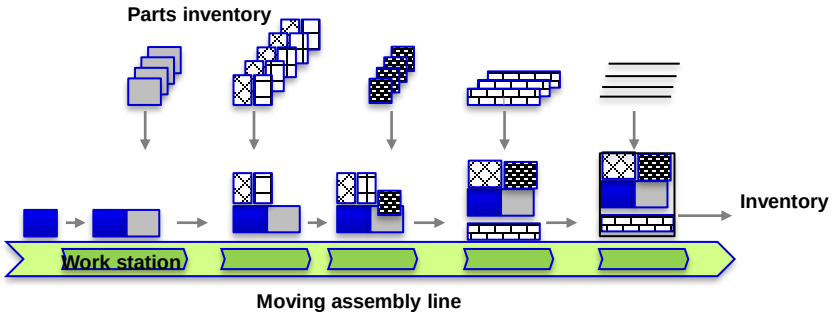
JOB SHOP
Jumbled flow



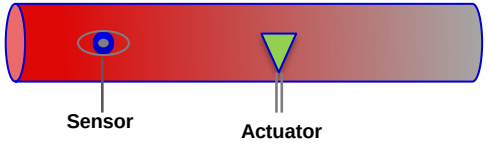
DISCONNECTED FLOW



CONNECTED FLOW

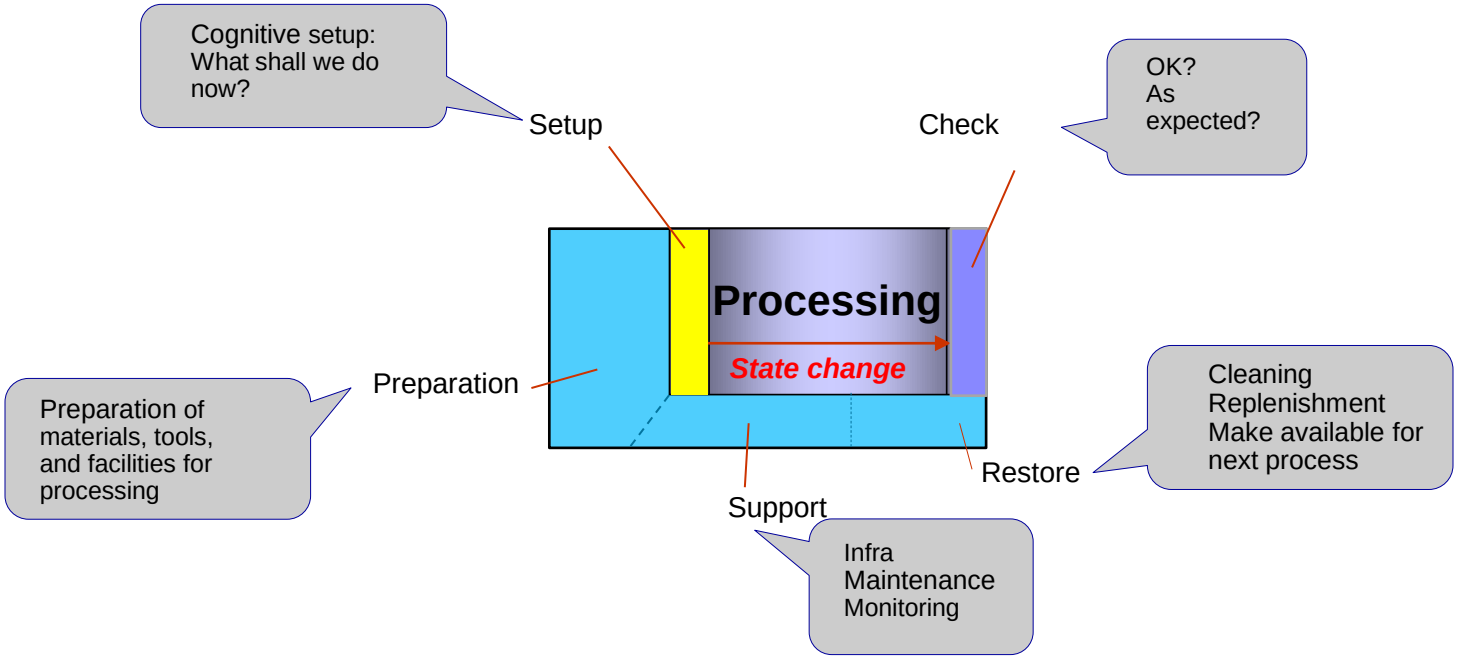


CONTINUOUS FLOW



Hopp, W.J. & Spearman, M.L. 2011. *Factory physics*. 3rd ed. Long Grove, IL: Waveland Press.

THE ANATOMY OF A PRODUCTION STEP



Processing builds on technologies (production function).

Processing changes the state of a flow unit (transformation)

Improvements in processing require investments in technology

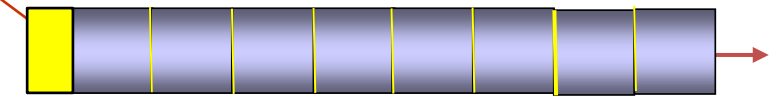
Setup and preparations can be done in many ways ← management

PROCESS TYPES (2)
Setup-to-processing ratio

Plannability
Control

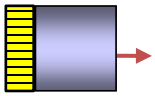
Setup *Step*

STANDARD PROCESS



Setup followed by identical repetition

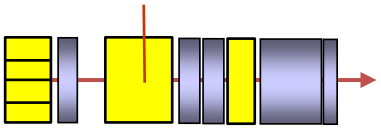
FORMATTED PROCESS



Individual setup with standard variables

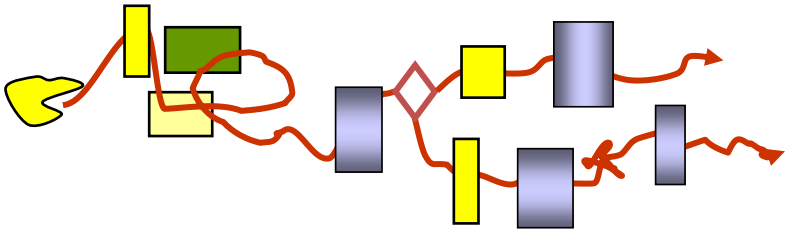
Bargaining

ROUTINE PROCESS



Individual setup, modules
Bargaining

EXPLORATIVE PROCESS



Unclear situation
Exploration
No end-to-end plan

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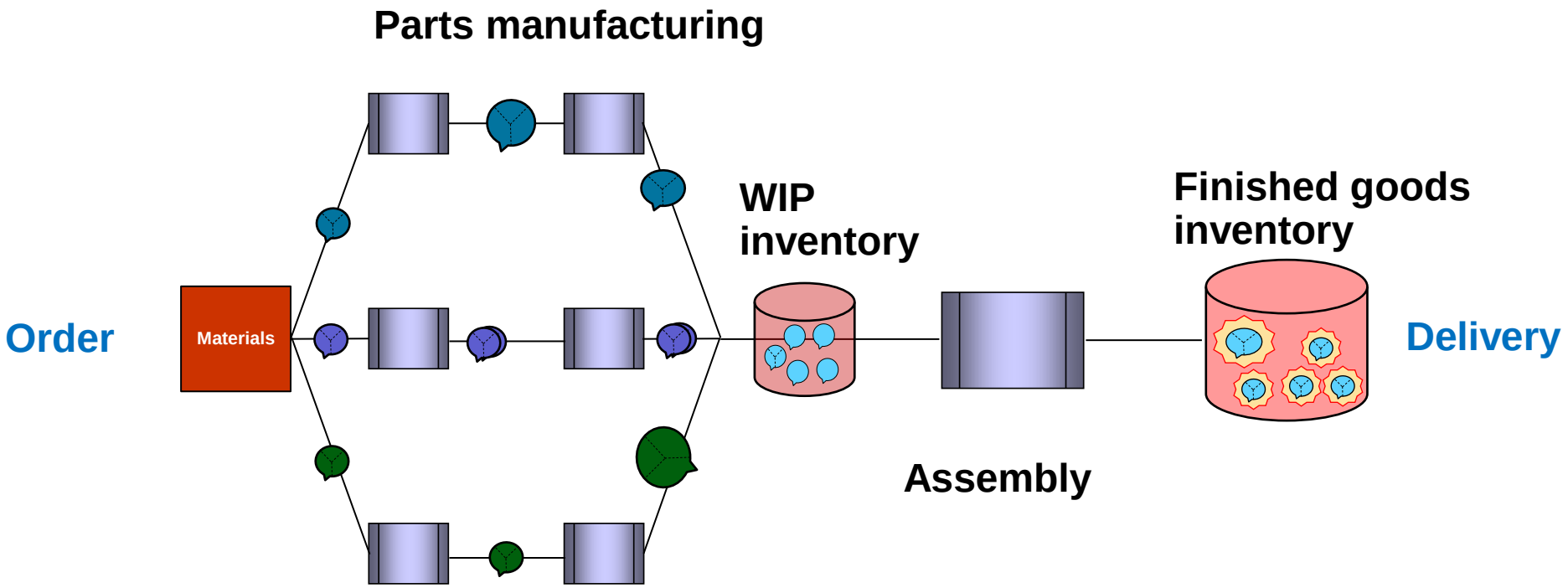
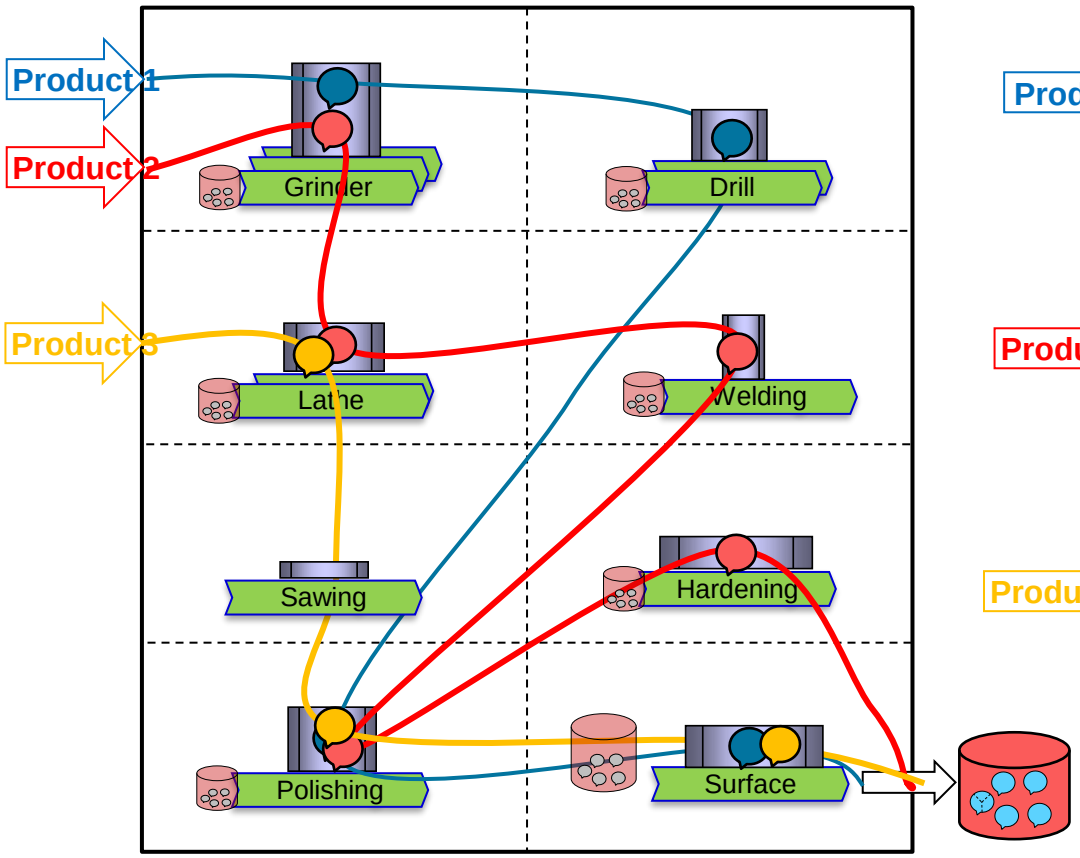
PARALLEL FLOWS

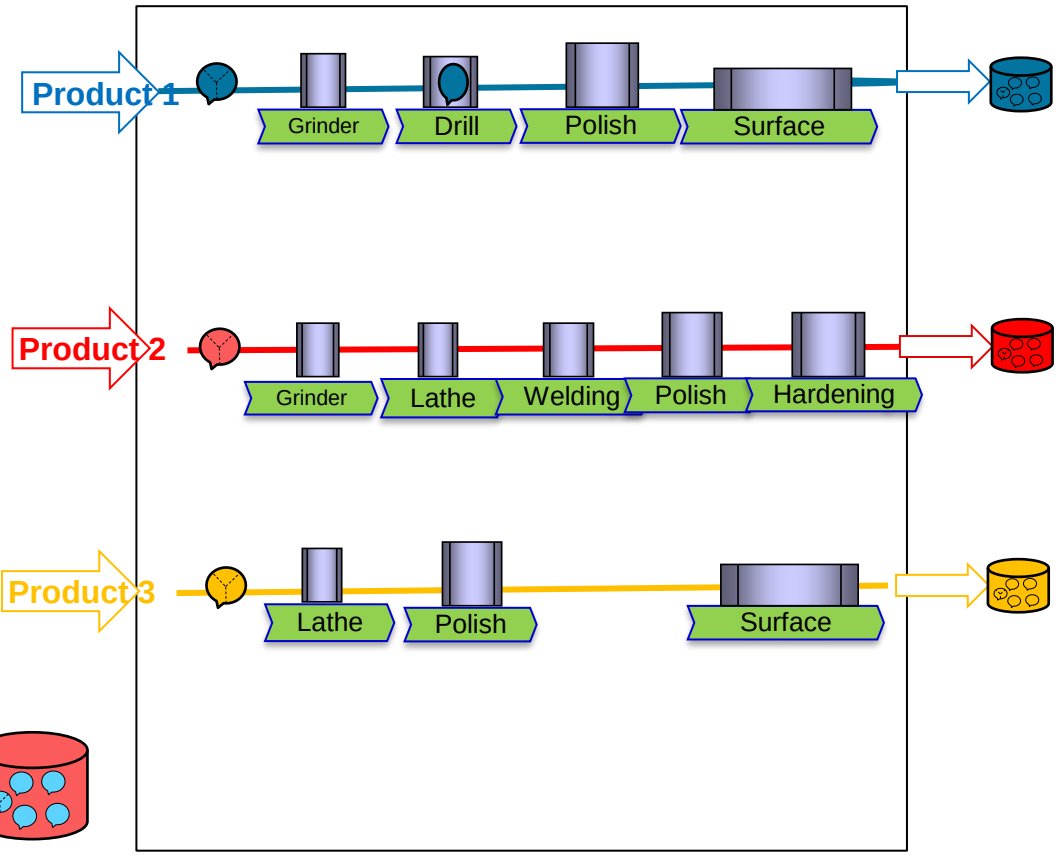


PRODUCTION LAYOUT

Functional layout



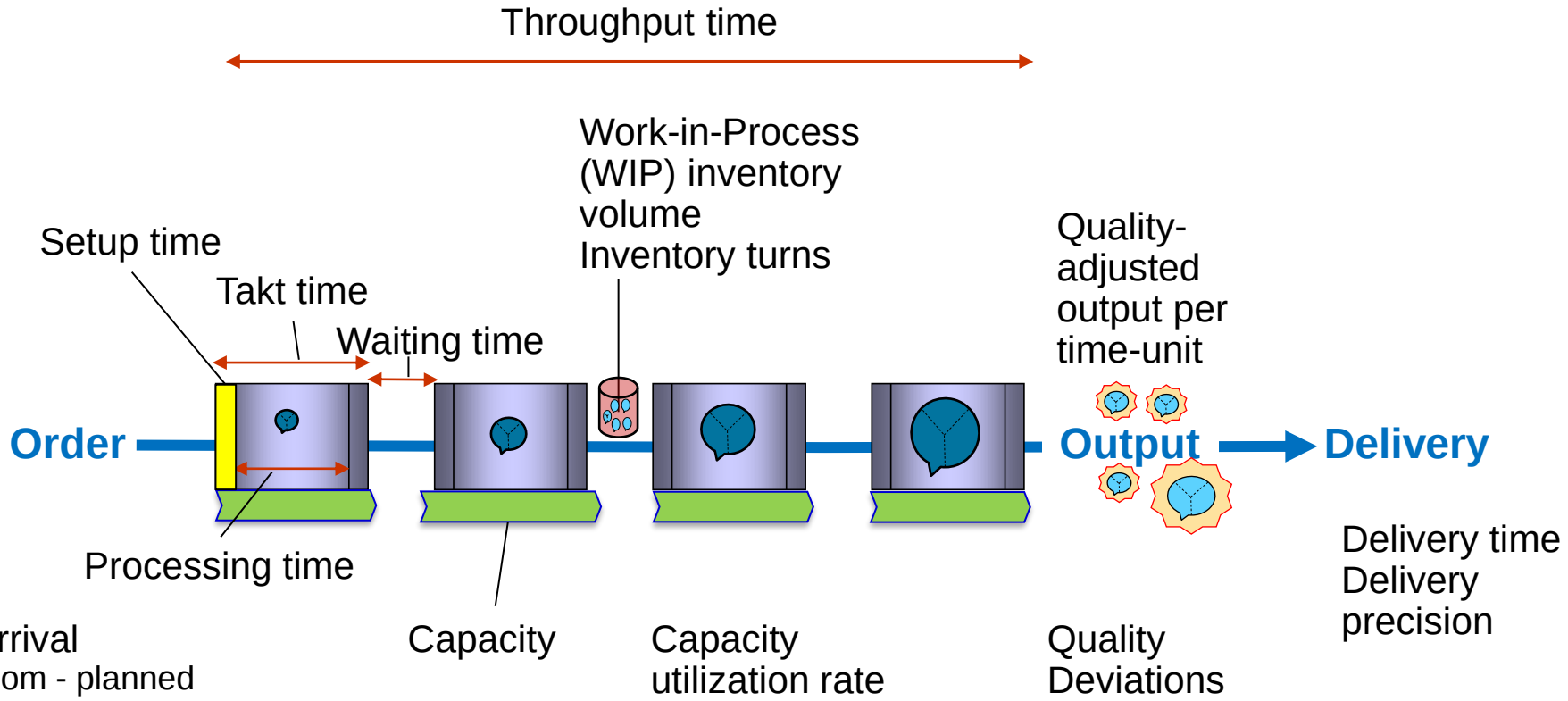
Process layout



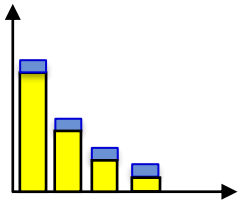
Similar work stations grouped together
→ Specialization, Capacity Utilization

Flow organized by product / flow unit
→ Throughput time, Inventory turns

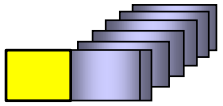
KEY INDICATORS



PROCESS DYNAMICS

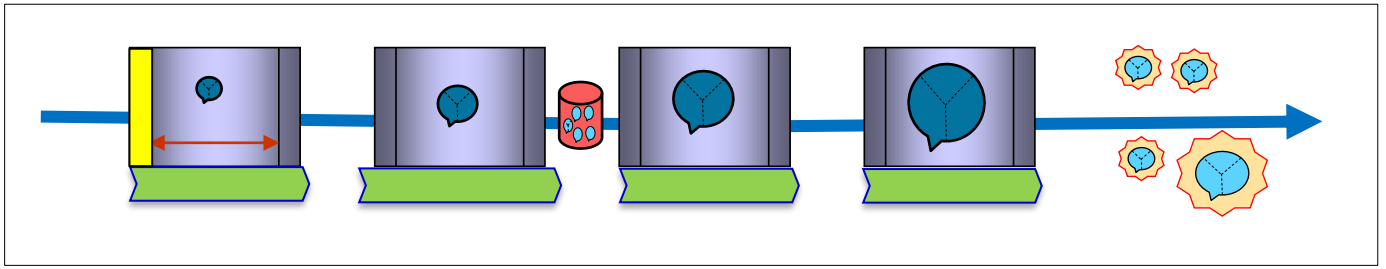


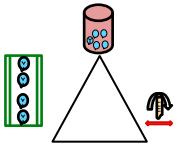
Volume



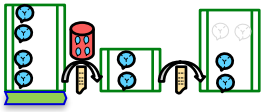
Batch size

Work-in-process

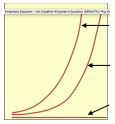




Buffer inventory



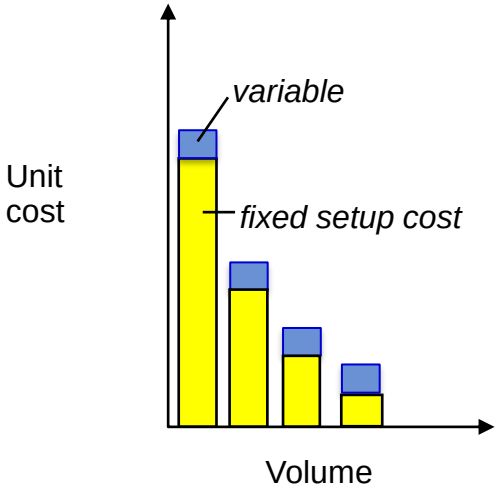
Bottleneck



Variability

SETUP AND PROCESSING - COST AND VOLUME

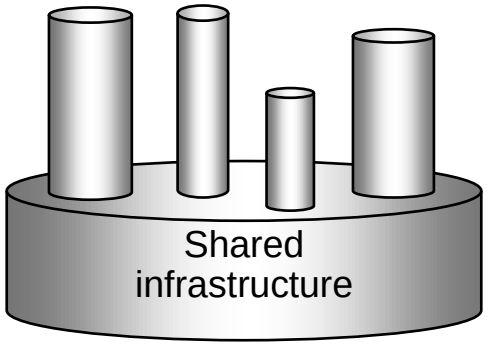
VOLUME



Economies of scale

- repeat with same setup
- the cost of setup is divided on a growing volume of throughput
→ unit cost (variable + fixed) decreases

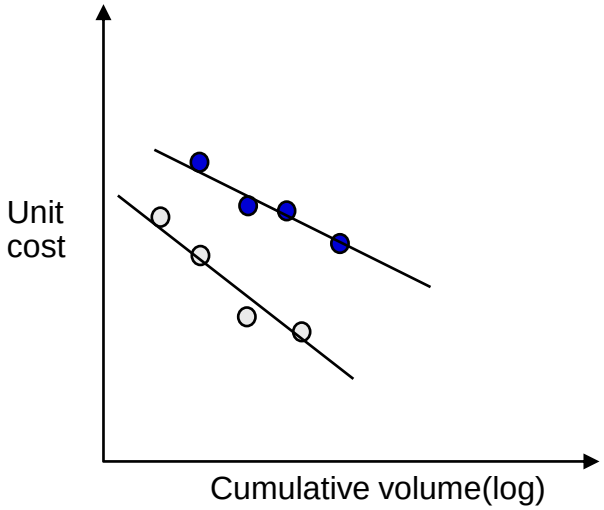
SYNERGY



Economies of scope

- different processes use same infrastructure
- infrastructure can exploit economies of scale

LEARNING

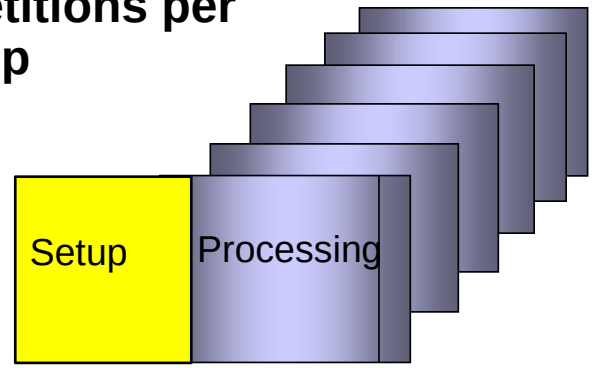


The experience curve
The learning curve

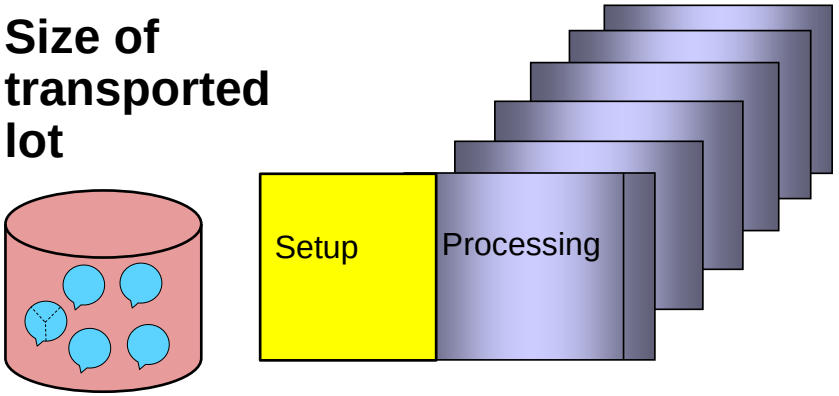
- unit cost falls predictably (%) by doubling of cumulative volume
- individual learning effect

LOT SIZE IS DETERMINED BY THE COST OF SETUP, TRANSPORT, AND INVENTORY

Lot size = repetitions per setup



Size of transported lot



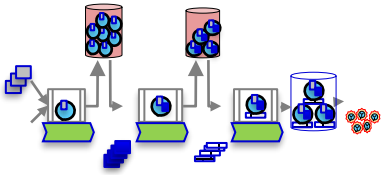
Setup cost
- *Time*
- *Labor, supplies*
- *Risks*

WIP inventory
Work-in-Process
- *Storage cost*
- *Cost of capital*
- *Spoilage*

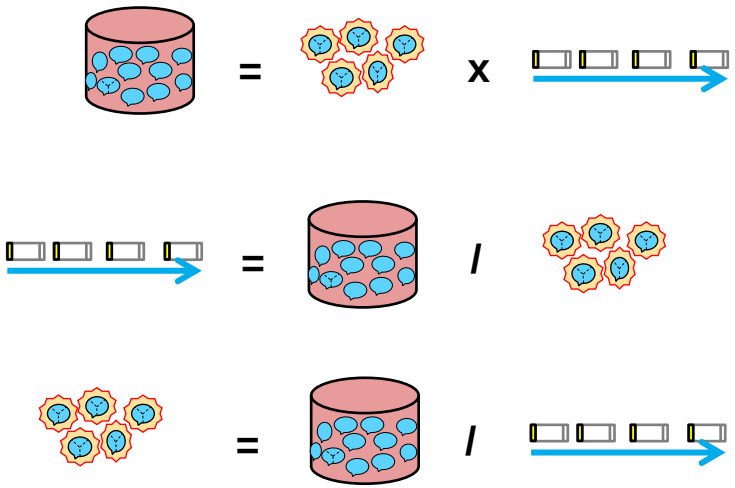
When lot size grows
+ capacity utilization improves
- WIP grows
- Longer throughput time

Leverage from improving setups!

LITTLE'S LAW



Applies to stationary queueing systems.



10 = 10/1

10 = 20/2

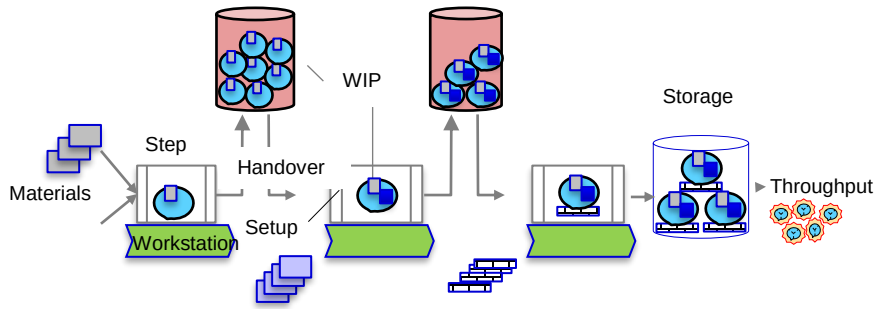
Same output can be accomplished
- Fast with small WIP
- Slow with large WIP

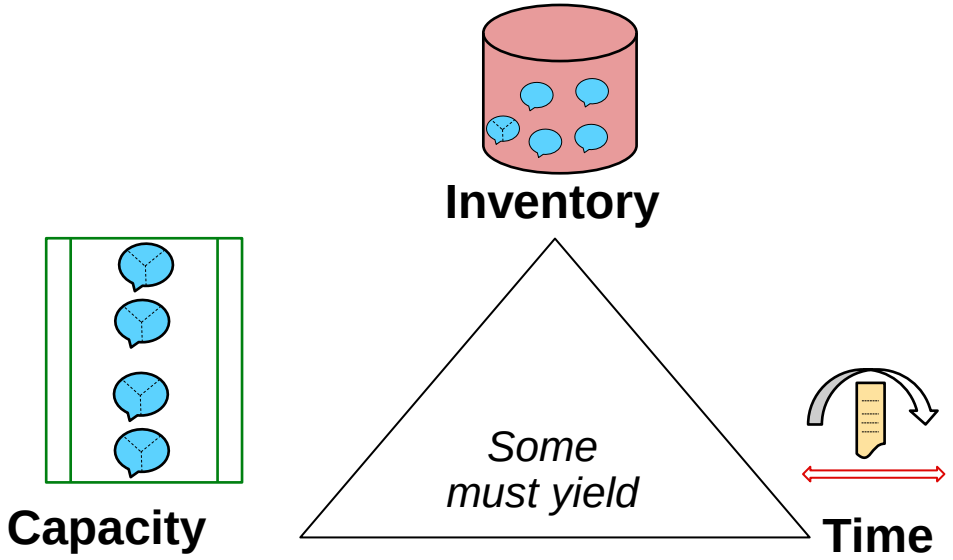
This is management!

INVENTORY AS BUFFER

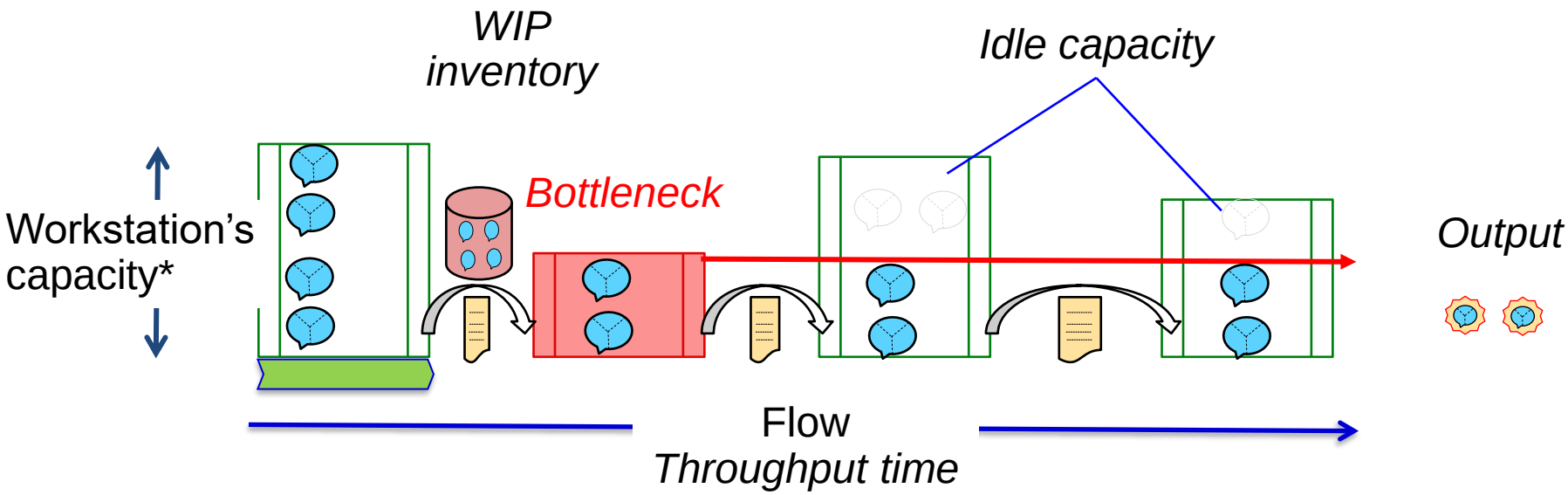
Variable demand

Disconnected flow





A BOTTLENECK DETERMINES OUTPUT



*) Flow-units per time-unit

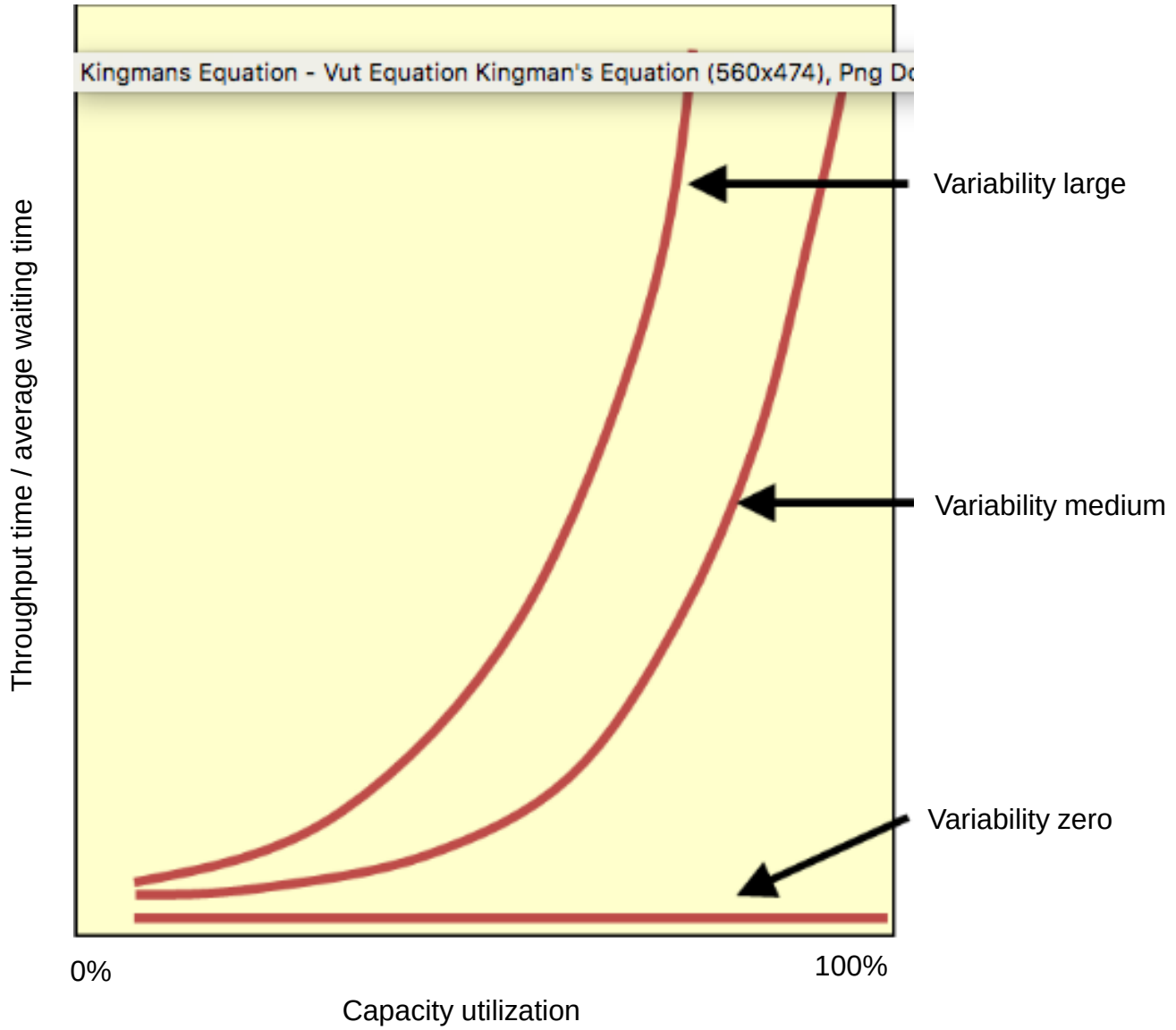
A chain is as strong as it's weakest link

WAITING TIME AND UTILIZATION

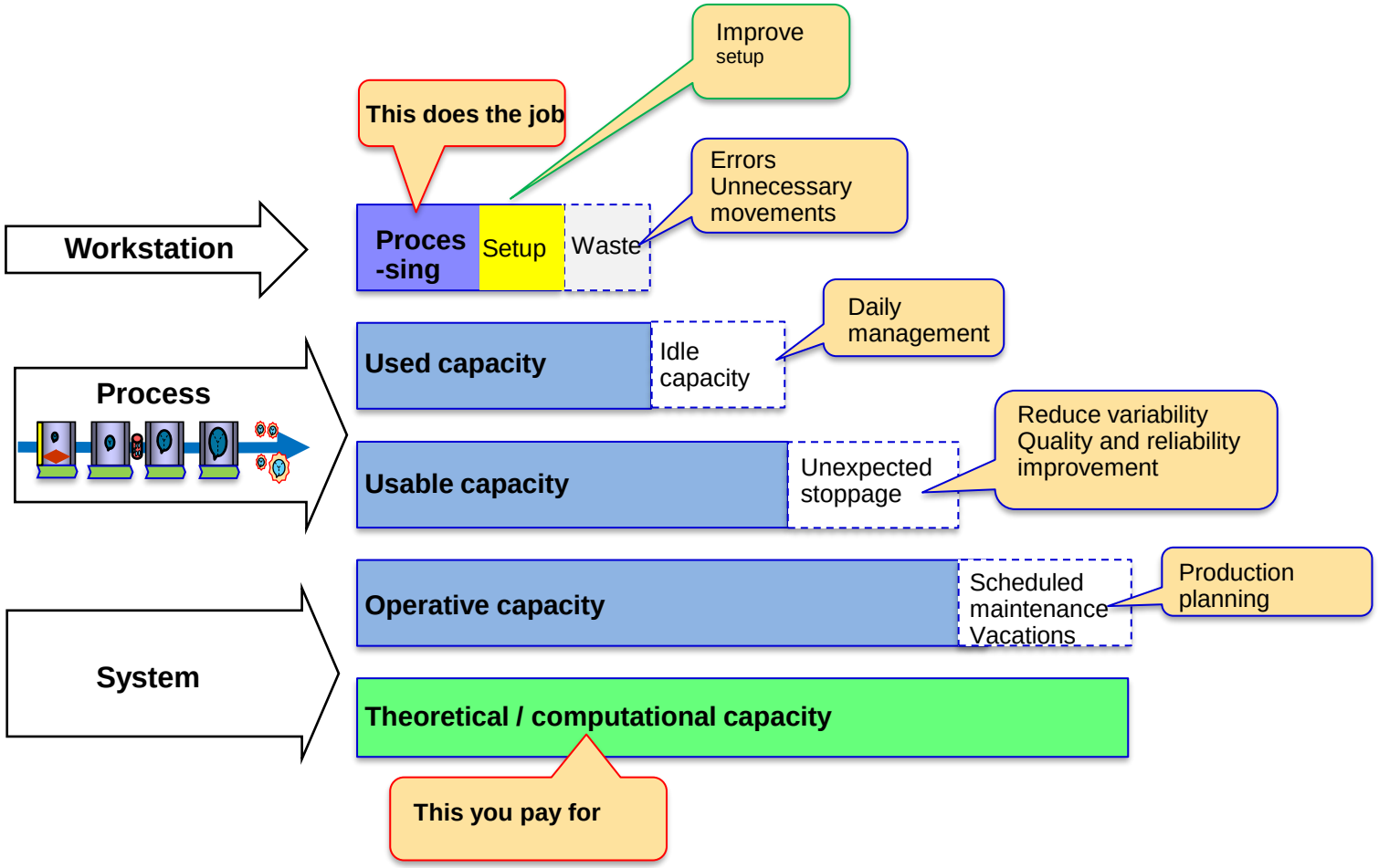
WT = VUT

WT= waiting time
V = variability component (arrival and process variability)
U = utilization rate
T = average effective proces time for one flow unit.

High variability is most damaging in situations with high utilization.

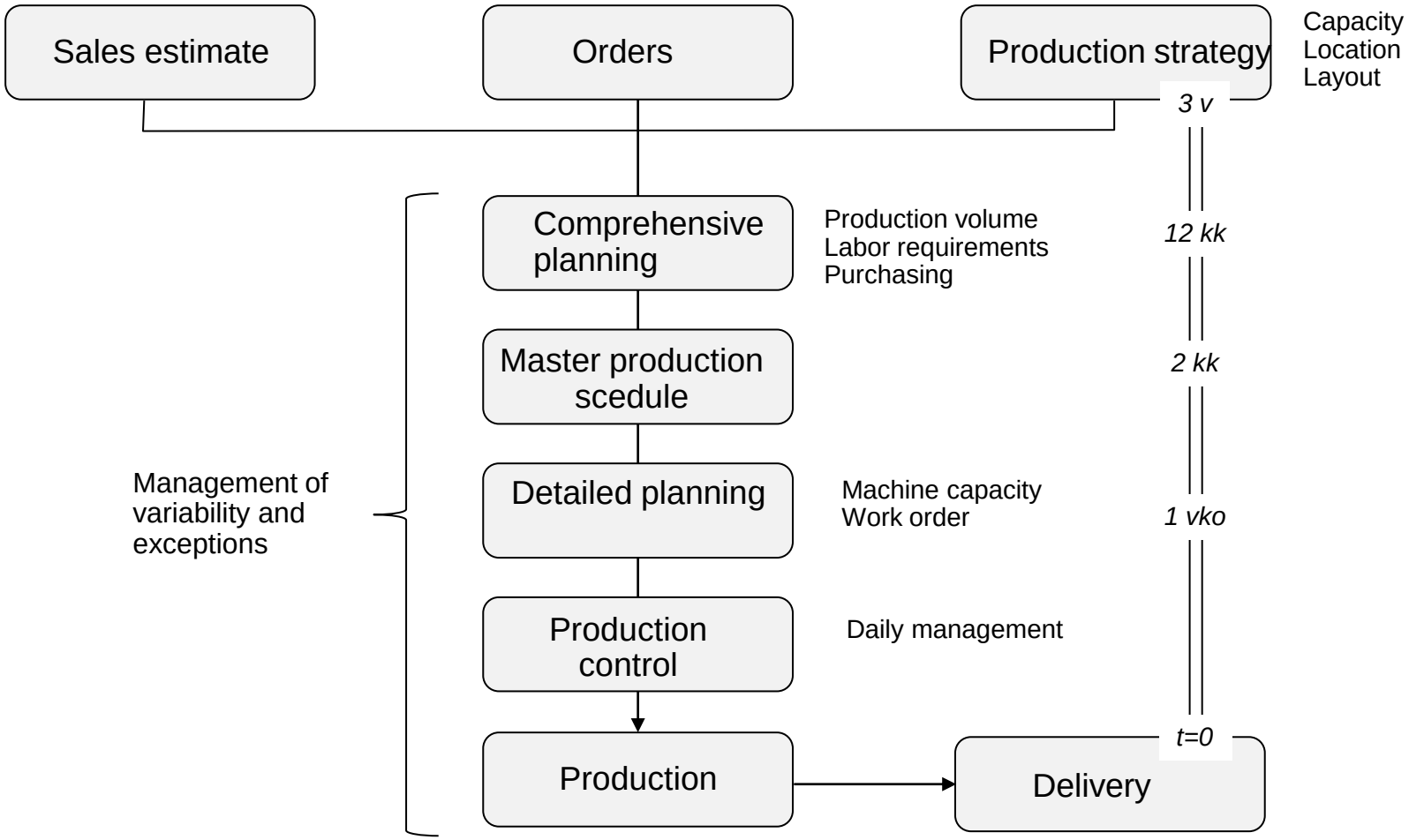


THE MANAGEMENT OF CAPACITY



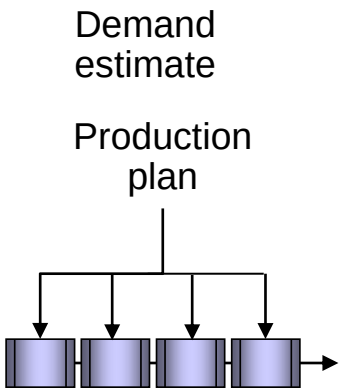
Demand is assumed to be constant

PRODUCTION PLANNING AND CONTROL

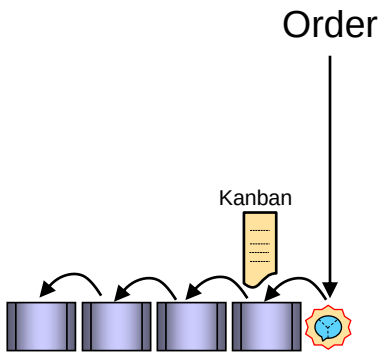


PUSH AND PULL

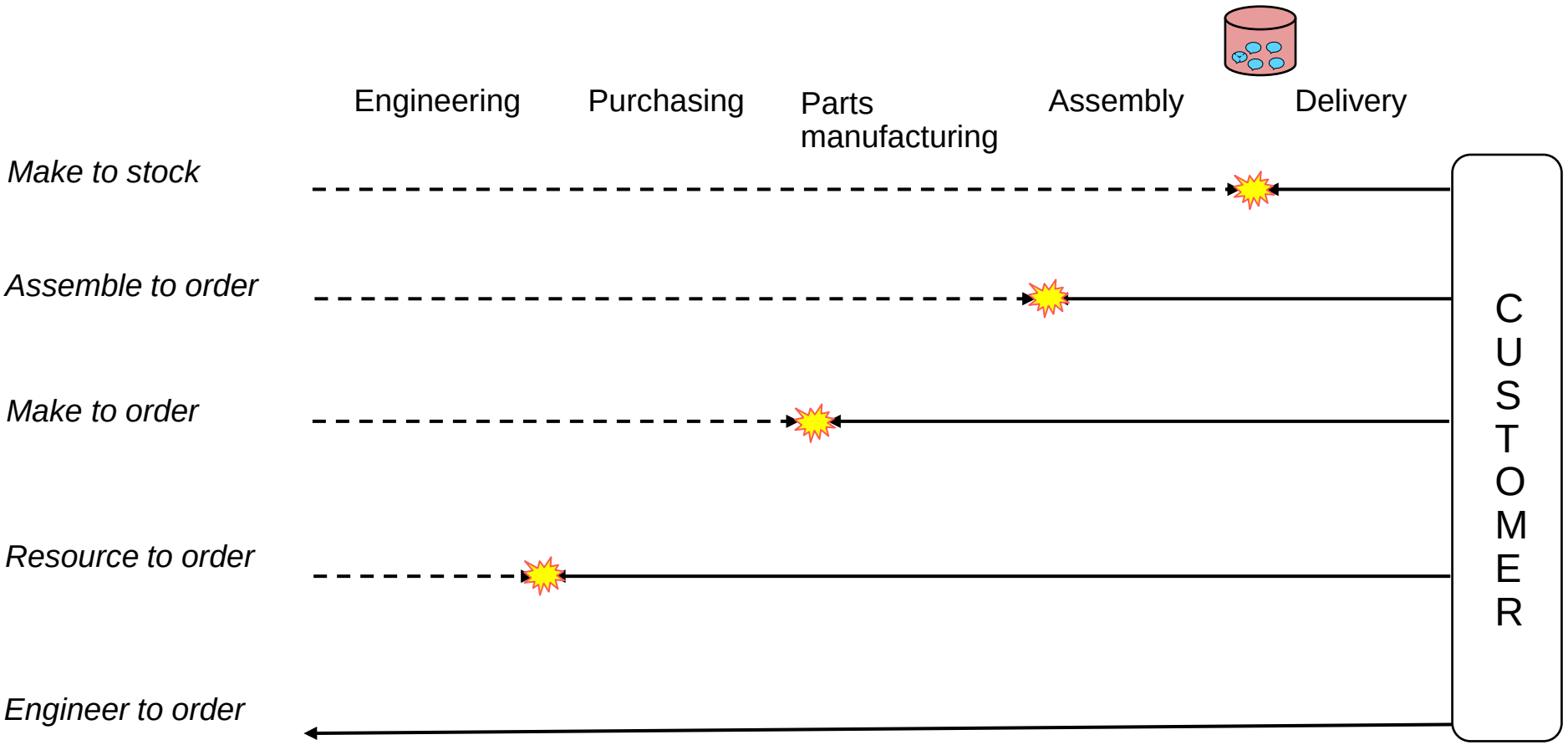
Push



Pull



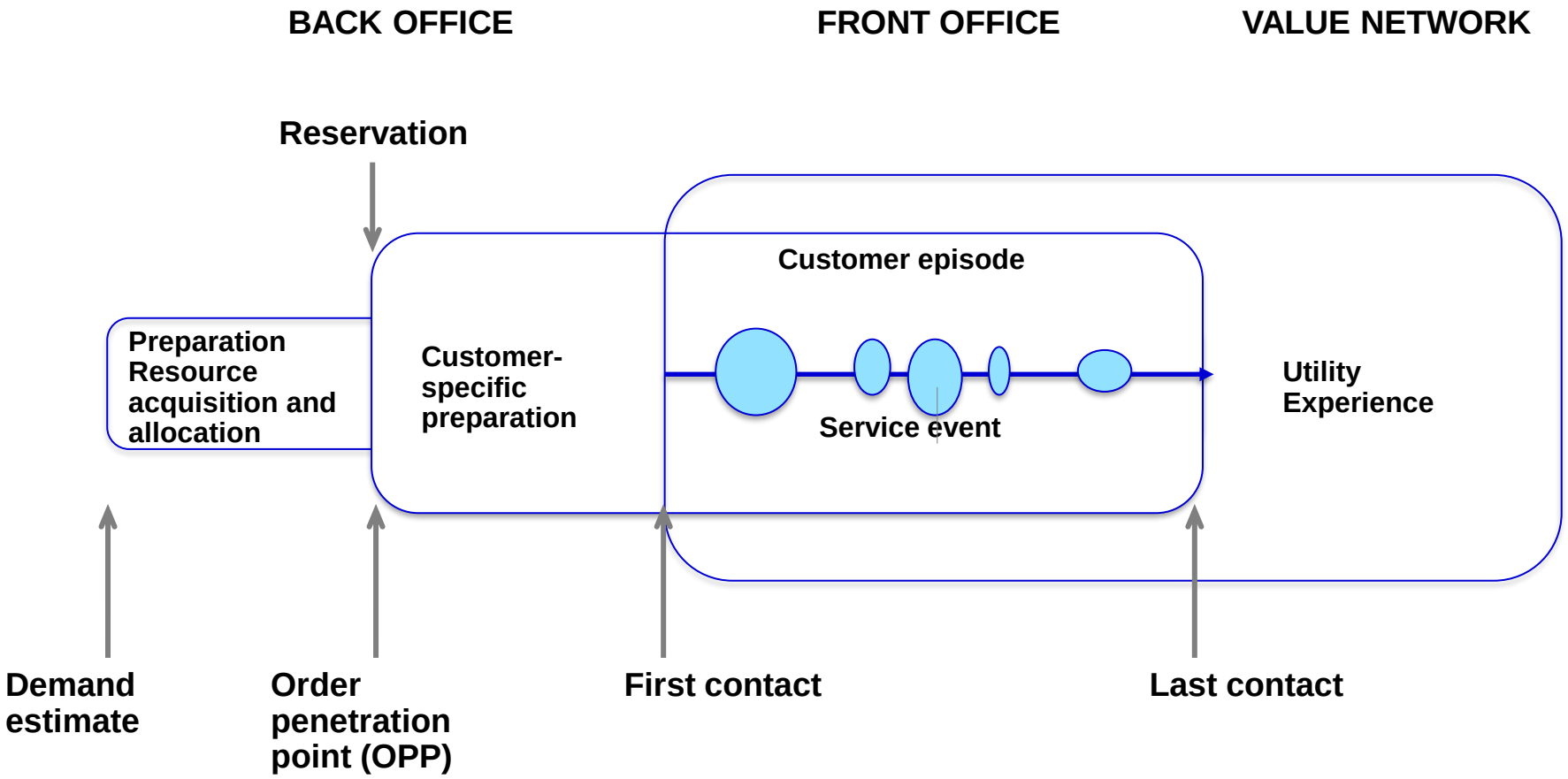
HOW CUSTOMER ORDER AND PRODUCTION MEET



= Order Penetration Point (OPP) the point in time when a specific customer order is attached to a specific flow unit – product.

= Activity based on demand estimate

THE FRONT OFFICE AND THE BACK OFFICE



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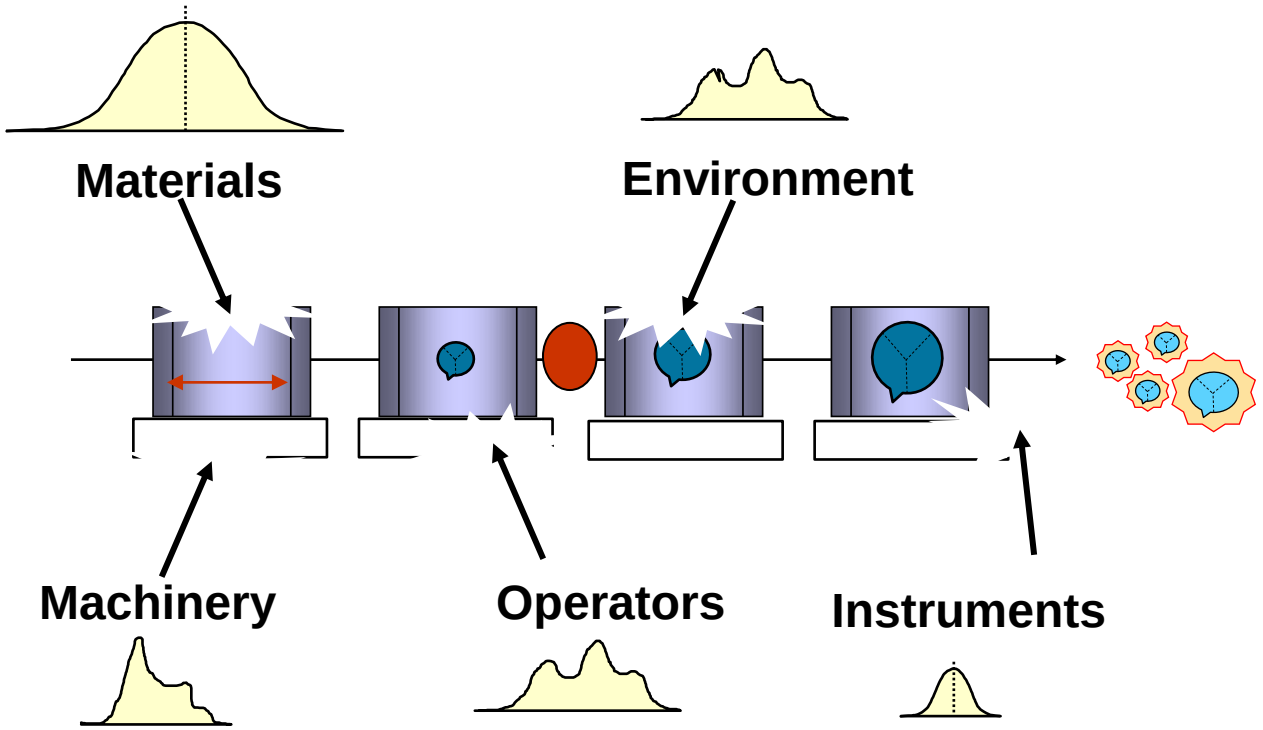
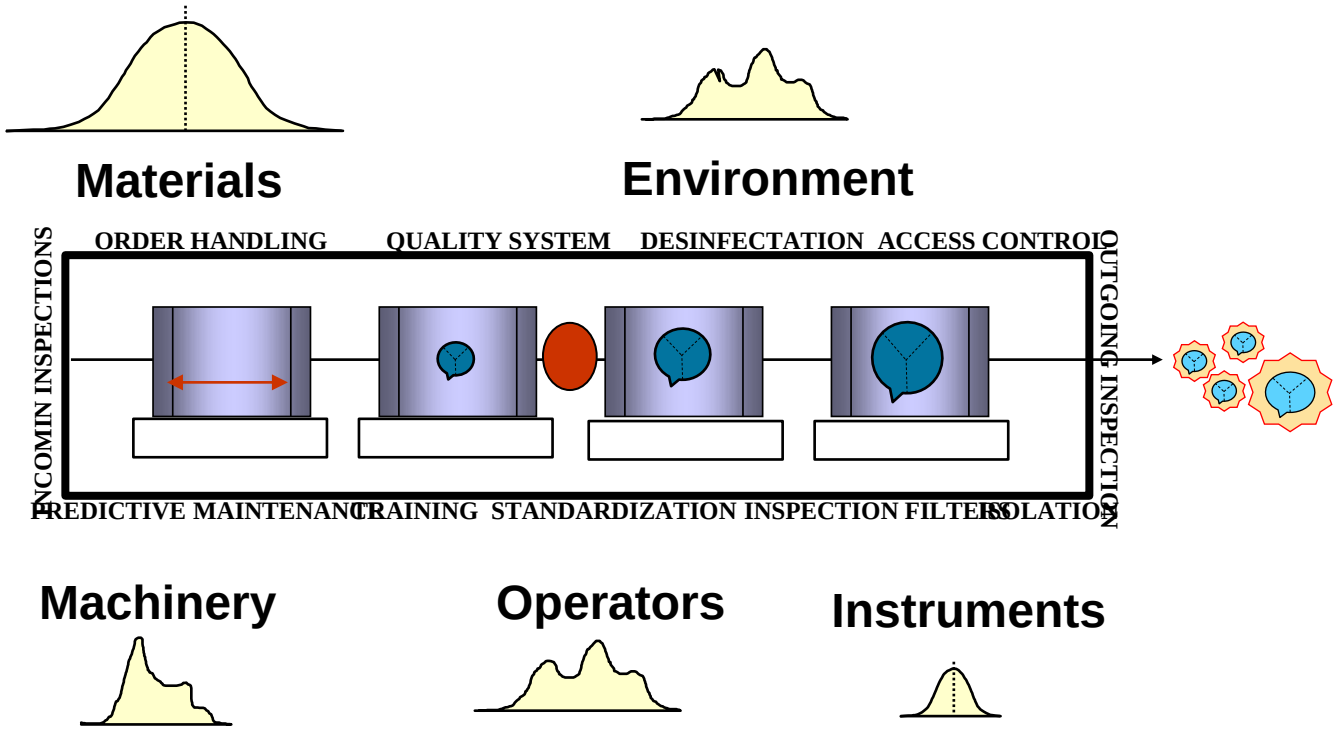
VARIABILITY HAMPERS PROCESSES



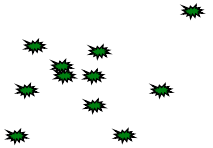
THE PROCESS IS PROTECTED FROM EXTERNAL DISTURBANCES



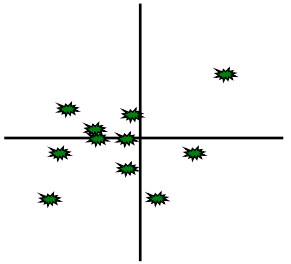
…REMAINS INTERNAL SOURCES OF VARIABILITY

VARIABILITY: SPREAD / CLUSTERING OF DATA

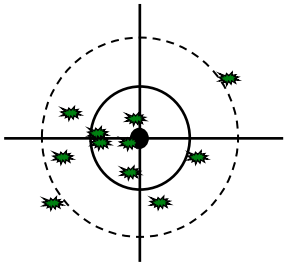
***Variance*: deviation**



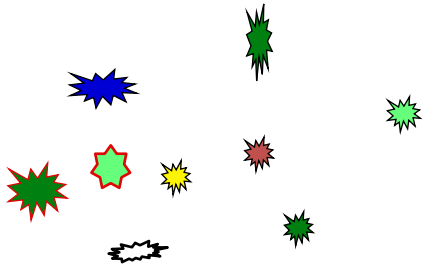
***Variation*: the spread in relation to a target…**



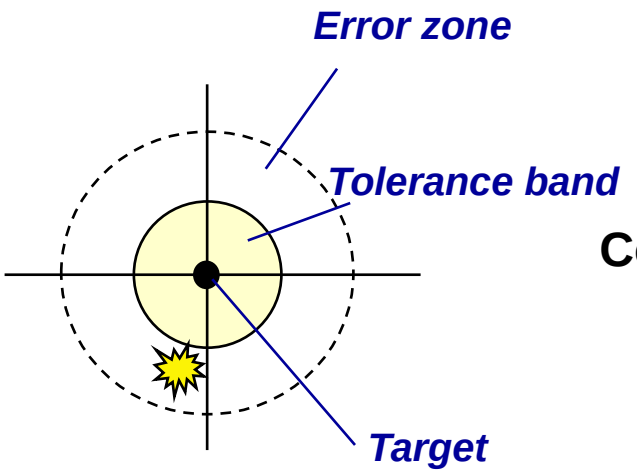
… and tolerances.

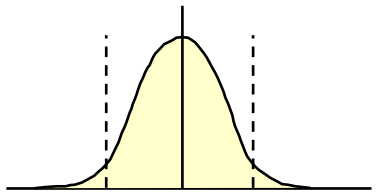


***Variety*: different types**



CAUSES OF VARIATION





Specific causes
- external source of variation
- uncontrolled
- time-location specific (ask why'?)
- can be found from time series analysis.

Common causes
- internal sources of variation
- capability under normal conditions
- random, probability distribution
- endemic to system architecture.

Errors due to specific and common causes often look similar. Can be identified by control charts that show behavior over time.

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QUALITY IS RELATIONS