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Process Analysis and Design

v2. Spring 2021

Learning goals

1. Understanding the concept of the production process map
2. Show how production processes are organised
3. Identify potential performance indicators - KPIs
4. Explain the trade-offs in designing/evaluating a production process

Process Analysis

- **Process:** part of an organisation that receives inputs and transforms them into outputsideally of greater value to the organization than the original inputs

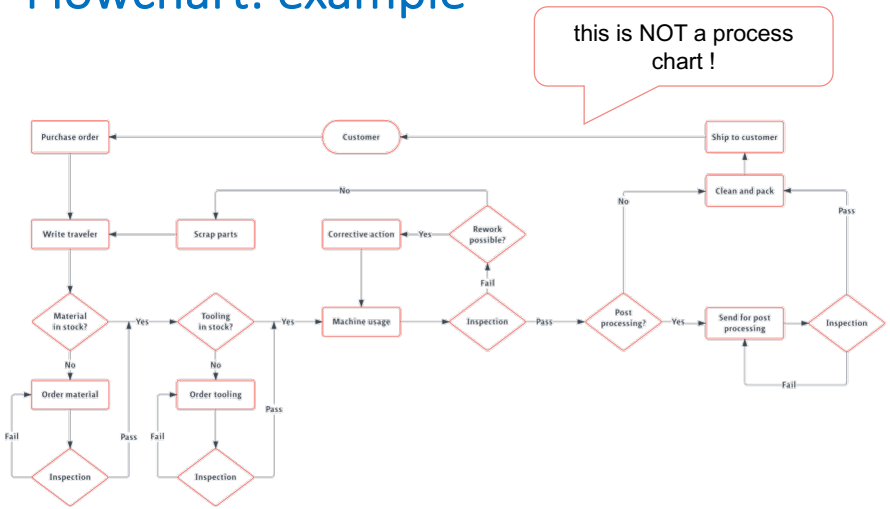
- Identifying potential performance indicators **- KPIs**
- **Cycle time:** average time between the completion of two successive units of output
- **Utilisation:** the ratio between the actual time a resource is used relative to the time that it is available for use

Process flow diagrams

- **Basic elements**
  - *task* or *operation*
  - *material flow*
  - *information flow*
  - *decision points*
  - *storage areas*
  - *Queues*

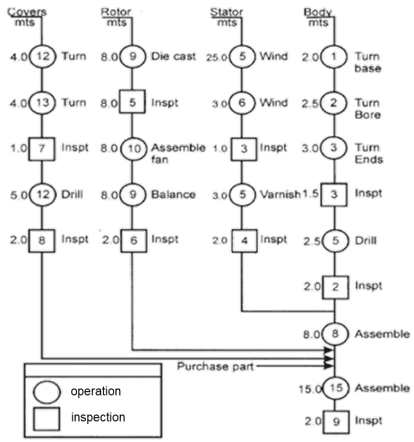
- **Objective: Identification of the bottleneck →**
  - phase that limits the capacity of the process

Flowchart: example



Callbacks: Operation Process Chart

- An operation process chart is a graphic representation of the sequence of all the operations taking place in a process (including inspections)
- It gives a bird's eye view of the overall activities

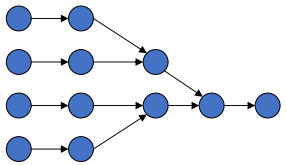


The figure shows operation process chart of a motor assembly unit

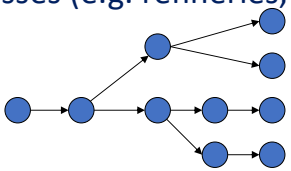
Callbacks: Processes classification

Single-line processes (e.g. cement production)

Synthetic Processes (e.g. assembly-lines)

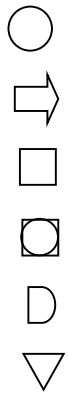


Analytical processes (e.g. refineries, petrochemical plants)



A.S.M.E. Symbology

American Society of Mechanical Engineers



Transformation (manufact./assembly)

Transport

Control

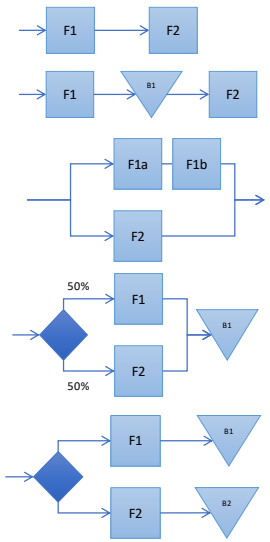
Transformation and control

Waiting

Warehousing

Multi-stage processes

1. Multi-stage process
2. Multi-stage processes with buffer
3. Simultaneous activities
4. Alternative processes
5. Divergent processes



Buffering, Blocking e Starving

- **Buffer**: A storage area between stages where the output of a stage is placed prior to being used in a downstream stage
- **Blocking**: The activities in the stage must stop because there is no place to deposit the item just completed
  - *Disturbances from dowstream*
- **Starving**: occurs when the activities in a stage must stop because there is no work
  - *Disturbance from upstream*

Stocks of materials

Purpose of the stocks

- To ensure independence between process steps
- To cope with changes in product demand
- To ensure flexibility of the production plan
- Safeguard against variations in delivery times
- Exploit the optimal purchase lot size

Safety Stock (SS)

The amount of inventory carried in addition to the expected demand

Digression….
"Make-to-Order vs Make-to-Stock"

Make-to-Order

- The process is only activated in response to an existing order
- A minimum stock is kept for both semi-finished and finished products

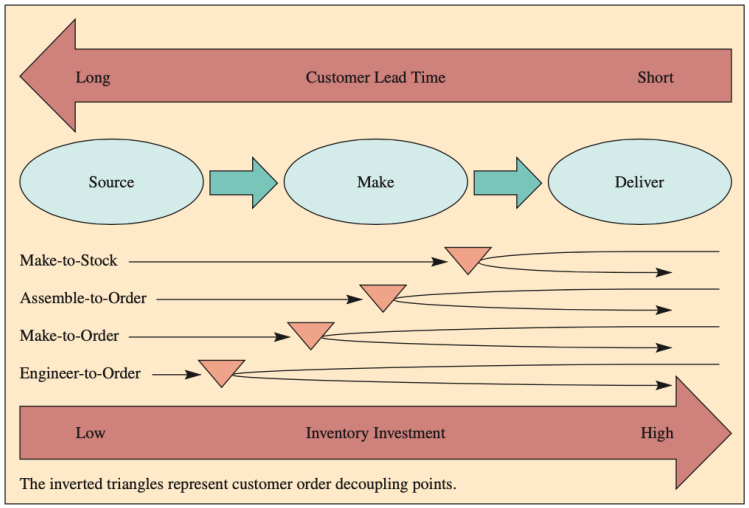
Make-to-Stock

- The process is activated to meet expected or forecast demand
- Customer orders for standard products are processed quickly from a pre-prepared stock.

Hybrid (es: **Assembly-to-Order**)

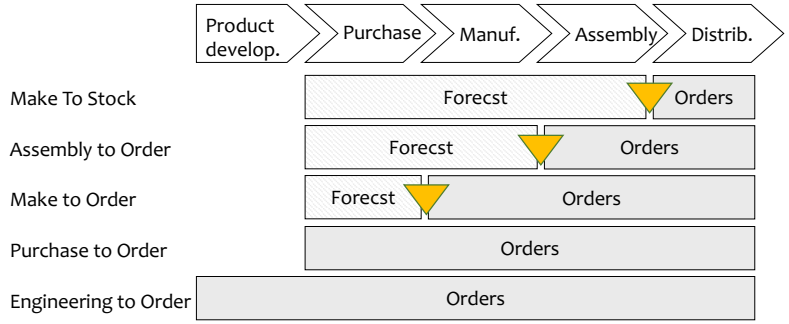
- Pre- assembled components, subassemblies, and modules (satisfying an expected or anticipated demand) are put together in response to a specific customer order

…. and stock positioning



Jacobs and Chase, Operation and Supply chain management, 2018

Demand forecasting and stock positioning



Does this mean that people working in ETOs or PTOs do not need to make forecasts?

Production Process Mapping

Run time

- Average time needed to produce a batch of parts

Set-up time

- Average time needed to prepare a process step for the production of an assigned product

Operation time

- Sum of tooling time and production time for a batch of parts

Production Process Mapping (2)

Lead Time (LT) *(Flow Time o Throughput Time)*

- Average time required for a product unit to go through the entire process
- The time needed to respond to a customer order

LT = [Actual processing time + waiting time in queues]

Throughput Rate

- Expected rate (long-term) at which the process generates a unit of output in a defined time horizon

Production Process Mapping (3)

Work-in-process WIP

- Value (or quantity) of stocks of material in process (and awaiting processing)

Average value of stocks

- Value of raw materials + WIP + value of stocks of finished goods

Inventory Turnover (value index)

- Ratio of cost of goods sold relative to the average stock value

Days-of-supply

- Average number of days a good remains in storage
- Corresponds to the expected number of days within which the company will be without the good if it is not replenished
- Inverse of stock rotation expressed in days

Little's Law

In the long run there is a stable relationship between production rate (*TR*), lead time (*FT*) and (*WIP*)

Under **stationary conditions** the relationship is

*WIP = Throughput Rate * Flow Time*

Process Flow Time Reduction

1. Perform activities in parallel

   Concurrent engineering

2. Change the sequence of activities

   Unnecessary transportation between stages

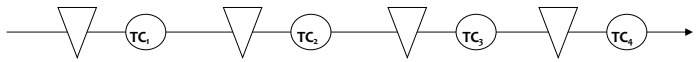
3. Reduce interruptions

Line cycle time and demand fulfilment

- Given a demand for orders to be fulfilled it must result:

$$TC_{LINE} \leq 1/TH \leq 1/demand$$

- The slowest workstation* determines the capacity of the line



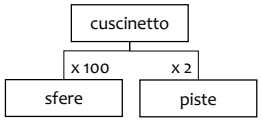
$$TC_{LINE} = Max_i(TC_i)$$

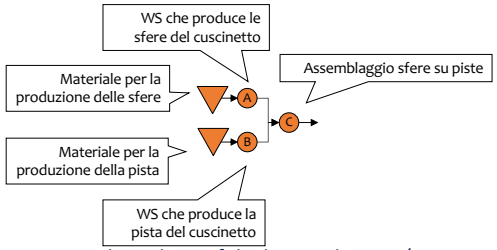
** The bottleneck station may not be the slowest if the process is not a simple line with a 1:1 transformation ratio!*

Why can the bottleneck not be the slowest station?

Example: production of ball bearings

- Bills Of Materials of the product:
- Process diagram





WS	TH	TC (Q/TH)	U
A	0,5 u/sec	100/0,5= 200 s	200/200 = 100%
B	1 u/min	2/(1/60)= 120 s	120/200 = 60%
C	2 u/min	1/(2/60)= 30 s	30/200 = 15%

- Maximum throughput of the line is 1 bearing/200 sec.
- The bottleneck is the station with the highest U

Exercise 1 – Sandwich and ….

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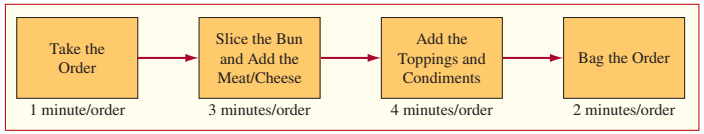

Hp: working day 8 [h/day]

a) What is the maximum output of the process?

b) If we were to add a resource, in which phase should it be placed and what would be the benefits?

c) Would it be useful to transfer one minute of work from the 2nd to the 1st step of the process?

Exercise 1

TC1= 1 [min], TC2= 3 [min], TC3= 4 [min], TC4= 2 [min]

TC= maxTCi= 4 [min]

FT= 10 [min]

TR= 1 [u] / 4[min]= 0.25 [u/min] = 15 [u/h]

WIP= TR*FT= 0.25*10= 2.5 [u]

a) What is the maximum output of the process?

T = 8 [h/giorno]

Max Prod= TR*T= 15*8= 120 [u/giorno]

Exercise 1

A

Operazione	Output
Prendere ordinazioni	(60 min. all'ora /1 min. per ordine) × 8 ore = 480 sandwich/dì
Pane e formaggio	(60 min. all'ora /3 min. per ordine) × 8 ore = 160 sandwich/dì
Guarnizioni/condimenti	**(60 min. all'ora /4 min. per ordine) × 8 ore = 120 sandwich/dì**
Sandwich in busta	(60 min. all'ora /2 min. per ordine) × 8 ore = 240 sandwich/dì

B

Operazione	Output
Prendere ordinazioni	480 sandwich/dì
Pane e formaggio	**160 sandwich/dì**
Guarnizioni/condimenti	2 × 120 = 240 sandwich/dì
Sandwich in busta	240 sandwich/dì

TR= 20 [u/h]
WIP= ?

C

Operazione	Output
Prendere ordinazioni	(60 min. all'ora /2 min. per ordine) × 8 ore = 240 sandwich/dì
Pane e formaggio	(60 min. all'ora /2 min. per ordine) × 8 ore = 240 sandwich/dì
Guarnizioni/condimenti	**(60 min. all'ora /4 min. per ordine) × 8 ore = 120 sandwich/dì**
Sandwich in busta	(60 min. all'ora /2 min. per ordine) × 8 ore = 240 sandwich/dì

Exercise 2

An automobile company assembles cars in a plant and purchases batteries from a vendor in China.

The average cost of each battery is $50. The automobile company takes ownership of the batteries when they arrive at the plant.

It takes exactly 10 hours to make a car in the plant and the plant assembles 200 cars per 8-hour shift (currently the plant operates one shift per day). Each car uses one battery.

The company holds, on average, 8000 batteries in raw material inventory at the plant as a buffer.

- Find the total number of batteries in the plant.
- How much are these batteries worth?
- How many days of supply are held in raw material inventory, on average?