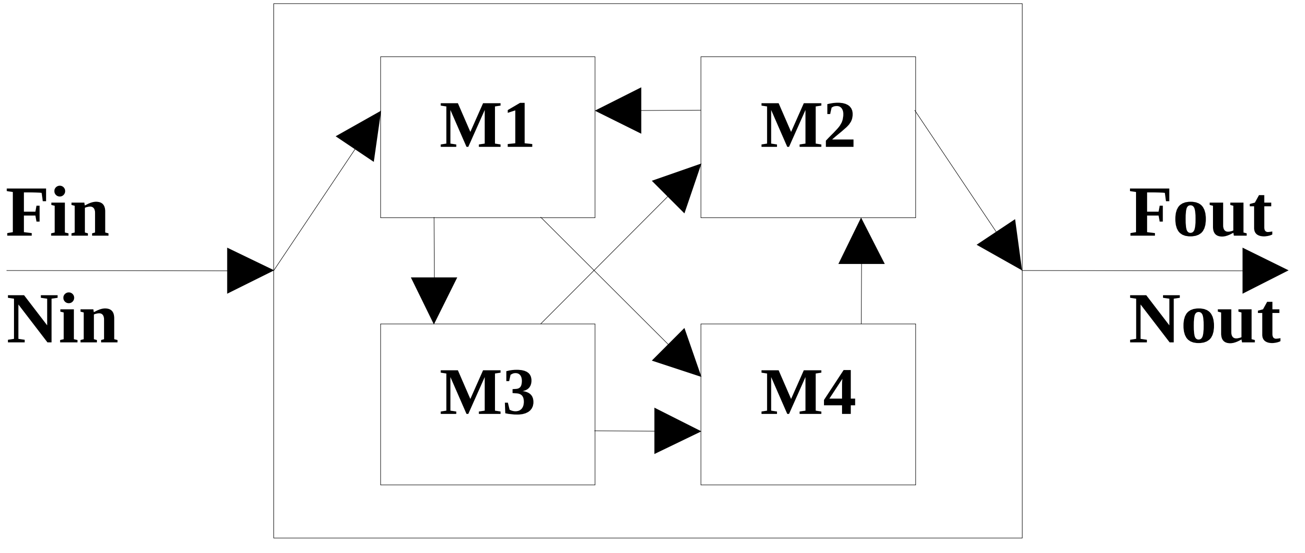
Throughput diagrams

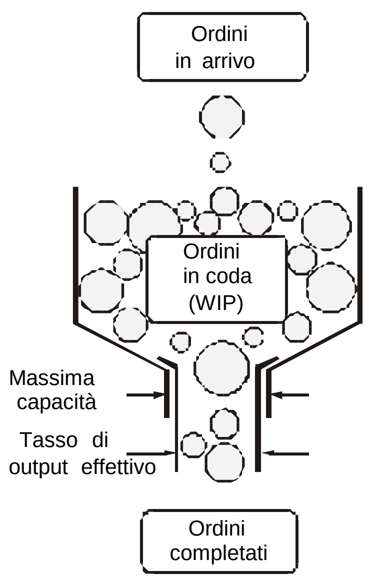
Given a production system

- Fin, Fout input/output frequency (rate) (pcs/d)
- Nin, Nout input/output number of pieces starting from t = 0 (pcs)

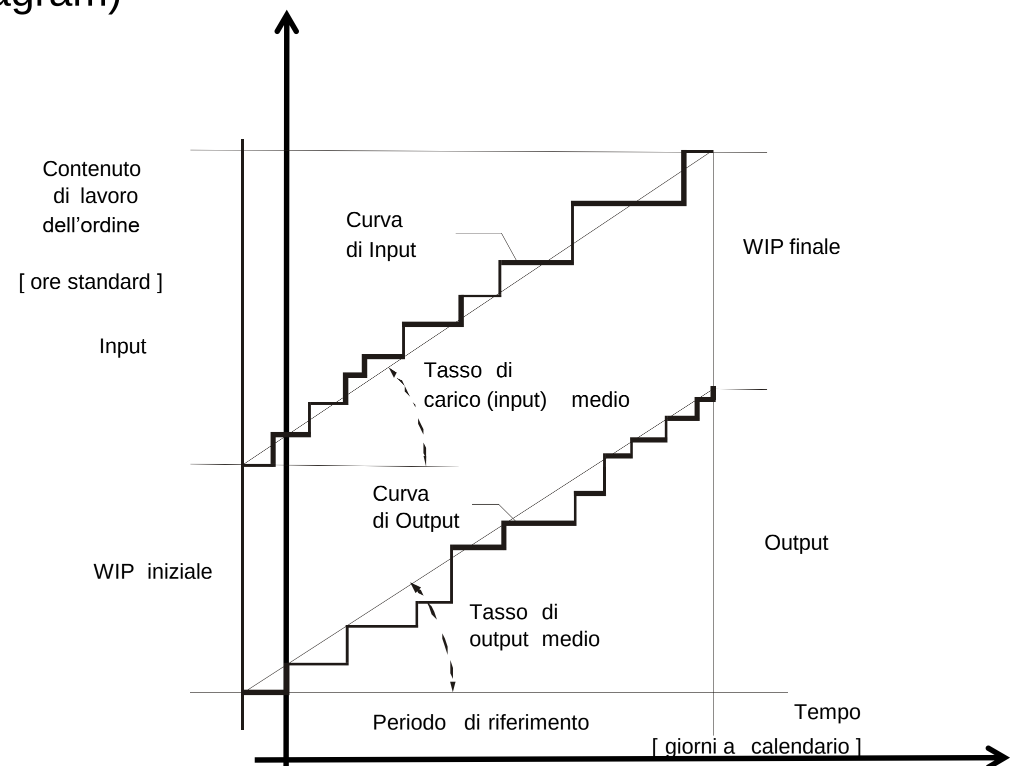


Funnel Model

The *throughput* diagram is a model used to monitor the process in the *funnel* (production system) ⇒ starting from the funnel events (arrivals, exit) it is possible to build up a *throughput* diagram per area (input/output diagram)

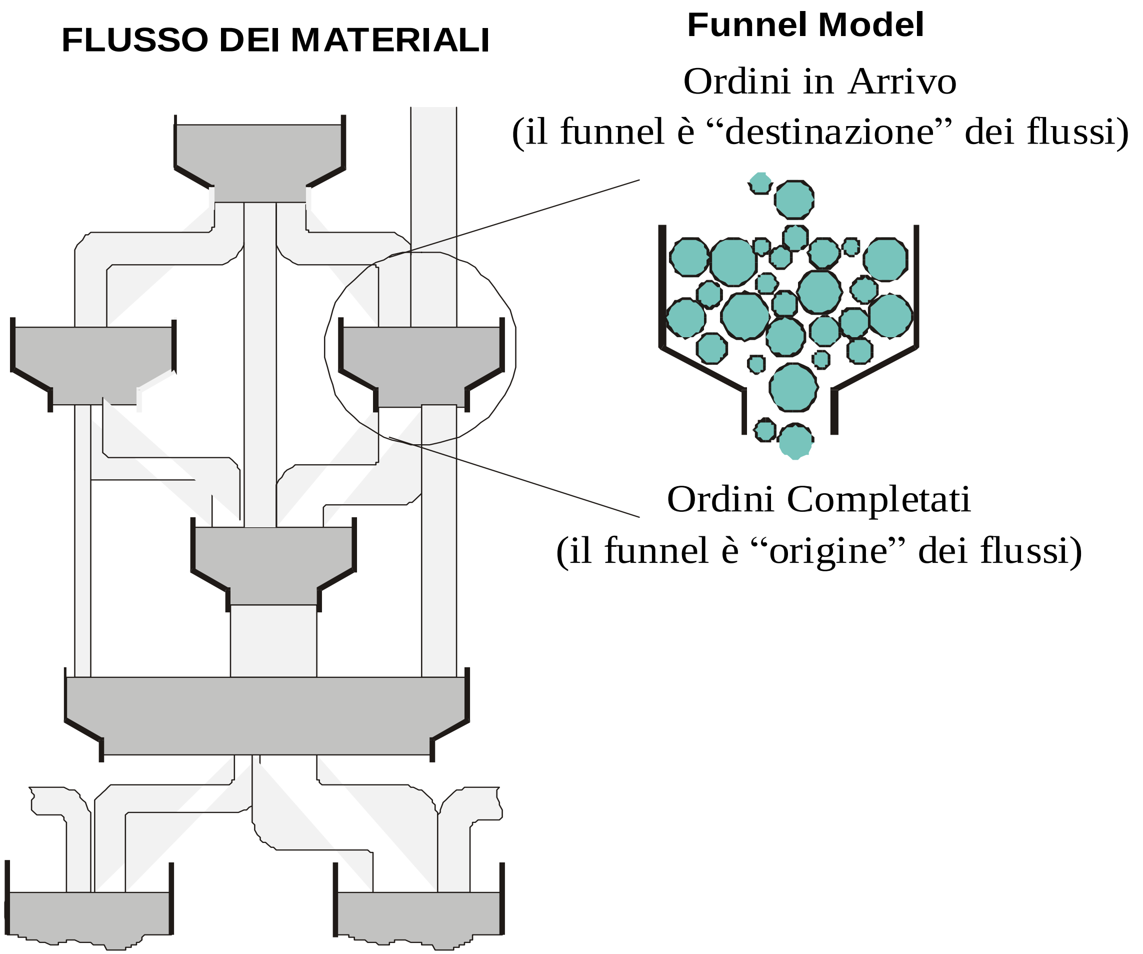


Funnel model



Throughput (input/output) diagram

Funnel Model



Input/output diagram

- Hp: production system with steady load (Fin = constant)
- On that condition, the trend of number of parts in input Nin is linear
  - If the bottleneck is not saturated (Fin < THmax), the number of pieces in output from the system Nout will have the same trend shifted to the right.

Input/output diagram

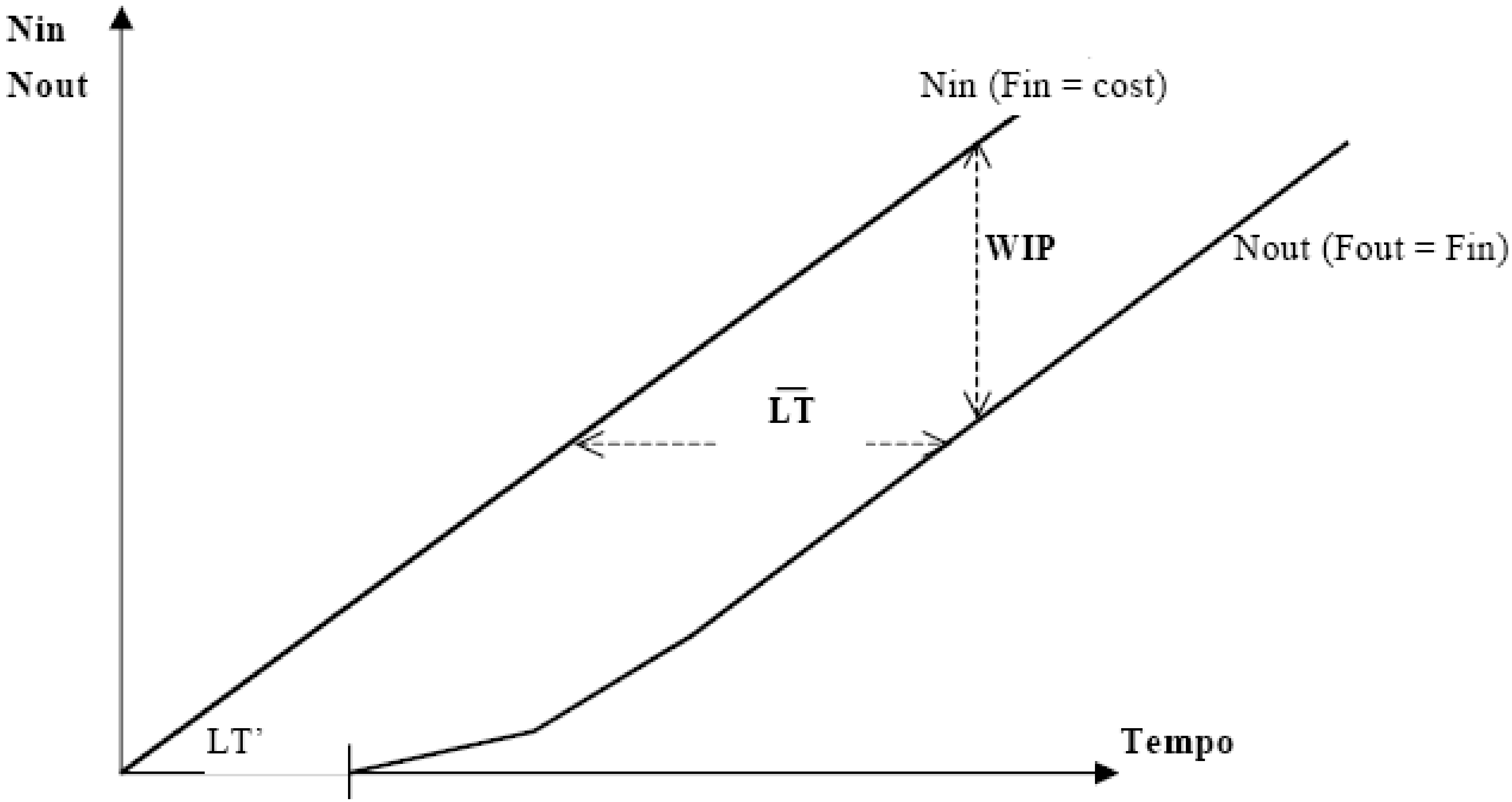
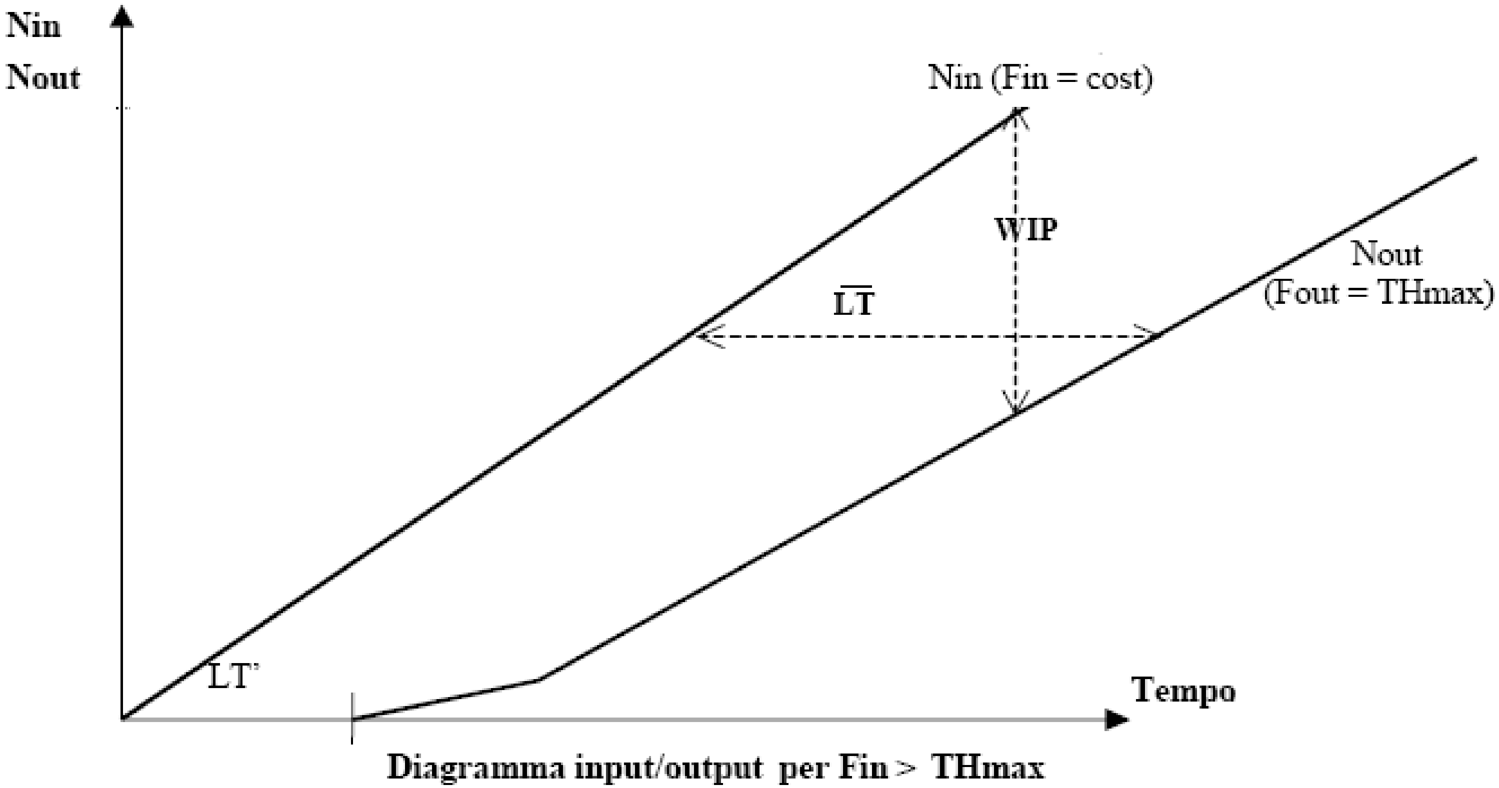


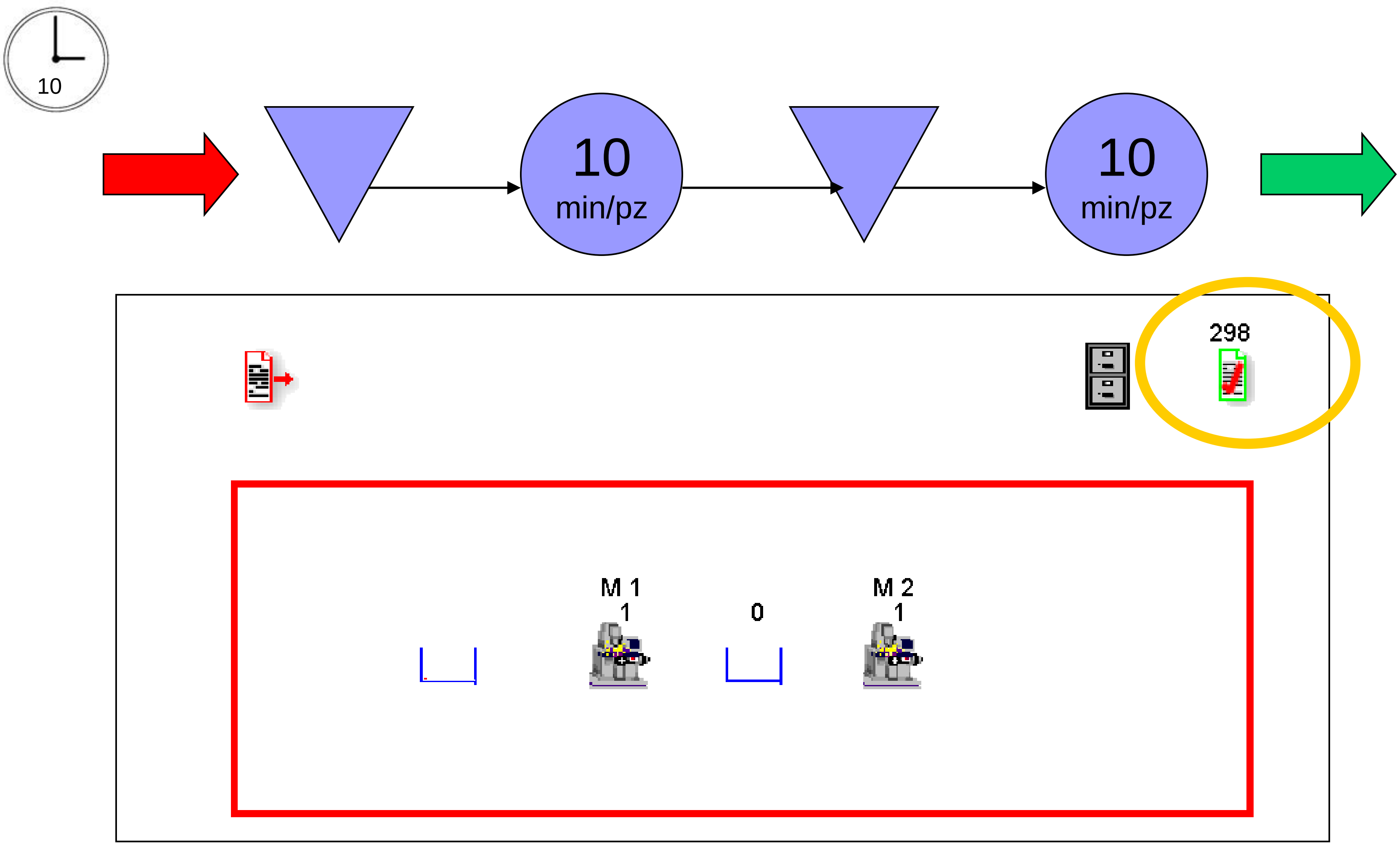
Diagramma input/output per Fin < THmax

Input/output diagram

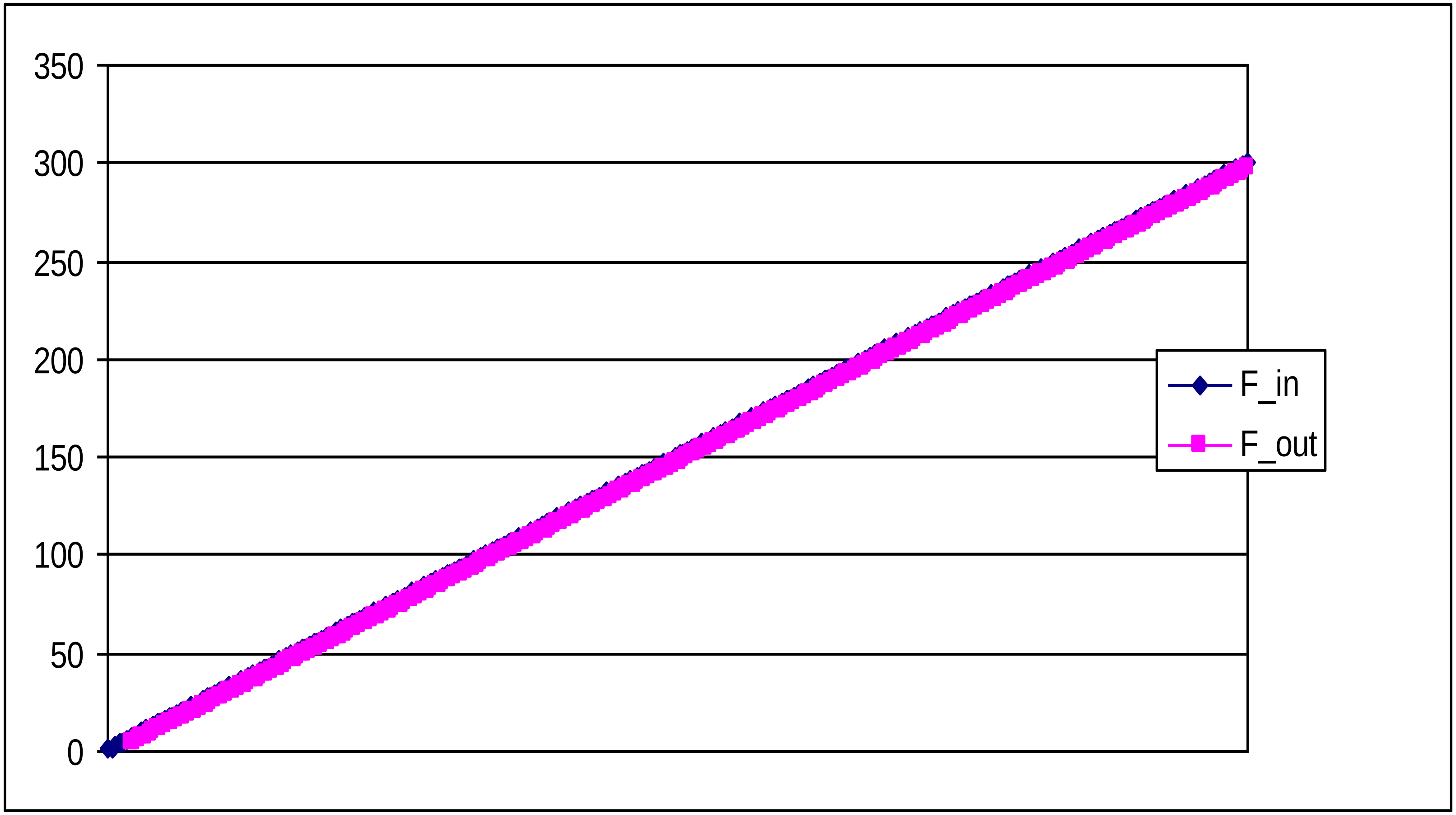
- When Fin is over THmax (THcb), the number of parts in input cannot be worked and, for that reason, WIP and LT will increase



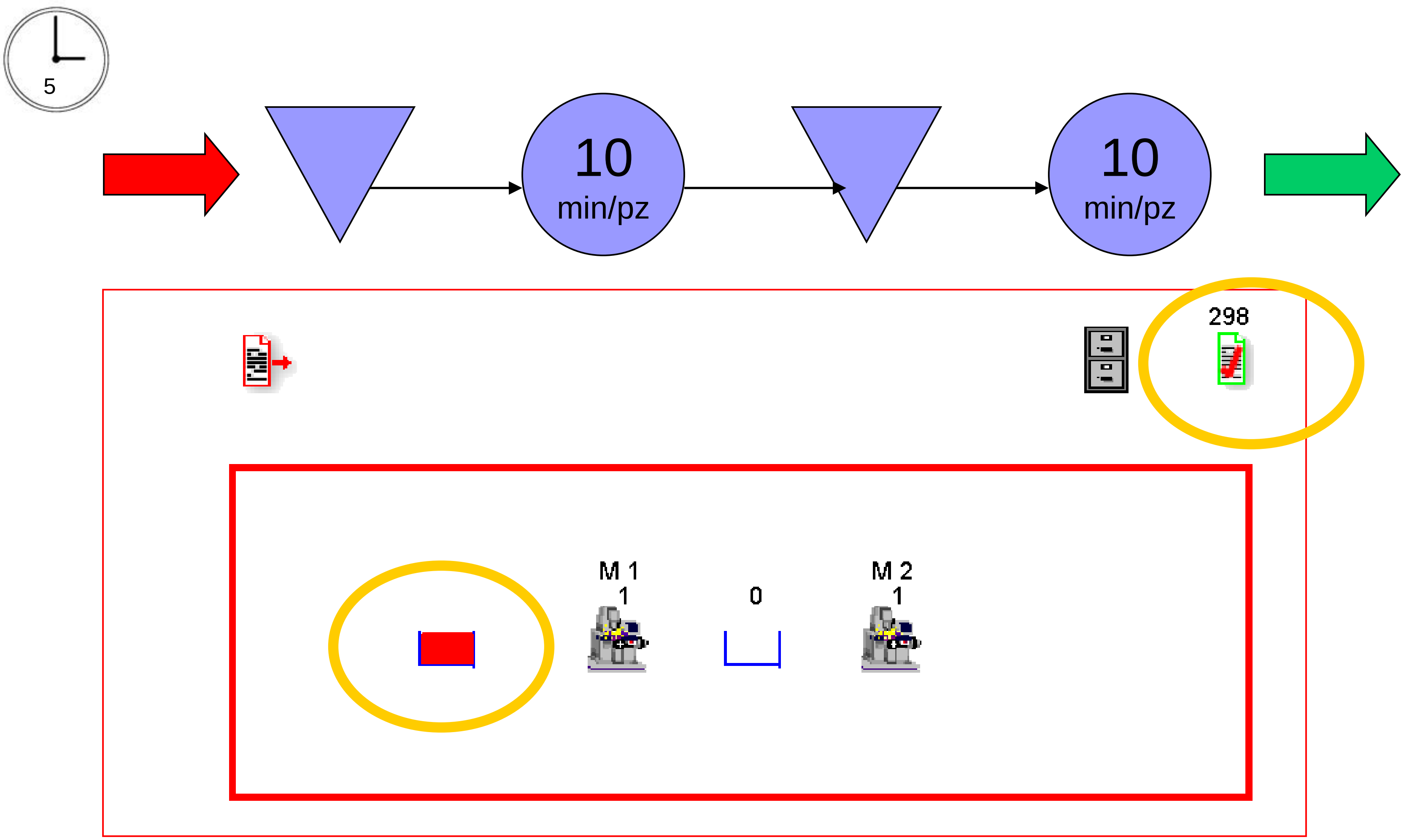
Input/output diagram



Input/output diagram



Input/output diagram



Input/output diagram

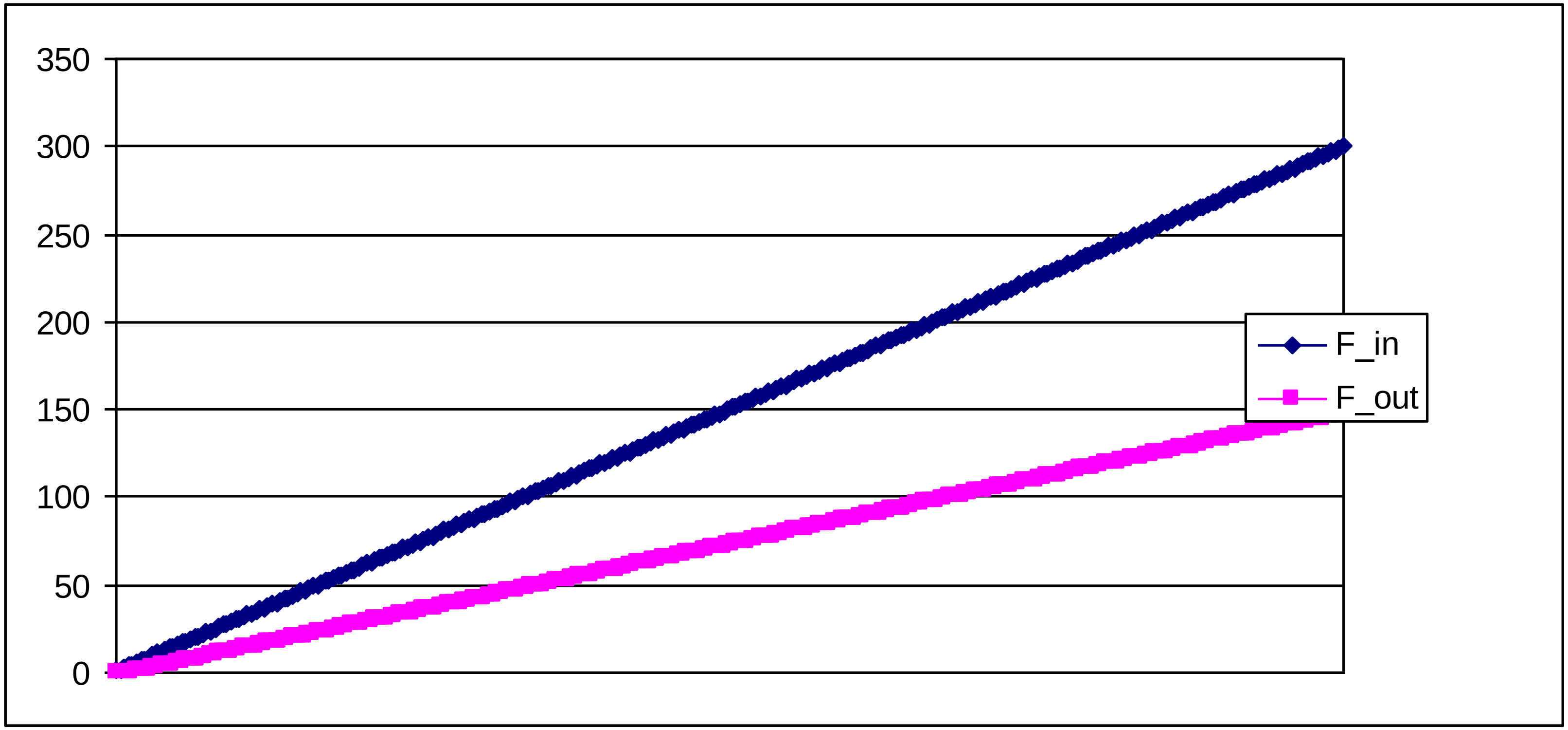


Diagram in a real situation

Data collection from production data feedback registry

Order number	Work content TO [hour/order]	Data input [calendar day]	Data output [calendar day]
1	20	98	100
2	21	94	102
3	19	101	103
4	23	101	105
5	11	102	106

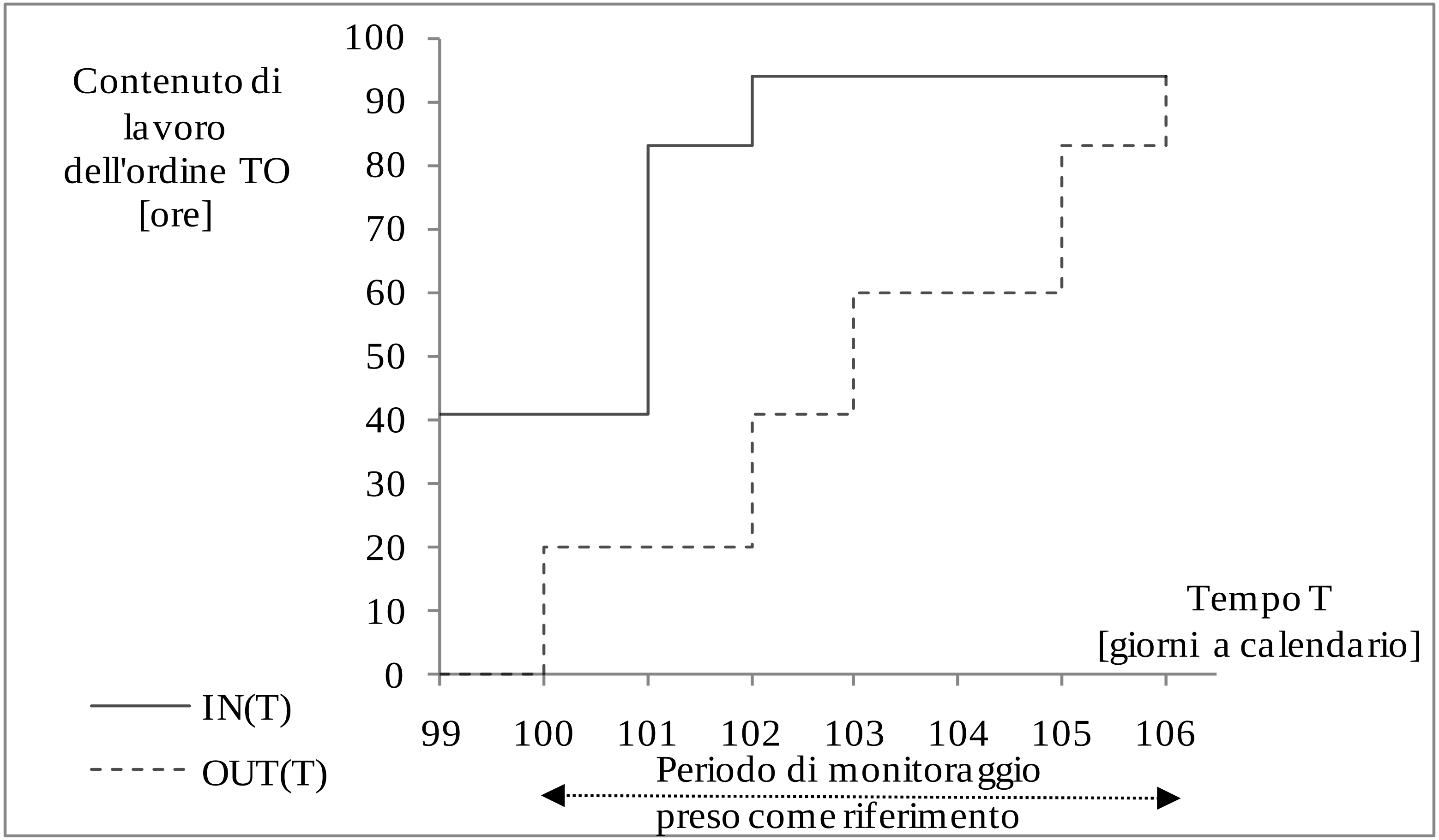
Work content of the orders

- Order work content (TO) is the sum of set up time and work time (or processing time) of the parts within a production batch

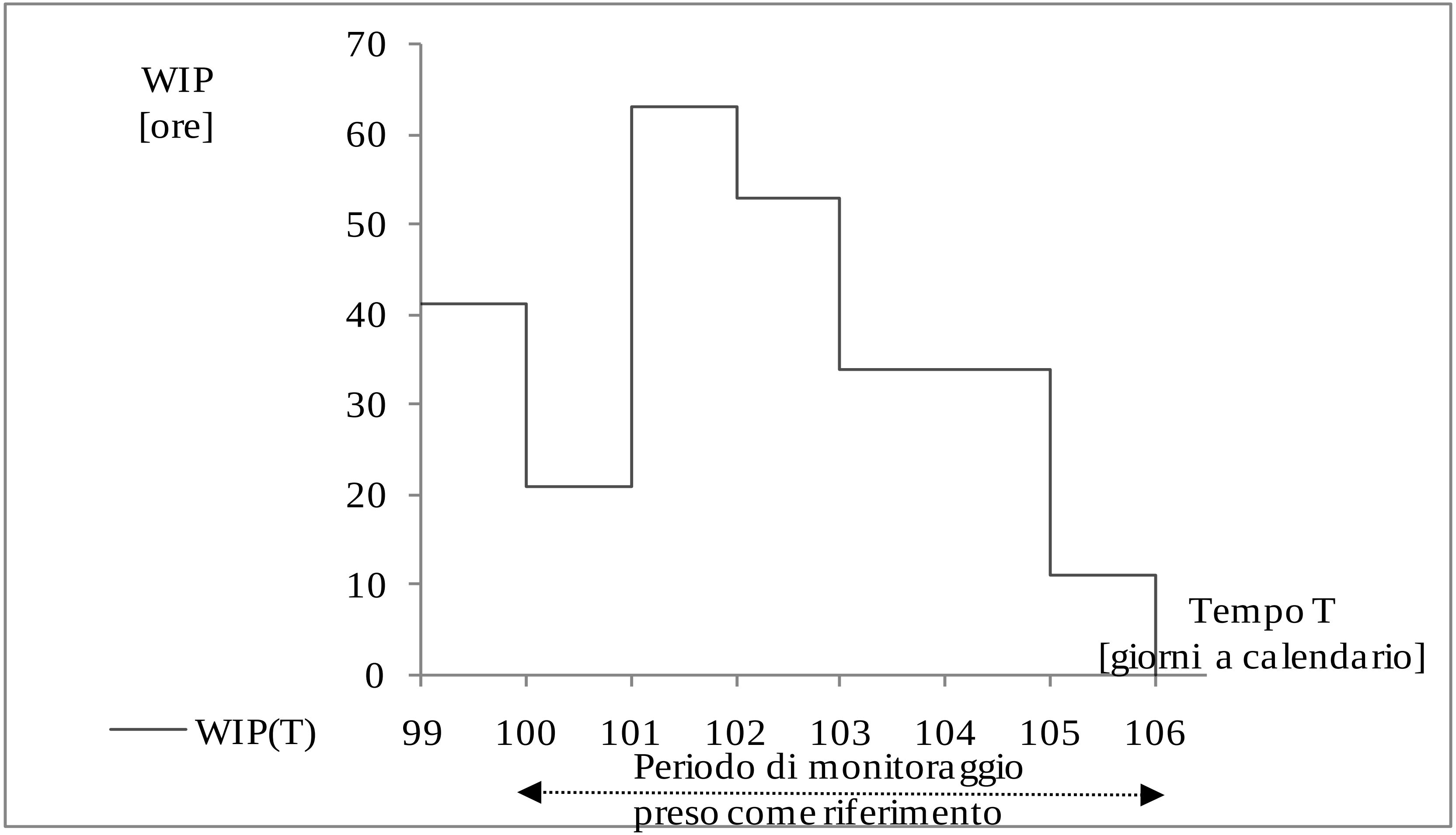
$$TO = \frac{TS + LS \times TP}{60}$$

- Where
  - TO work content of the order [hour / order]
  - TS standard setup time [min / order]
  - LS standard batch dimension [# parts / order]
  - TP standard processing time of a single piece [min / part]

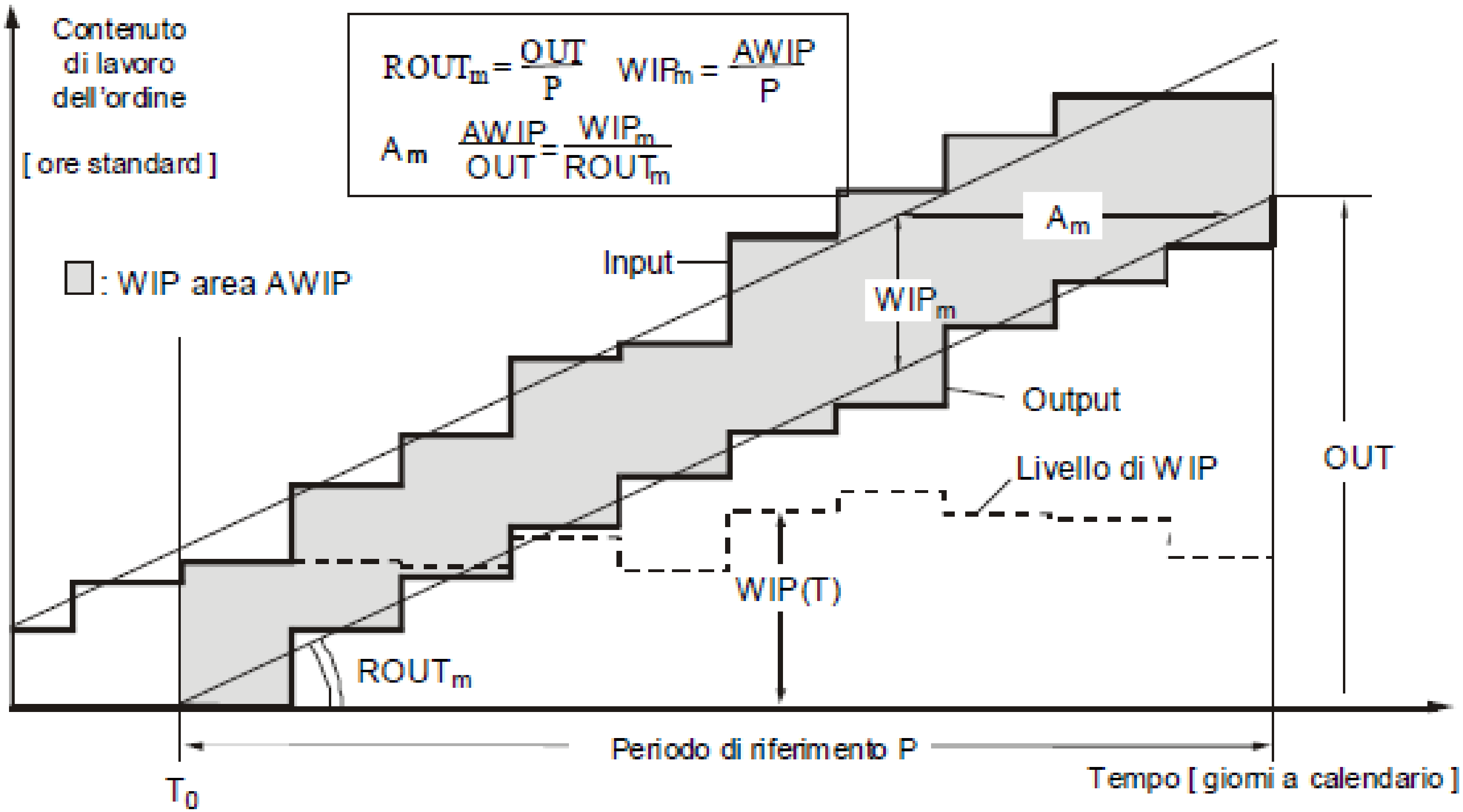
Input/output curves



WIP level curve



Performance indicators



ROUTm Tasso output medio WIPm Livello WIP medio Am Autonomia media

Performance indicators

- Vertical distance

$$WIP(T) = IN(T) - OUT(T)$$

  - WIP(T)   WIP level at time T
  - IN(T)   Sum of work content orders arrived in the system before time T
  - OUT(T)   Sum of work content orders completed by the system before time T

Performance indicators

- Mean vertical distance

$$WIP_m = \frac{\int_{T_0}^{T_1} IN(T) \times dt - \int_{T_0}^{T_1} OUT(T) \times dt}{T_1 - T_0}$$

  - WIPm Mean level of WIP [hour]
  - T0 start of monitoring period [SCD – Stock Calendar Days]
  - T1 end of monitoring period [SCD]

Performance indicators

- Mean rate of Output curve (ROUTm)
  - ROUTm   mean output rate [SCD]
  - TOj   work content of order j [hour/order]
  - nout   number of orders completed within monitoring period
  - P   length of monitoring period [SCD]

$$ROUT_m = \frac{\sum_{j=1}^{n_{out}} TO_j}{P}$$

  - RINm rate is defined in the same way, using the number of incoming orders nin within monitoring period

Performance indicators

- The higher RINm, the greater the number of hours requested, in terms of production capacity, from the orders in input within the monitoring period
- The higher ROUTm, the greater the available production capacity to complete the orders arrived within monitoring period

- A stable system has ROUTm $\cong$ RINm

Performance indicators

- Mean horizontal distance
  - Operative autonomy Am is a measure of the time (calendar time) after which, in absence of incoming orders, the station becames empty

$$A_m = \frac{WIP_m}{ROUT_m}$$

  - Am Mean operative autonomy [SCD]
  - WIPm Mean level of WIP [hours]
  - ROUTm Mean output rate [hours / SCD]

Performance indicators

- Mean use of production capacity measures how much production capacity (ROUTm) is used given the maximum production capacity (ROUTmax)

$$UT_m = \frac{ROUT_m}{ROUT_{\max}} \times 100$$

  - UTm   Mean use of production capacity
  - ROUTmax = Maximum (standard) production capacity available in a station
- UTm measures the percentace of inefficiencies (leaks) related to internal and external causes
- 1-UTm is the mean leak

Use of diagram

- The analysis of throughput diagram helps to check the existence of production capacity leaks.
- This leaks can be caused by:
  - “**Internal**” **causes**
  - “**External**” **causes**

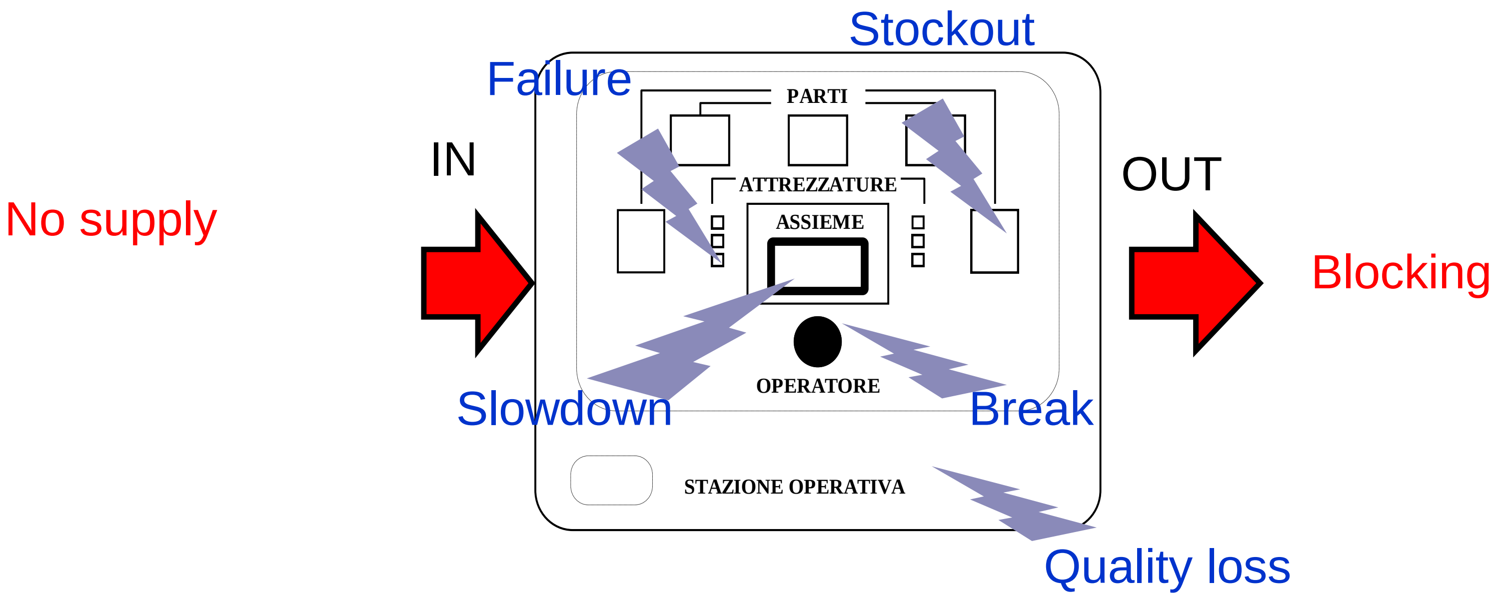


Diagram uses

- Leaks are characterized by
  - **Causes**: Events within production area (es. failures, breaks, operators unavailability)
  - **Symptoms**: Decrease of ROUTm without RINm reduction
- “Internal” leaks can depend on performances of external support processes
  - E.g. no supply
    - Symptom: reduction of RINm
  - E.g. the next station/area does not consume correctly the material produced by this station/area and, for that reason, the interoperational buffer is filled (blocking)
    - Sympton: reduction of ROUTm

Diagram uses

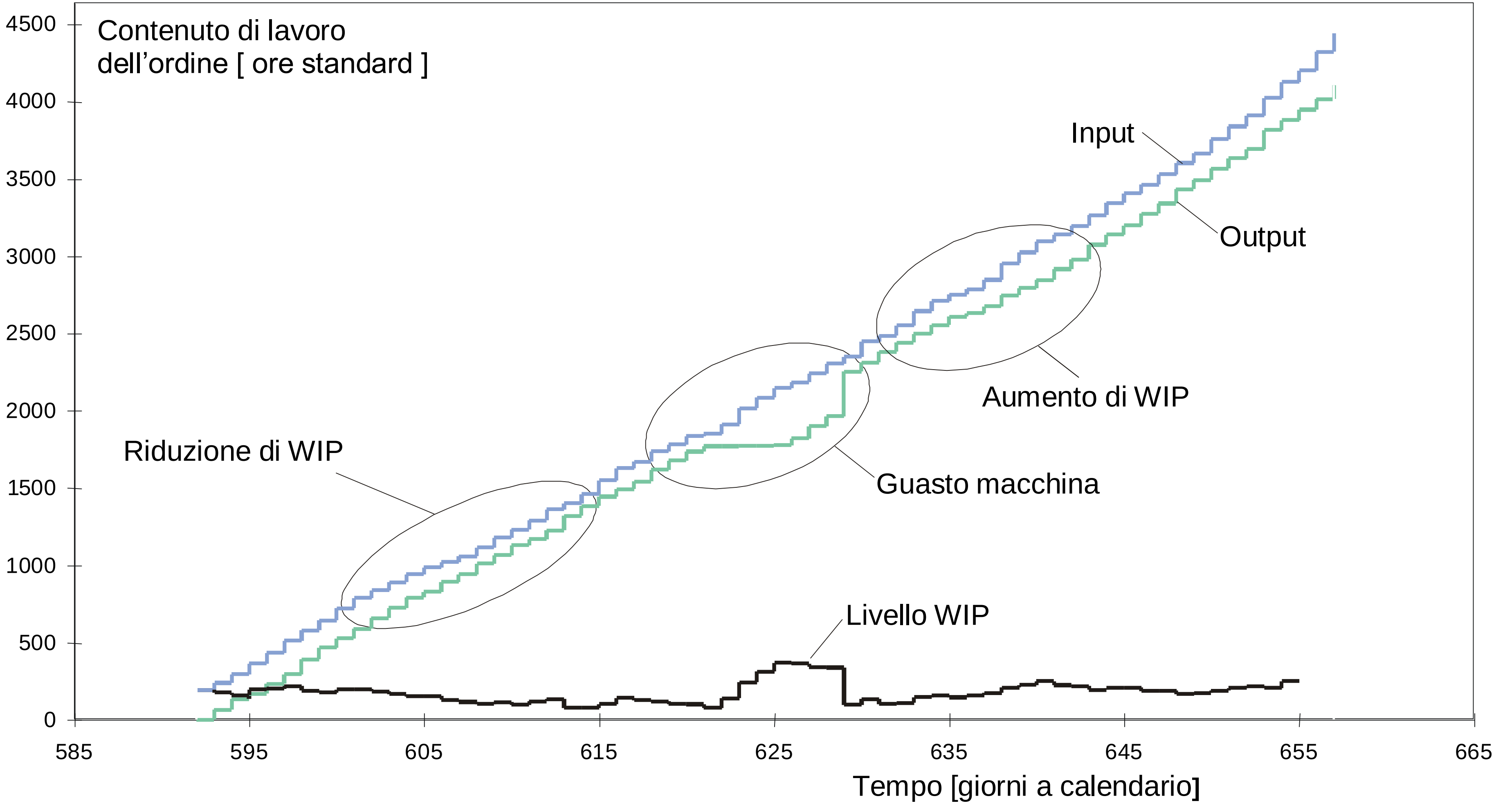
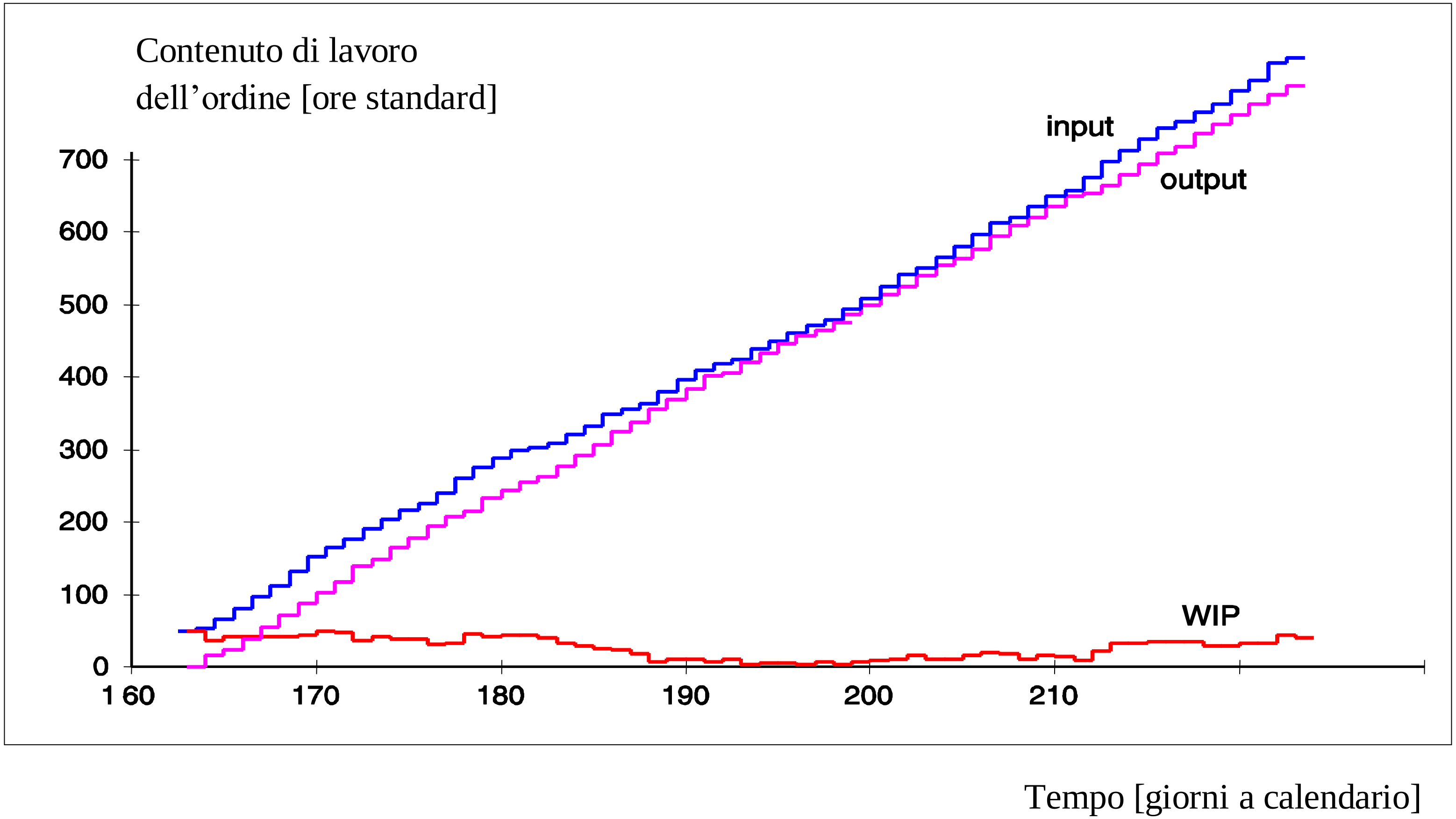
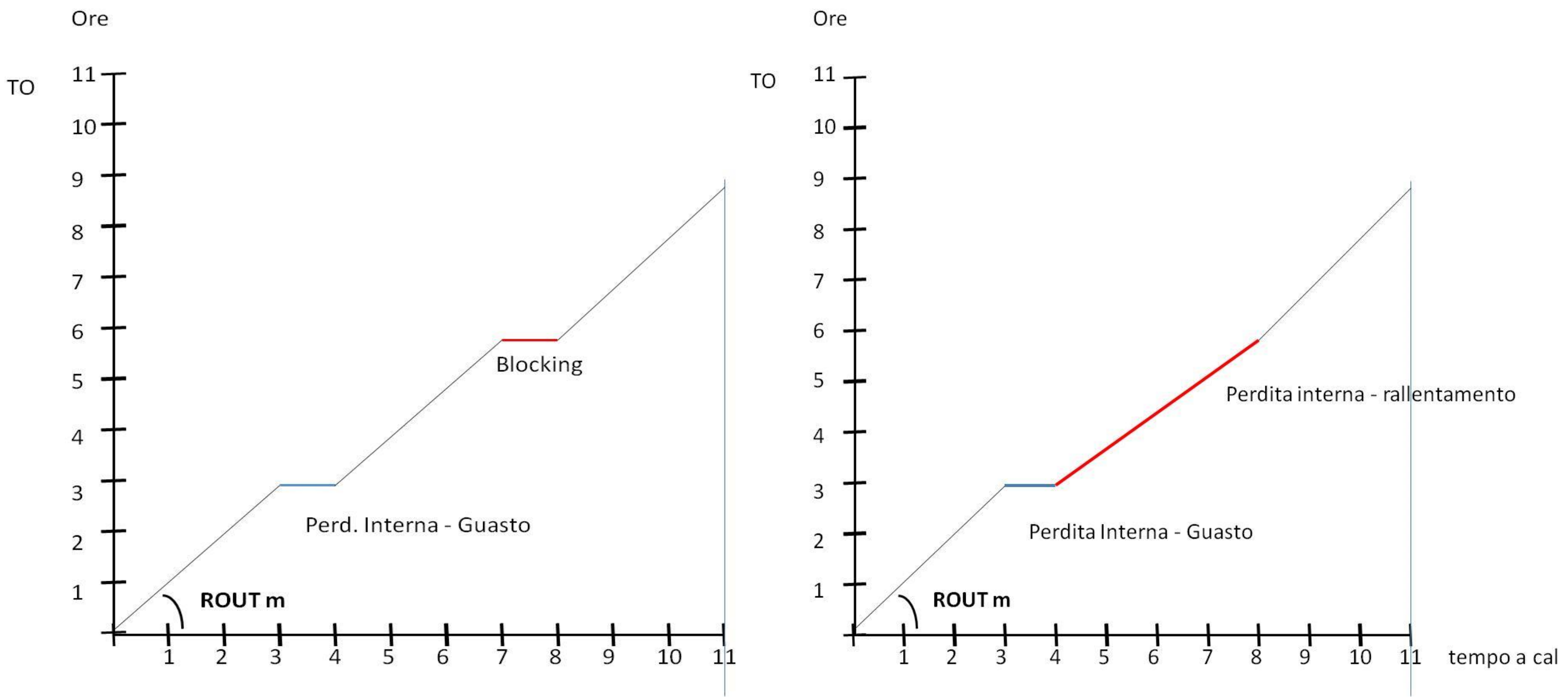


Diagram uses



Uses of diagram



Uses of diagram

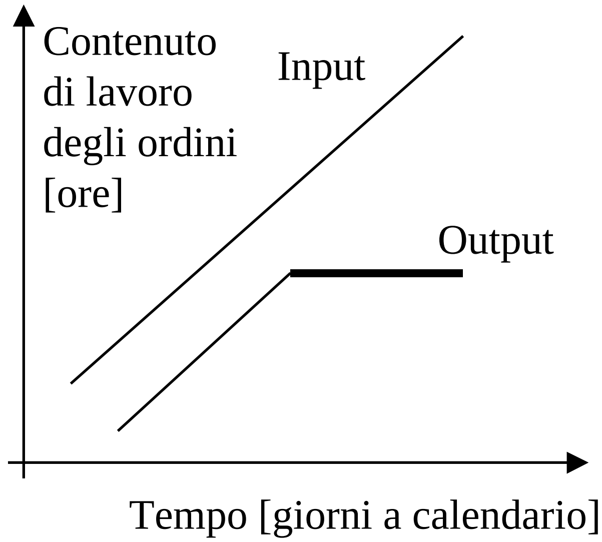
Input / output curves	**Causes**
	Internal leaks (e.g. failures, unavailability of auxiliary resources, etc.) or external (blocking)

Diagram uses

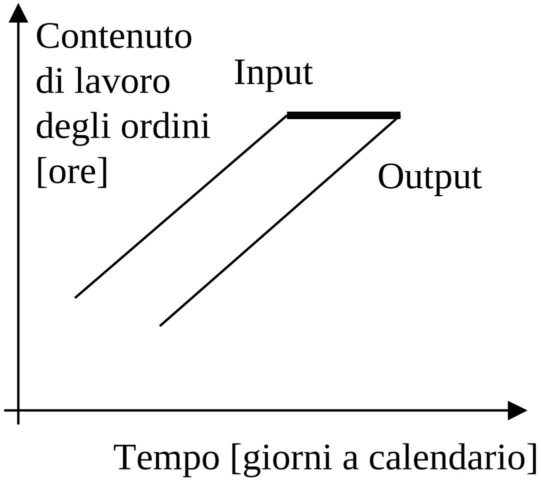
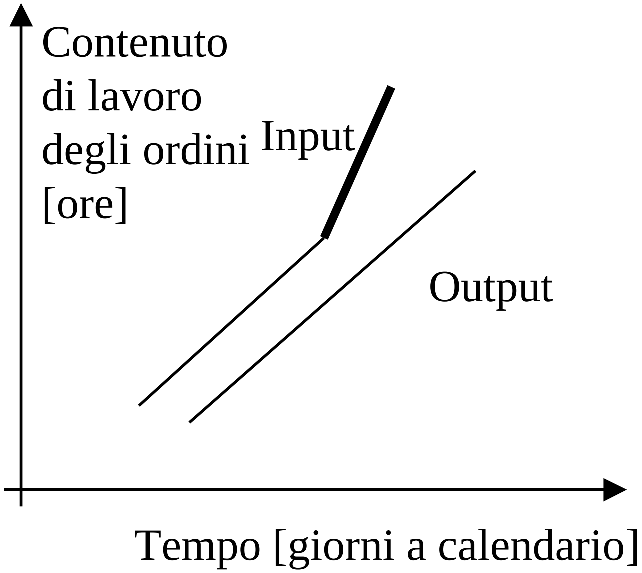
Input / output curves	Causes
	External leaks in a previous area, that lead to a ‘no supply’ situation

Diagram uses

Input / output curves	Causes
	The available capacity cannot be increased in order to follow the requested capacity : increasing of Rin without a correspondent increasing of Rout (the available capacity is already fully used)