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Performance

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What is the value of using PMS?

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- Increasing relevance of Performance Measurement and Performance Management Systems

- Typical objectives of a PMS:
  - monitor productivity
  - communicate strategy
  - reduce costs
  - review business strategy
  - support compensation systems
  - control operations

- Studies suggested that the effects of PMS need to be better understood in order to maximise their benefits

Characteristics of an “ideal” PMS

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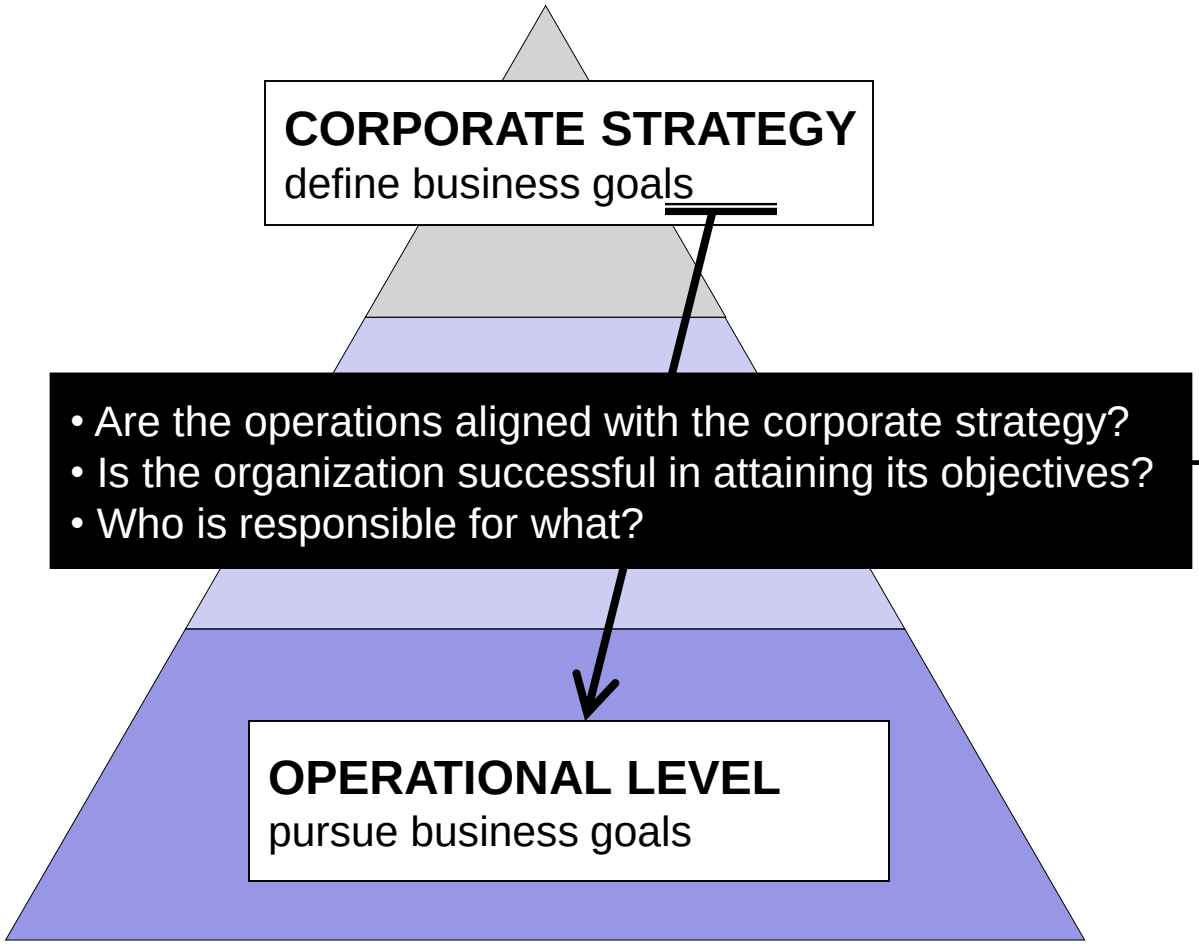
- Completeness
- Promptness
- Synthesis
- Measurable
- Aligned to company goals

Why using KPIs



- Cash Flow
- Employees satisfaction
- Customer satisfaction

KPIs related to the areas of day by day activity: the actual measures used to quantitatively access performances vs the CSF

- Measurements **affects behaviour** …either in the right or in the wrong way (i.e. controlling or distorting the performance of a process…)
- By modifying the system performances, also the company's **ability to pursue the corporate strategy** can change significantly
- The performances of a production system can be defined through a set of performance indicators which are often in a situation of **overlapping** and **mutual interdependence**

Effective production management requires the ability to **measure and control** the performances of the logistic/production system in order to reach a **high profitability level**

Productivity performance

Productivity

Productivity of production resources

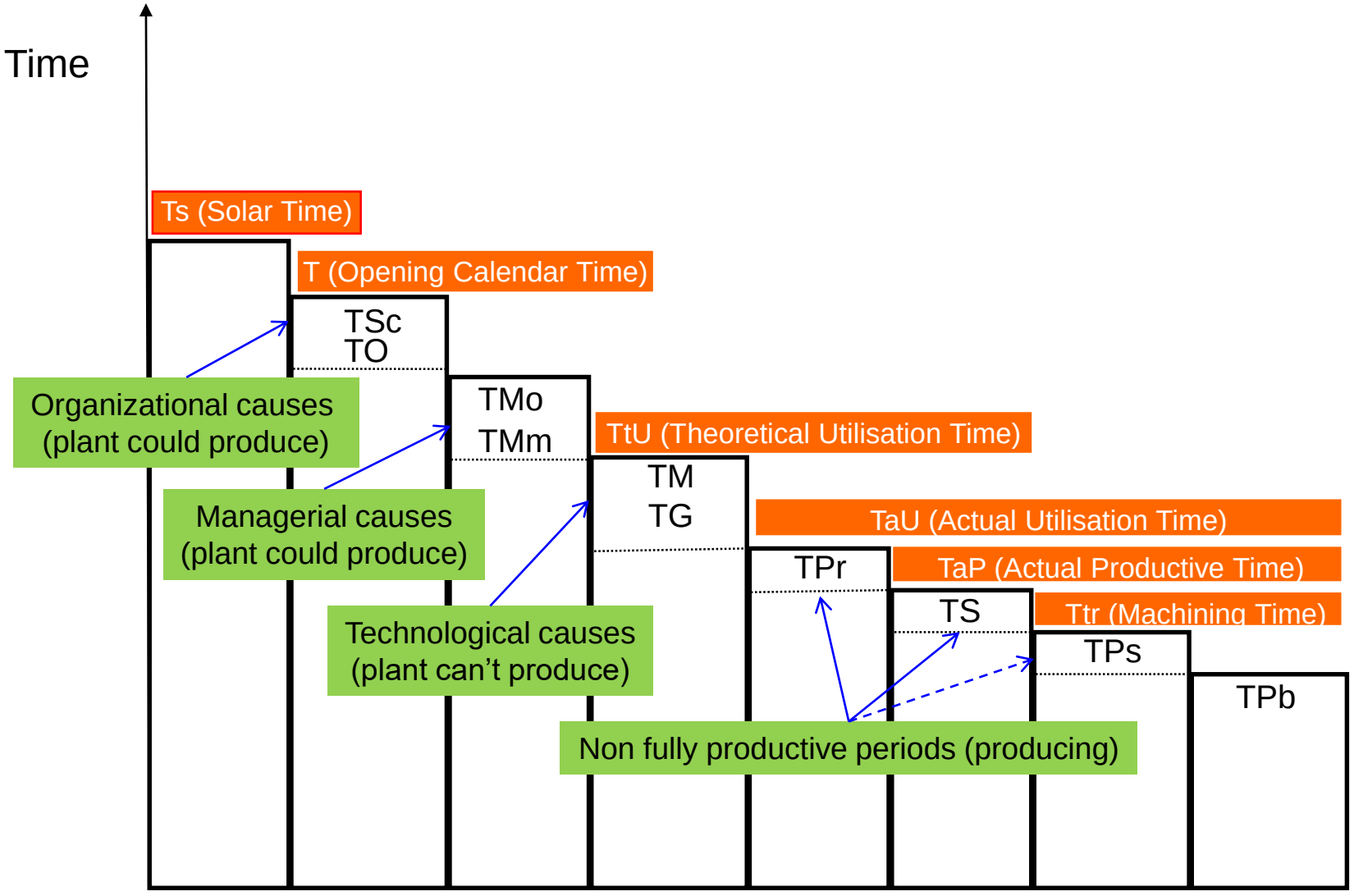
- **Workforce**
- **Machines/Plants**
- **Materials**

Availability and Throughput

Warehouses productivity

- Stock turnover and days of inventory
- ABC-ABC analysis

The reference framework for internal performance



Measuring the internal performances

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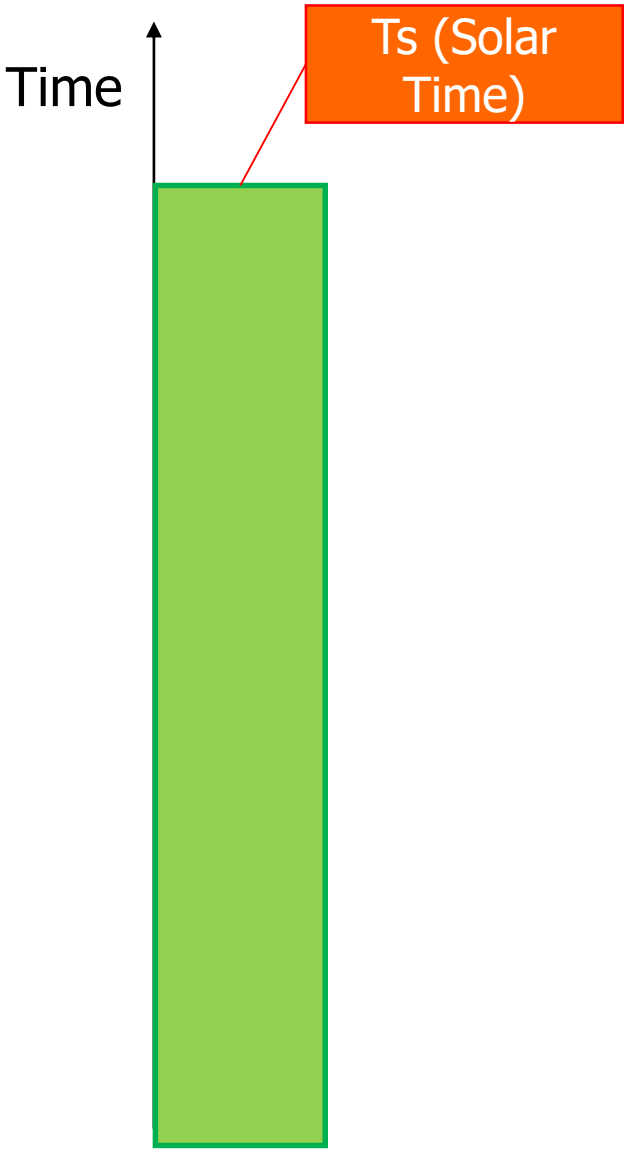
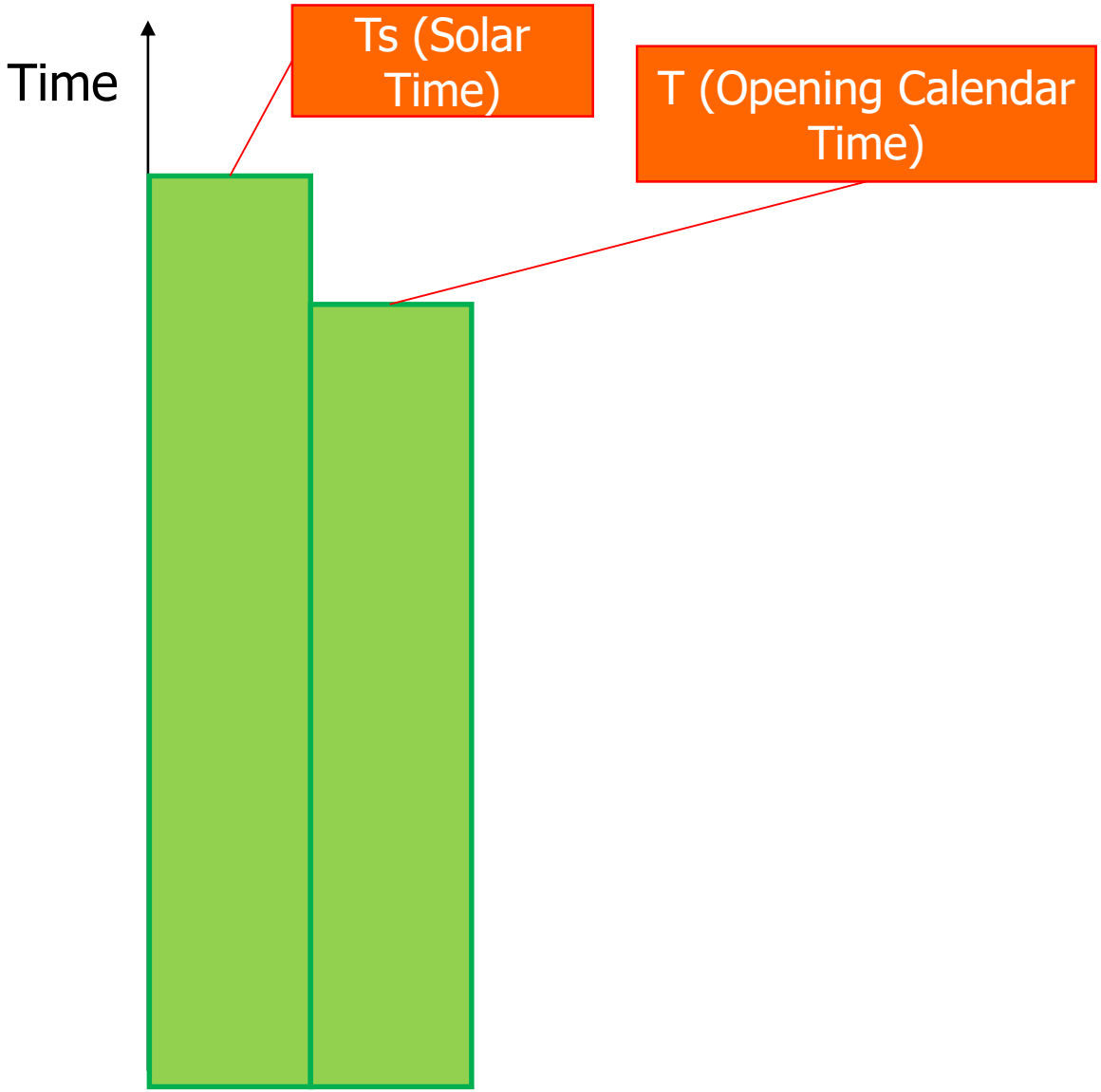
The states of a plant (a machine or in general a productive resource)

- Ts solar time
- T opening (calendar) time (potentially productive)
- TSc strikes
- TO organizational causes
- TMo idle time due to lack of orders
- TMm idle time due to lack of materials
- TM idle time due to maintenance
- TG idle time due to breakdown
- TPr time for tests (and trials)
- TS time of setup
- TPs time of waste (non-compliant) production
- TPb time of good (compliant) production

Measuring the internal performances



Measuring the internal performances



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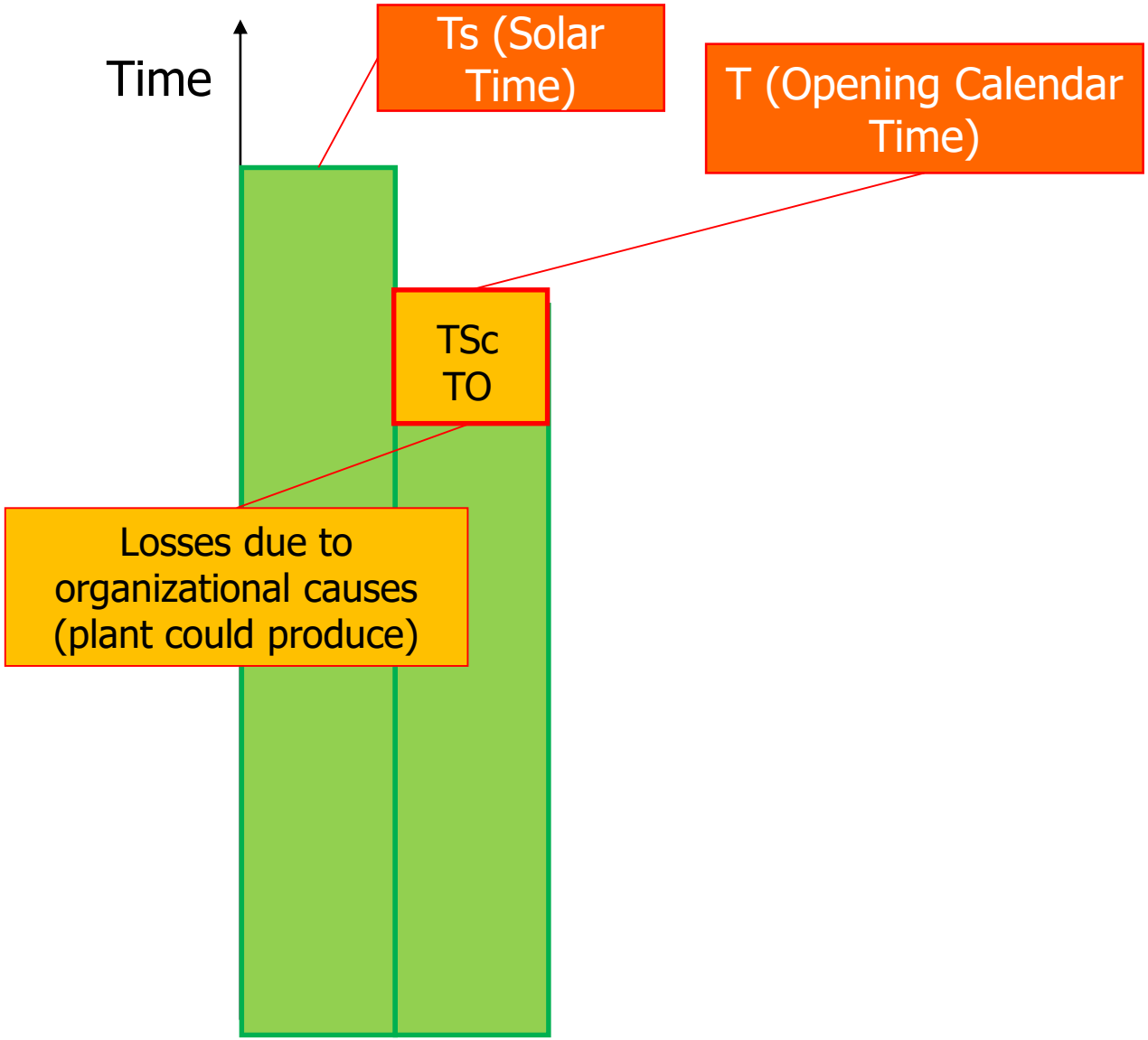

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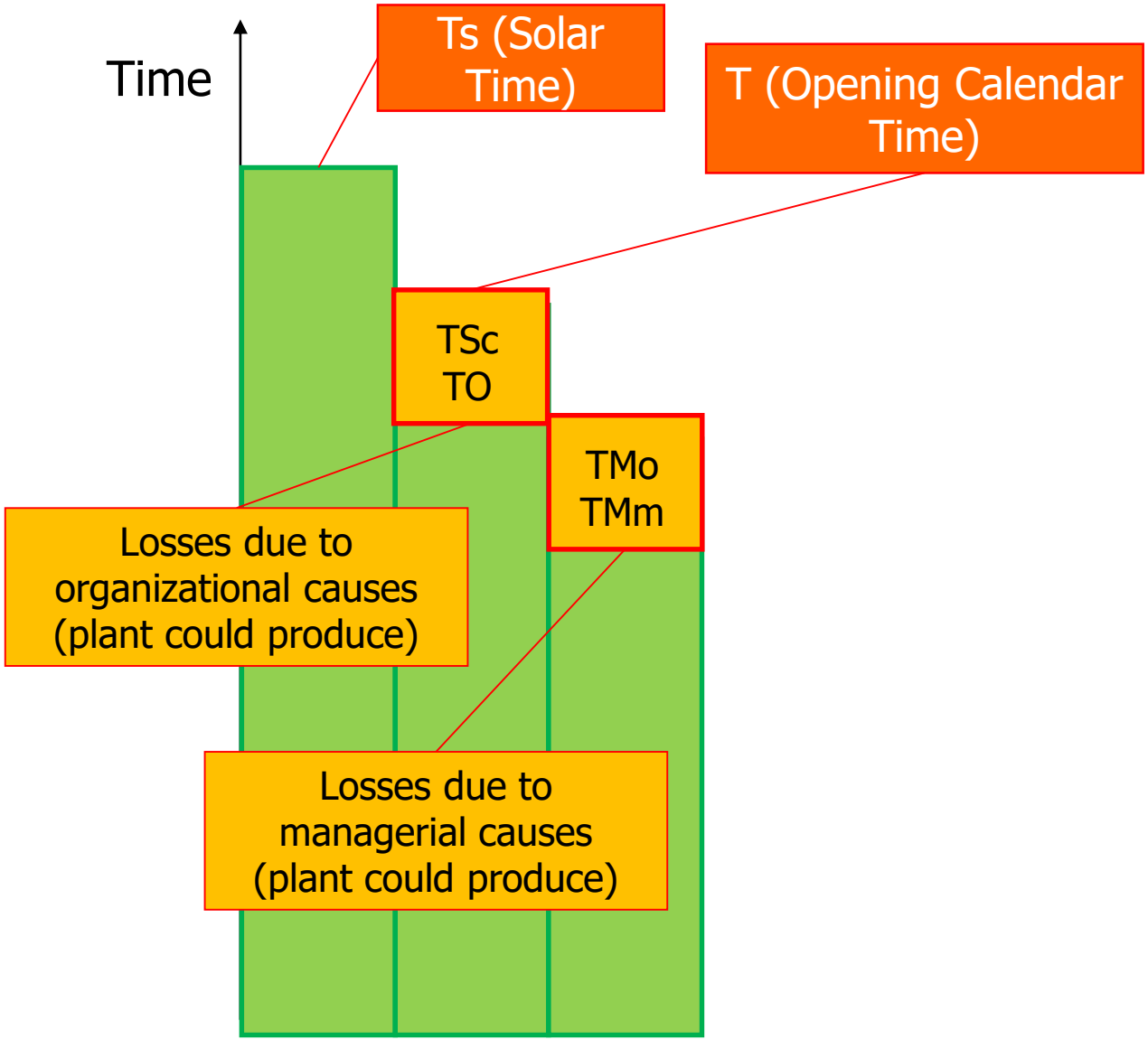

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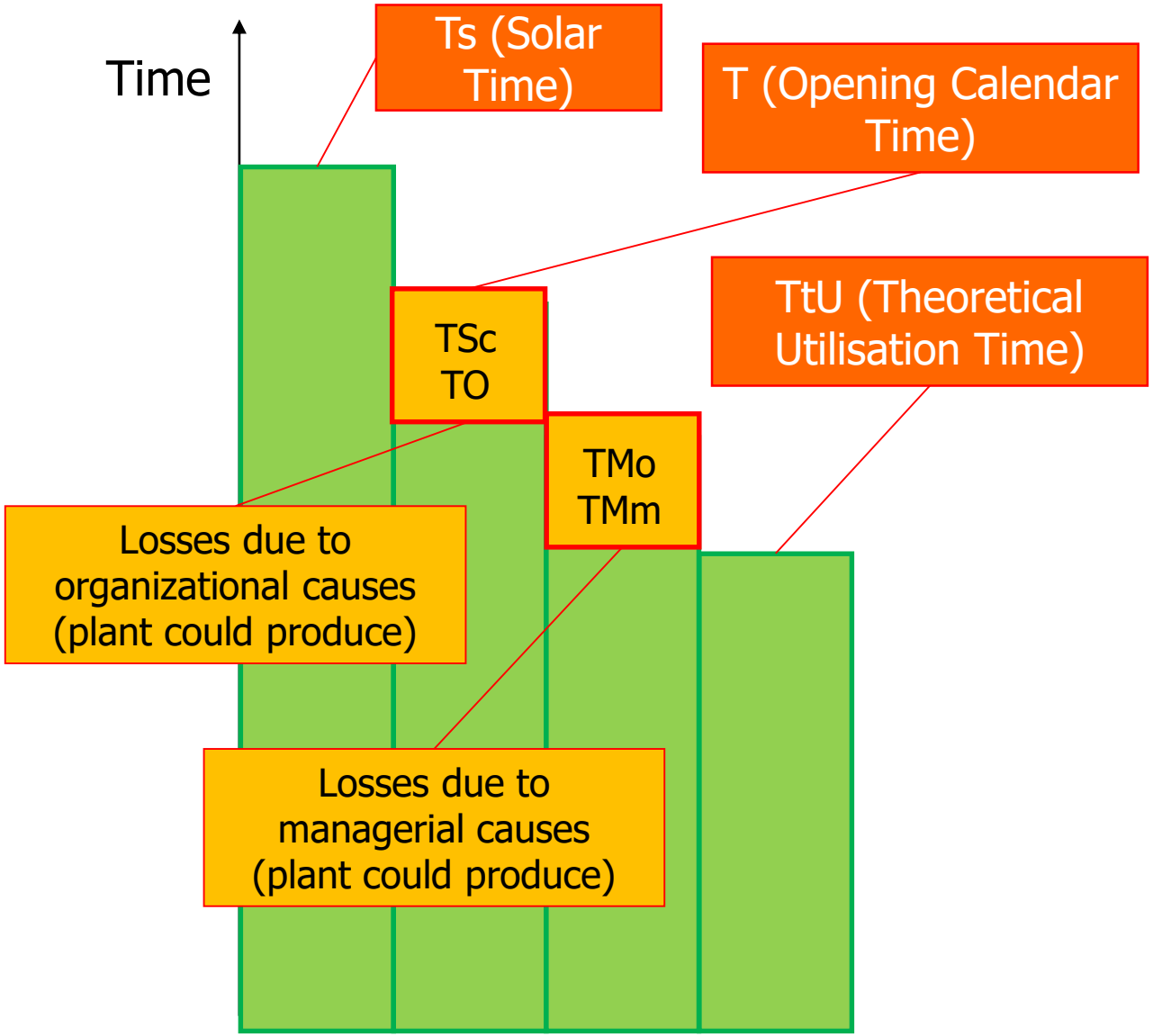

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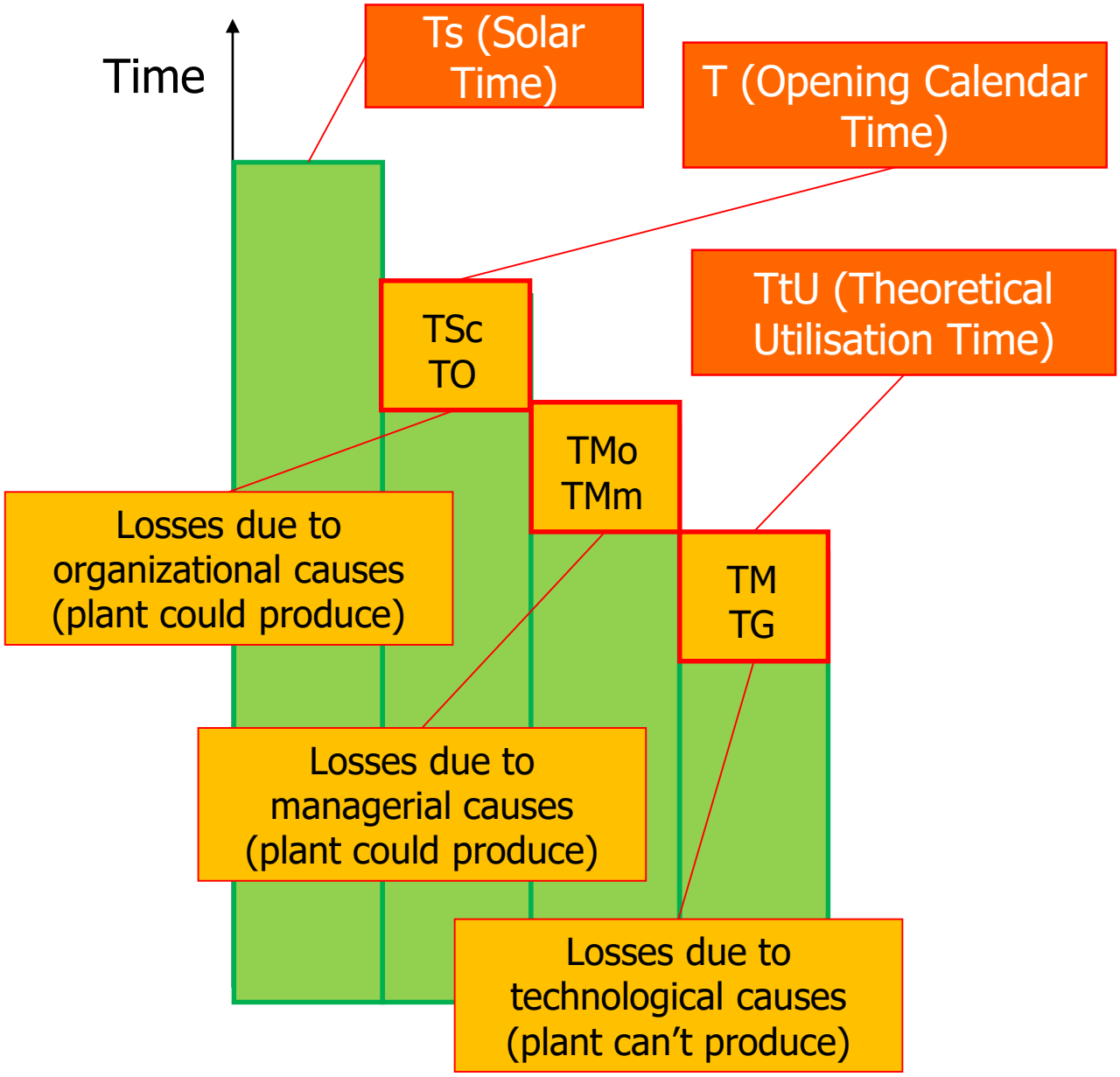

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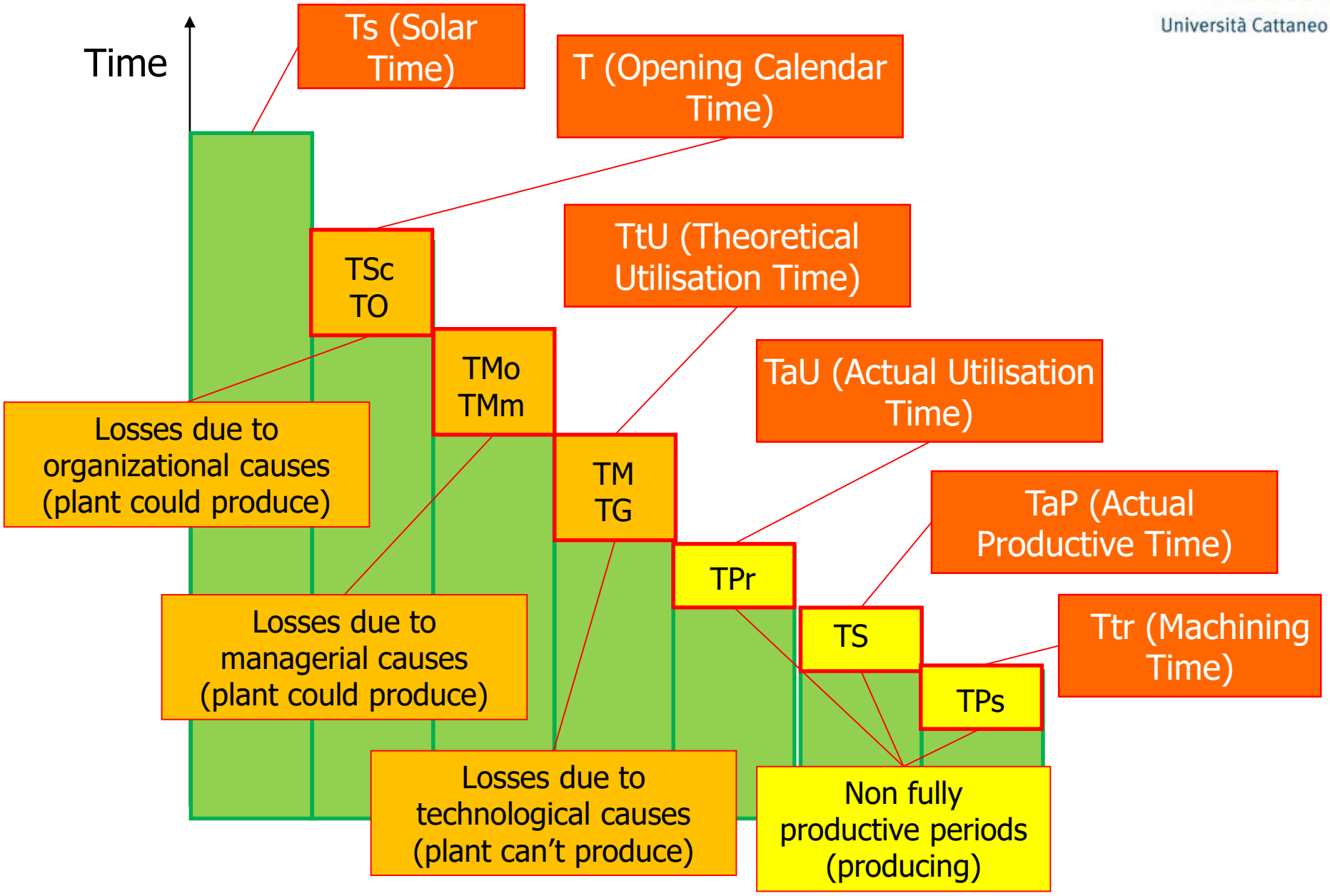
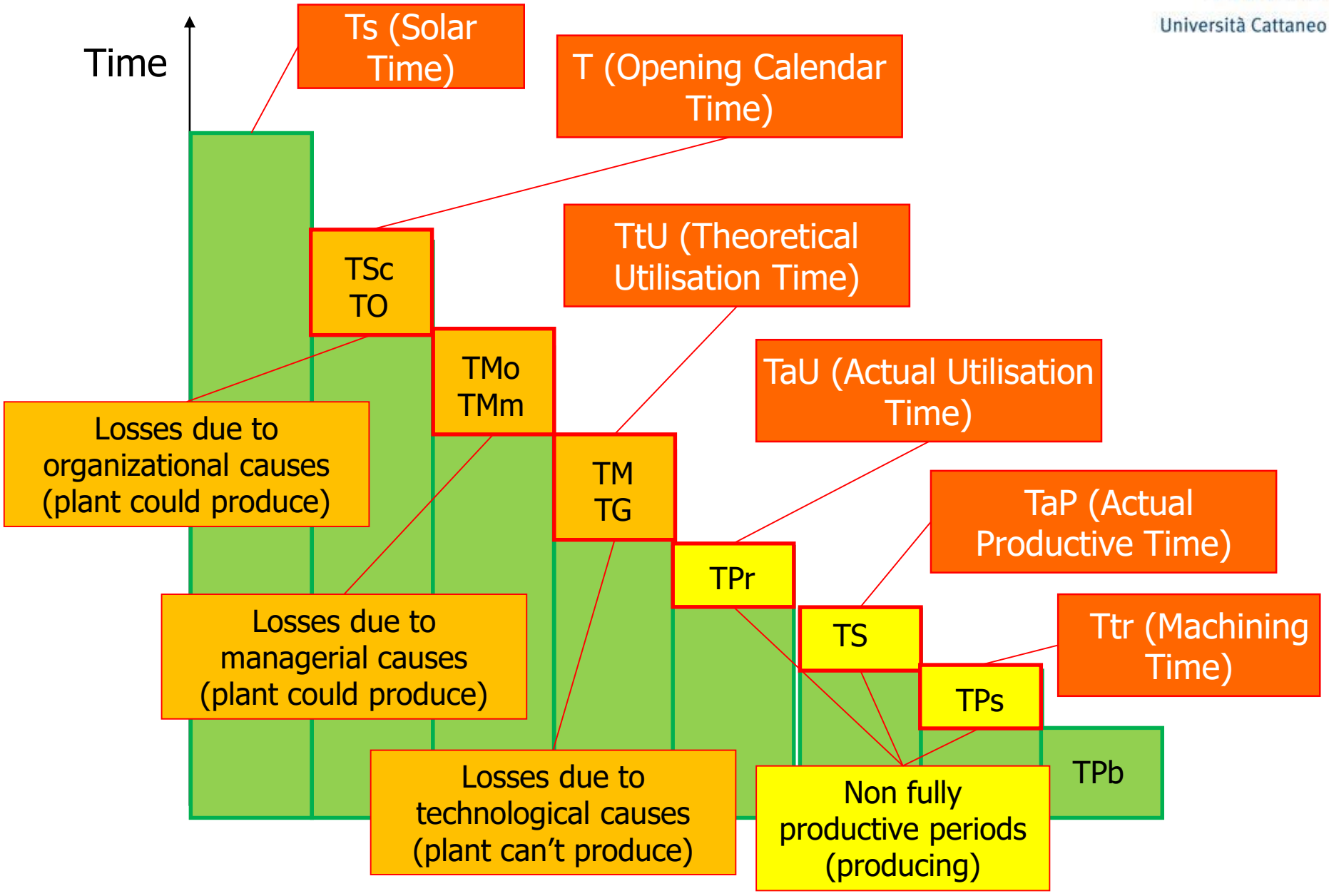
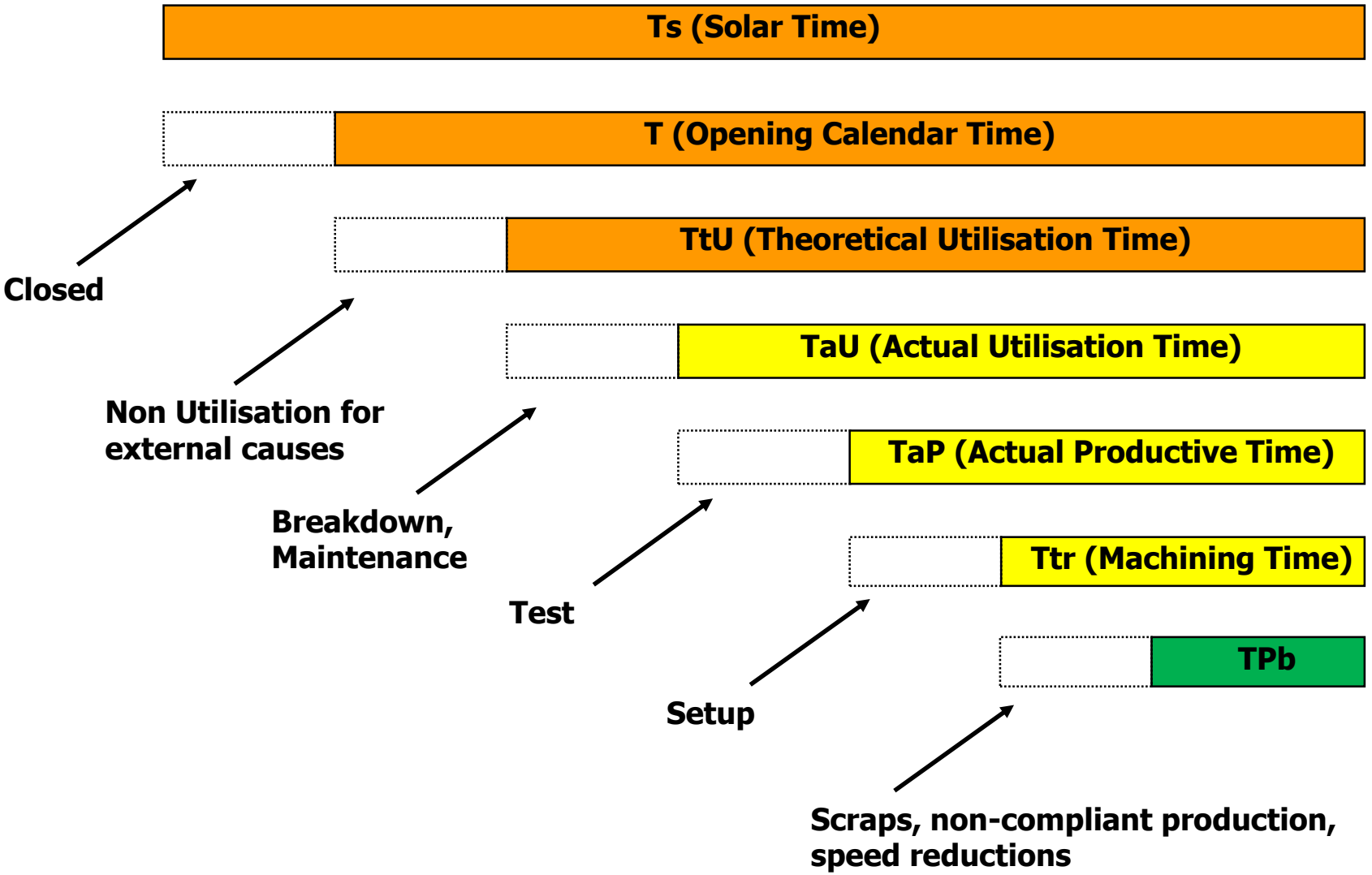


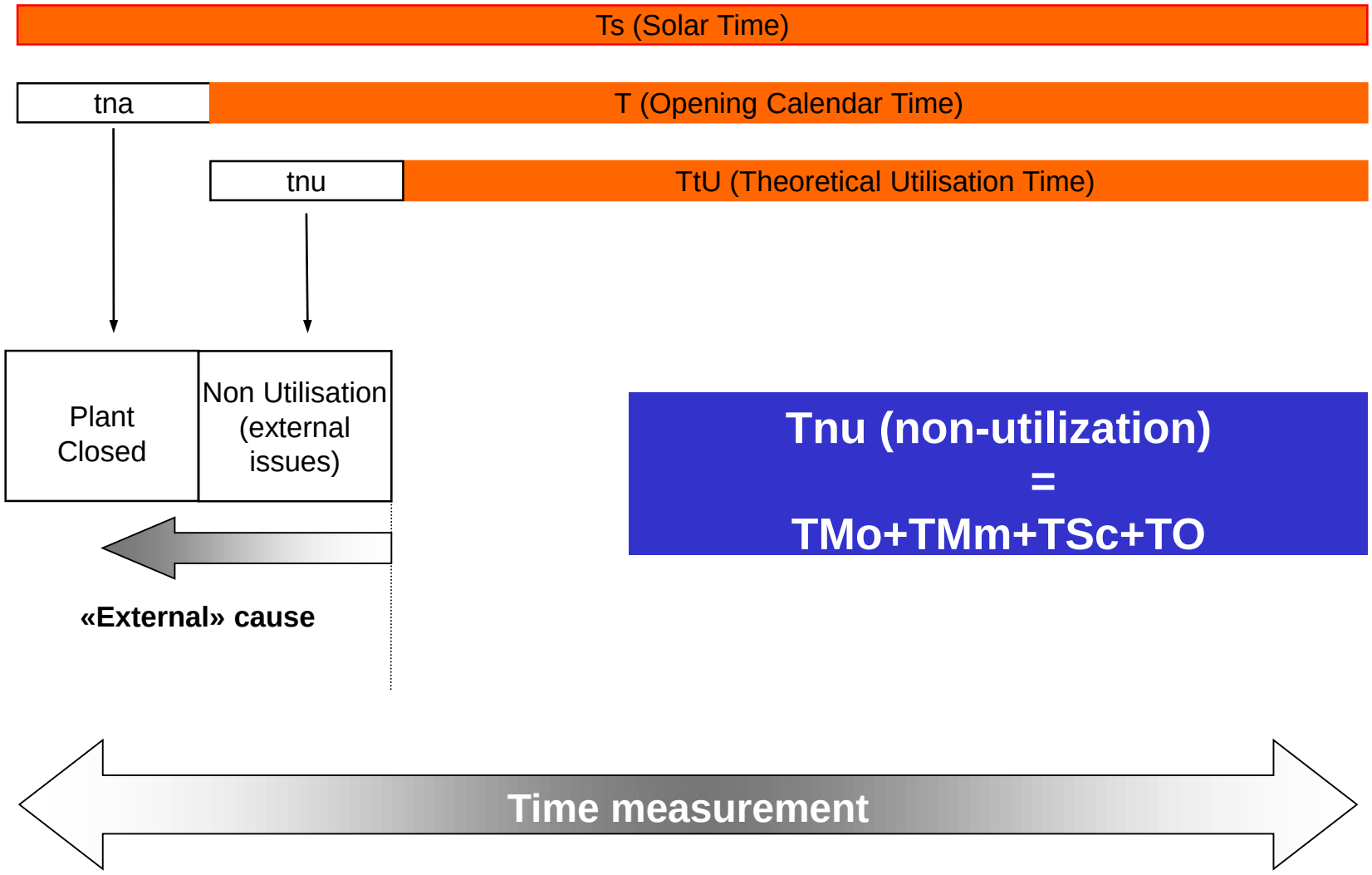
Measuring the internal performances



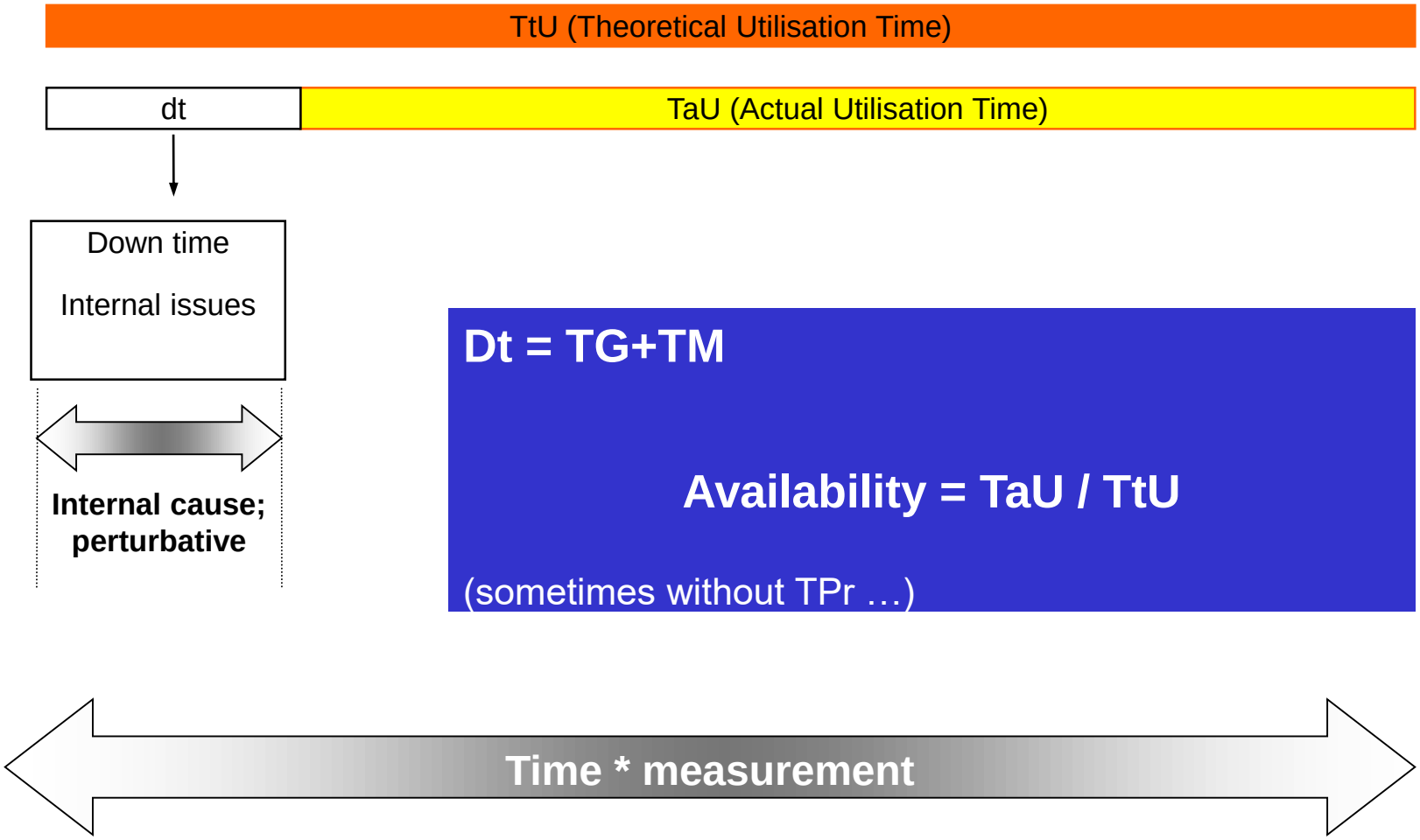
Measuring the internal performances



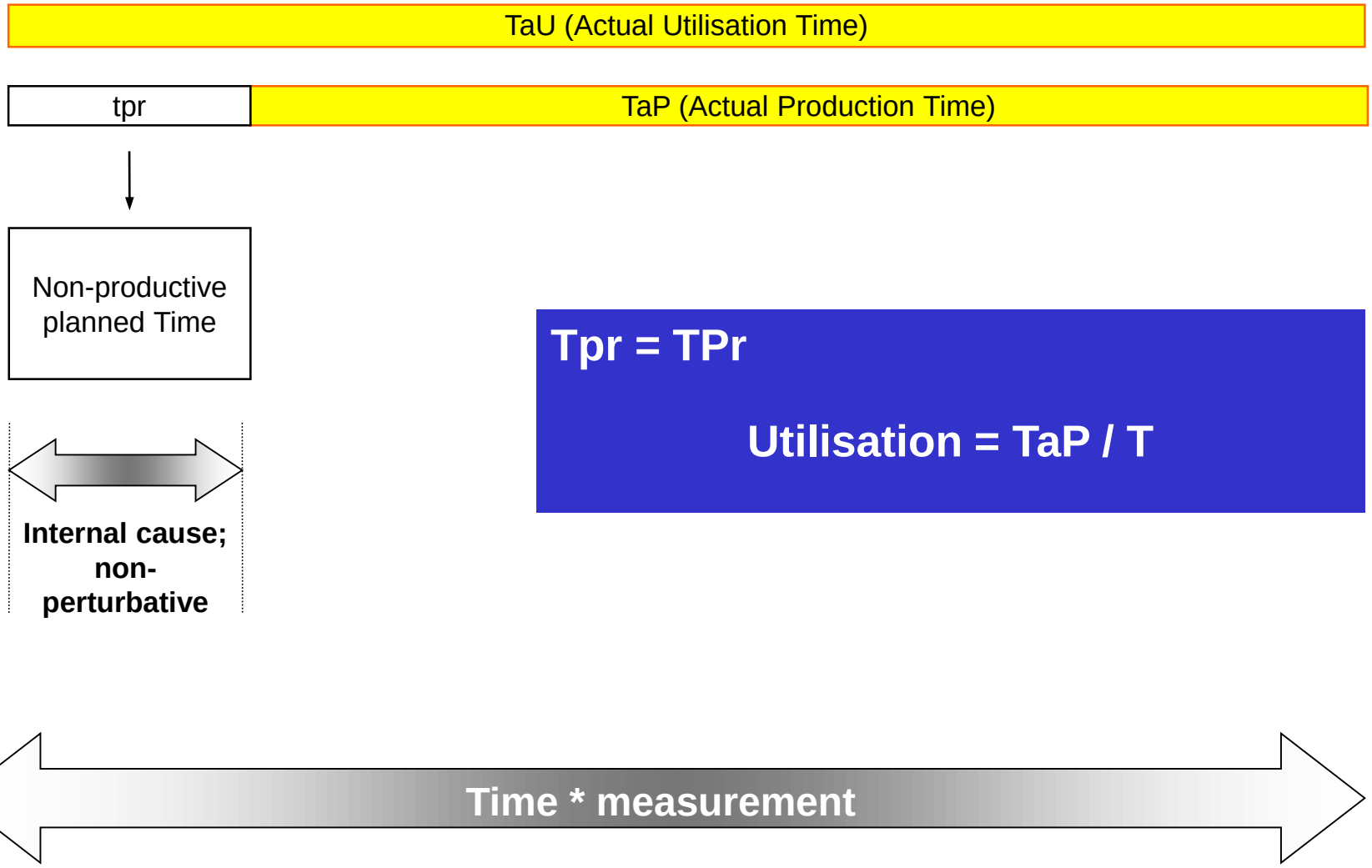
External causes



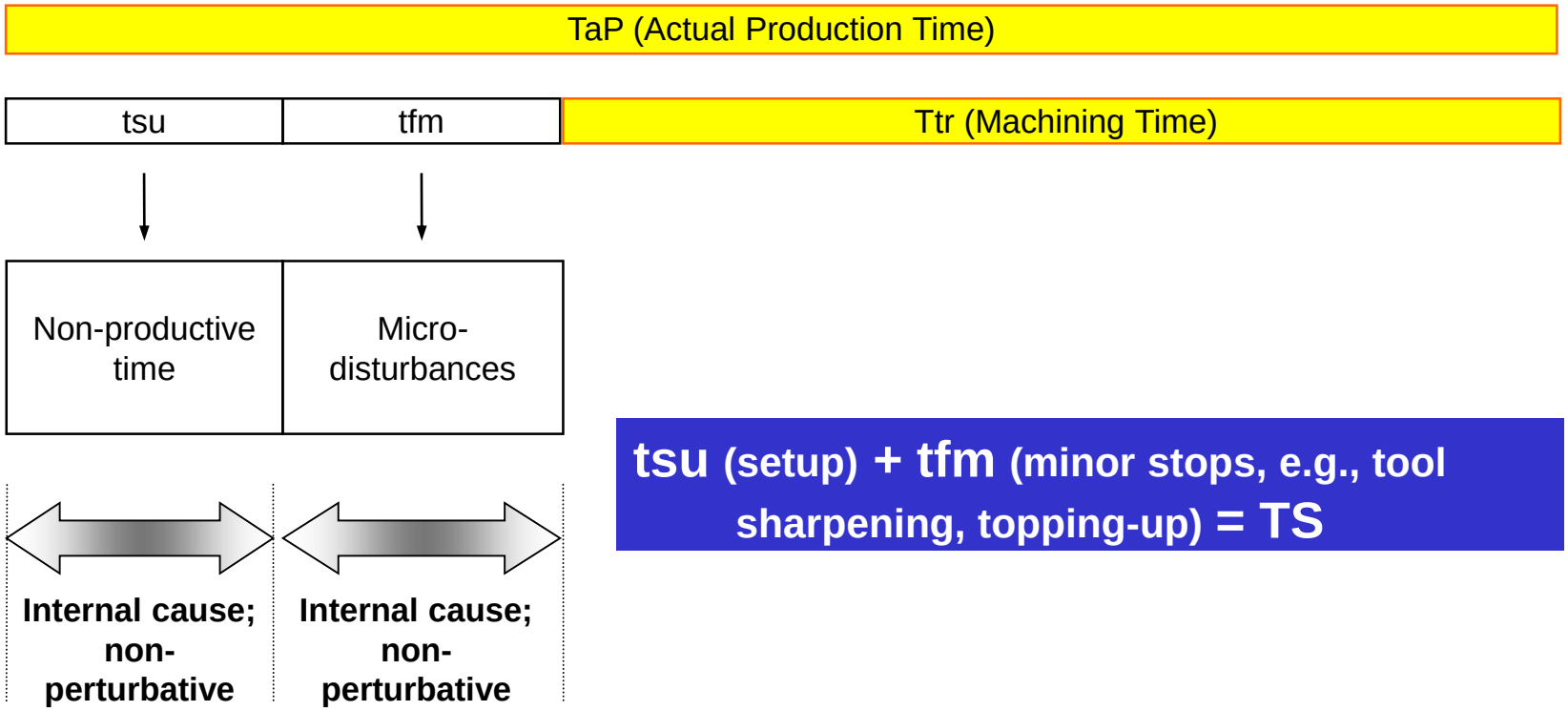
Availability



Utilisation and Tests

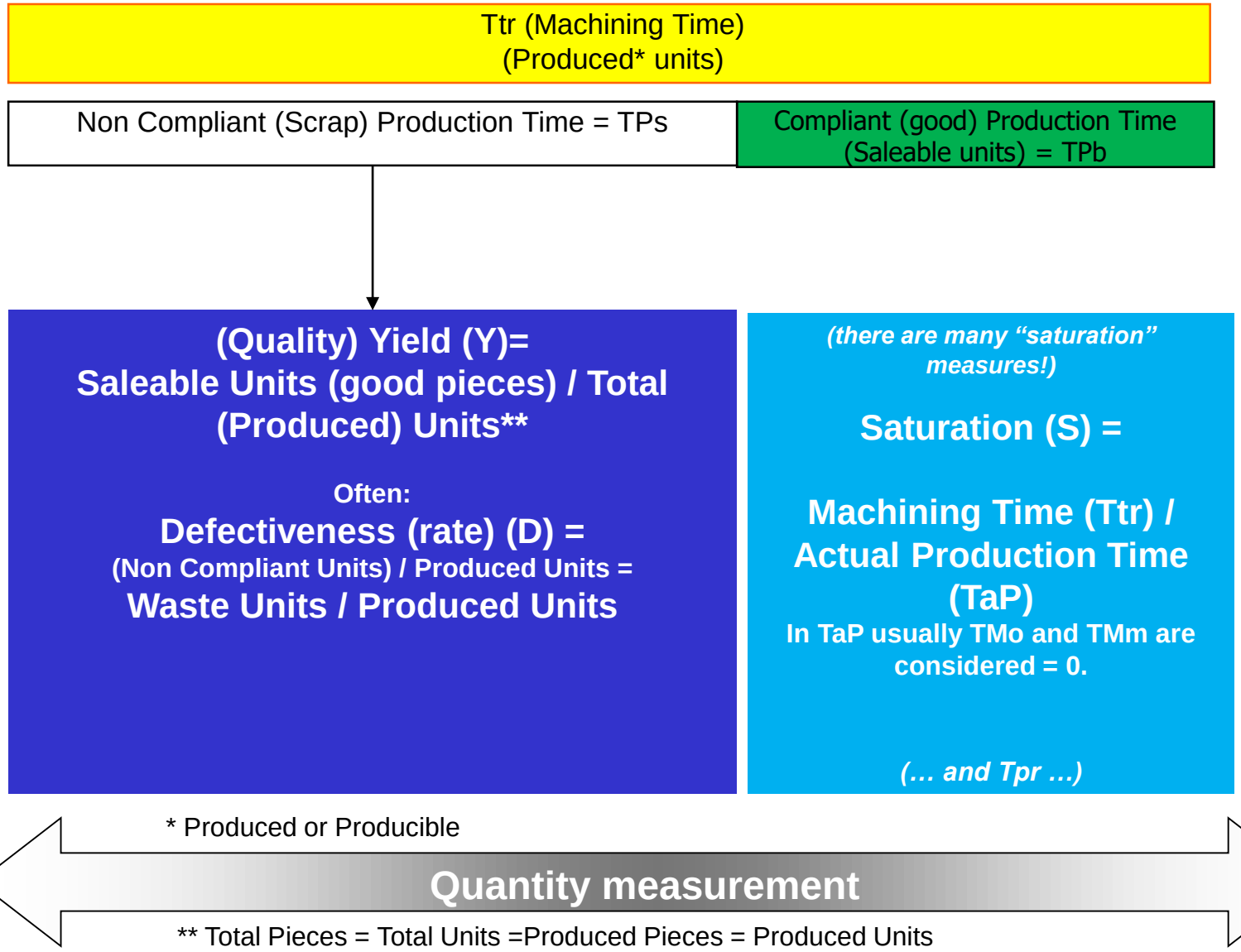


Setup



tsu (setup) + tfm (minor stops, e.g., tool sharpening, topping-up) = TS

Performance (P), Yield (Y) and Defectiveness (D)



Standard vs. Actual

In the real life, actual performances are often lower than the expected.

This is happening also in production systems:

- an **actual status** (and an actual time registration) of a production system is the collection of what happened in the system;
- a **standard status** (or planned, or expected) of a production system is an a priori definition, based on previous knowledge and experience.

Standard vs. Actual

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We can have:

- Actual production volume vs. Standard production volume
  [pieces]
- Actual production time vs. Standard production time
  [h dedicated in a certain period]
- Actual production rate vs. Standard production rate
  [pieces produced in a due amount of time]
- …

Productivity measures

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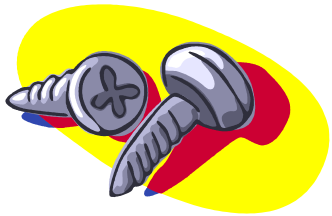
$$\text{Productivity} = \frac{\text{Production volume (expressed in a certain unit of measurement)}}{\text{Level of use of a certain production factor}}$$



Material Productivity

Machine productivity

Workforce productivity

Productivity measures

Productivity measurements are, generally, expressed by indicators of efficiency such as:

P = Output / Input

These can be measured with reference to:

-a single machine,

-a group of machines,

-stages of the production process or

-the entire production system

(see later “Hamlet’s question”)

Productivity

- Partial measures*: output / single input
  - Output/energy , output/machine hour, output/labor
- Multi-factor measures: output / multi input
  - Multi-factor: output/(energy + machine cost), output/(labor + capital)
- Total measure : output / all inputs
- In general, Productivity = output / input

Improving Productivity

- Develop productivity measures
  - First measure, then manipulate
- Establish reasonable goals (and dynamics …)
  - Golf: bogey (+1), par (even), birdy (-1; scoring one under par), eagle (-2), … phoenix (-5) !
- Publicize improvements
  - Incentives, positive feedback, awards
- Extensive training
- Efficient workplace design-ergonomics … (human factors engineer)
- Get management support
- Develop methods for productivity improvements
  - Venues for ideas to prosper
- High technology
- High quality (products)
  - Less scrap
- High standardization

Productivity measures

To make a diagnosis is, generally, not so useful to aggregate the productivity measures.

More useful indications derive from the decomposition of productivity measurements (P) in:

- Utilisation (U) and
- Efficiency (η)

of productive factors.

The output of the process is always the good (compliant) production that is stocked measured against “standard hours” (i.e. the hours that according to standard are necessary to produce a specific object, including the setup time).

The input changes according to the productive factors considered (machine, material or workforce)

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- Workforce Utilisation

$$U = \frac{\text{ACTUAL PRODUCTION TIME}}{\text{PAID HOURS}}$$

$$U = \frac{T - TMo - TMm - TSc - TO - TG - TM - TPr}{T}$$

$$U = \frac{TPb + TPs + TS}{T}$$

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- Machine Utilisation

$$U = \frac{\text{ACTUAL PRODUCTION TIME}}{\text{OPENING CALENDAR TIME}}$$

$$U = \frac{T - TMo - TMm - TSc - TO - TG - TM - TPr}{T}$$

$$U = \frac{TPb + TPs + TS}{T}$$

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- Efficiency

The concept of standard time is fundamental.

$$\eta = \frac{\text{Actual Production in std. hours}}{\text{ACTUAL PRODUCTION TIME}}$$

$$\eta = \frac{\text{STD H. “STOCKED”}}{\text{ACTUAL PRODUCTION TIME}}$$

$$\eta = \frac{\sum \left[\left(\overline{TPb_i} + \overline{TPs_i} \right) + \overline{TS} \right]}{\sum \left[\left(TPb_i + TPs_i \right) + TS \right]}$$

Productivity measures

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Factor	***PRODUCTIVITY***	***UTILISATION***	***EFFICIENCY***
WF	$\frac{\text{produced volume}}{\text{paid hours}}$	$\frac{\text{actual worked h.}}{\text{paid h.}}$	$\frac{\text{vol. in h. std.}}{\text{actual worked h.}}$
MAC	$\frac{\text{produced volume}}{\text{installed cap.}}$	$\frac{\text{act. prod h.}}{\text{opening h.}}$	$\frac{\text{vol. in h. std.}}{\text{actual prod. h.}}$
MAT*	$\frac{\text{produced volume}}{\text{mater. used}}$	$\frac{\text{theor. consum.}}{\text{actual consum.}}$	$\frac{\text{vol. in material}}{\text{theor. consum.}}$

PRODUCTIVITY = UTILISATION x EFFICIENCY

- Production Capability refers to the technical and physical limitations of a plant.

- Several dimensions of this capability can be identified:
  - Technological Processing Capability, i.e. the available set of production processes
  - Physical Product Limitations, i.e. the limitations in terms of the size and the weight of the product that can be accommodated
  - Production Capacity (Productive Capacity or Plant Capacity), i.e. the production quantity that can be produced within a given time period (e.g., year)

Production Capability

Production Capacity

- Production (or Productive or Plant) Capacity is defined as the maximum production that a plant can achieve in a given time period (e.g., a year) under assumed operating conditions (e.g., shifts per month, direct labor manning levels in the plant, hours per shift).

- Production Capacity is usually measured in terms of output units (e.g. tons of steel produced by a steel mill or number of cars produced by a final assembly plant). In these cases, the outputs are homogenous.

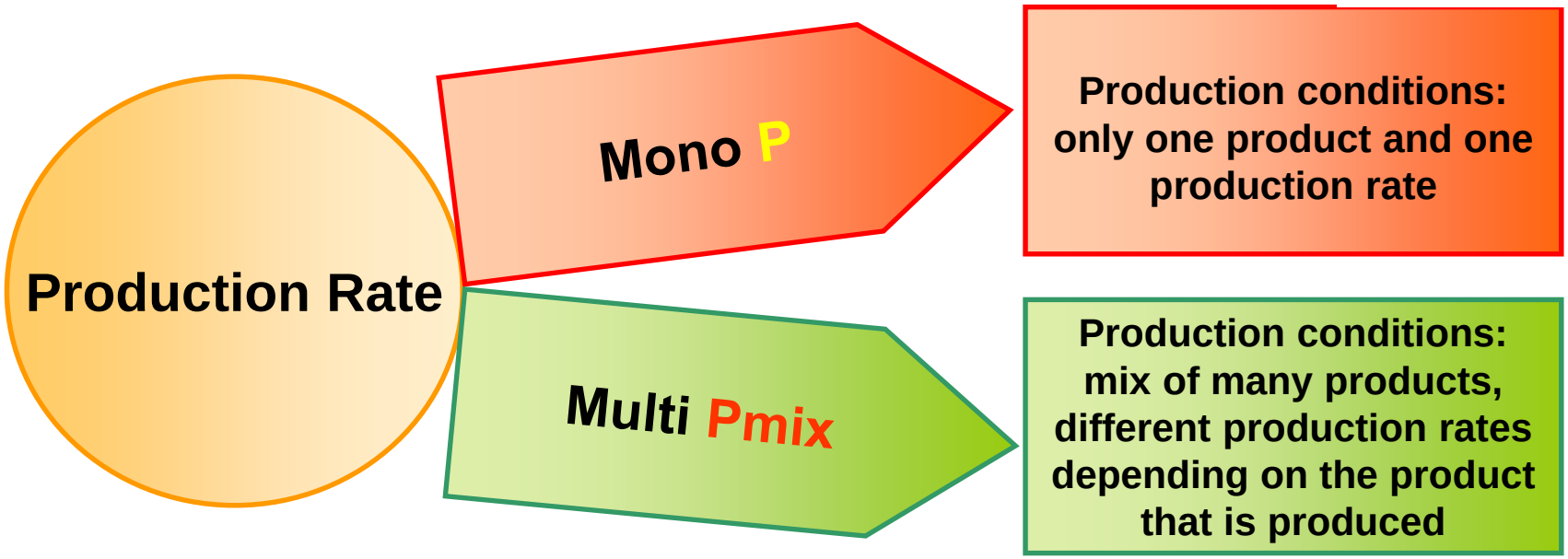
  In cases in which the outputs units are not homogenous, other factors may be more appropriate measures (e.g., available labor hours of productive capacity in a machine shop that produces a variety of parts)

Production Capacity

- Production capacity is always calculated with reference to a given production mix

- Even if Production Capacity is a flow (units/year), often is referred as a (production) volume (units), implying the time unit (year)

Production (Throughput or Run) Rate (Production potentiality)



- In multi product situations it is useful to use the Mix Production Rate (Pmix), i.e. the ratio between the quantities of the different codes that have been produced and the time that is needed to produce them including the setup time
- With reference to a specific mix of products, it is defined as the average number of units that can be produced per time unit.
- Pmix = quantity produced / time required

Mix Production (Throughput) Rate (mix potentiality)

$$Pmix = \frac{\sum_i (QB + QS)}{\sum_i (TPb_i + TPs_i) + TS}$$

QB = number of good pieces (units)

QS = number of scrap pieces (units)

TPb = time devoted to produce QB

TPs = time devoted to produce QS

TS = time for setup

With reference to a specific production mix

Mix Production Rate (mix equivalent unit)

$$Pmix_{std} = \frac{\sum_i (QB + QS)}{\sum_i \frac{(QB + QS)}{RS_i} + \overline{TS}}$$

$$Pmix_{std} = \frac{\sum_i RS_i \times (TPb_i + TPs_i)}{\sum_i (TPb_i + TPs_I) + \overline{TS}}$$

QB = number of good pieces (units)

QS = number of scrap pieces (units)

TPb = time devoted to produce QB

TPs = time devoted to produce QS

TS = time for setup

RS_i = standard production rate of the generic item i (e.g., pcs/h)

Mix Production Rate
(reference item equivalent unit)

$$Pmix = \frac{\sum_i [(RS_k / RS_i)(QB_i + QS_i)]}{\sum_i (TPb_i + TPs_i) + \overline{TS}}$$

QB = number of good pieces (units)

QS = number of scrap pieces (units)

TPb = time devoted to produce QB

TPs = time devoted to produce QS

TS = time for setup

RS_i = standard production rate of the generic item I (e.g., pcs/h)

k = reference item (equivalent units base)

Service performance measurement – General framework

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Service

Systems working "to Stock" (MTS)

Availability

Stock-out persistency

Delivery Accuracy and Completeness

Systems working "to Order" (MTO, ATO….)

Promptness

Punctuality

Service performance measurement – General framework

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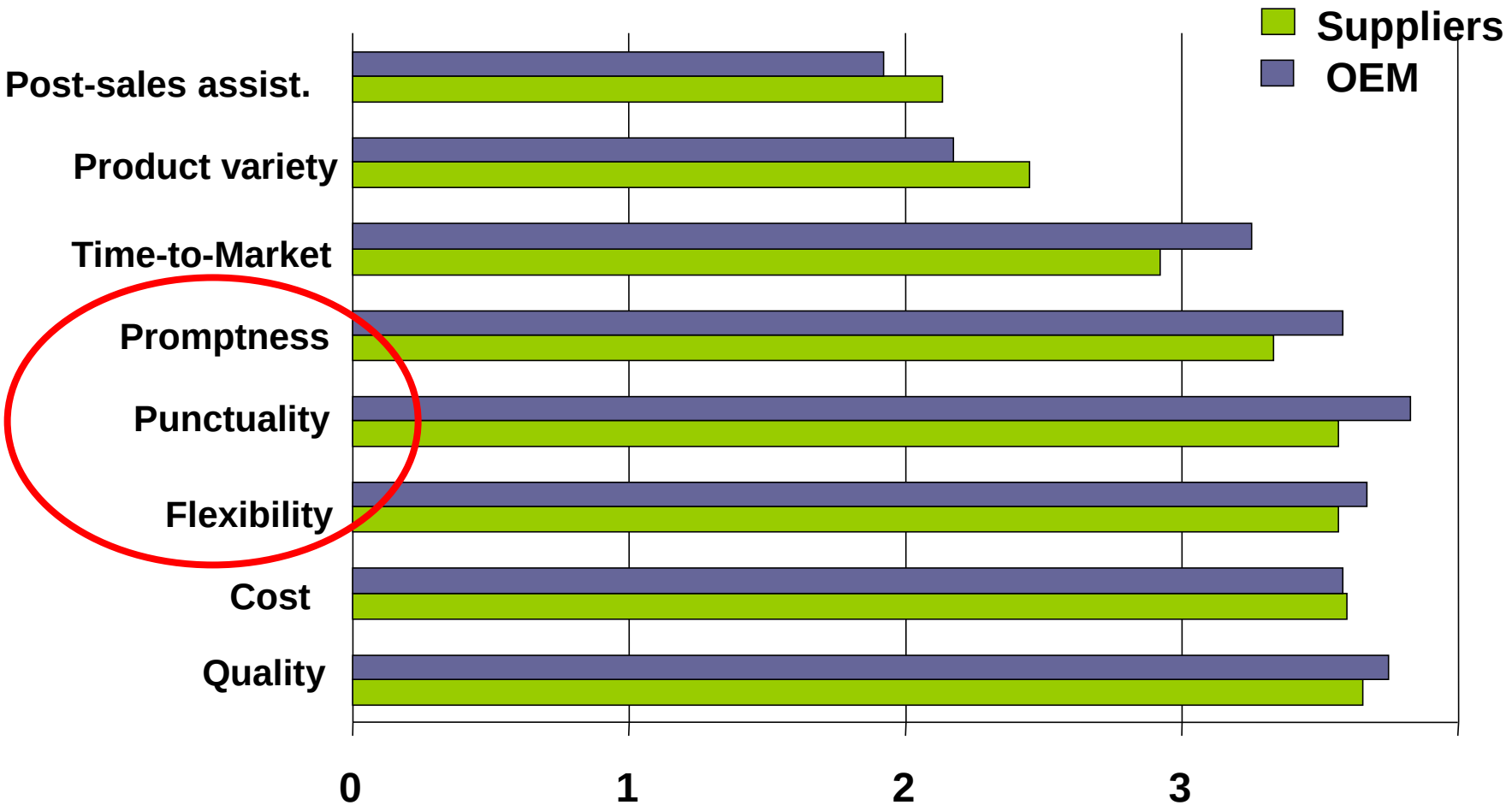
The aim of service performance measurement is to evaluate the "immaterial" performance connected to clients' needs and desires satisfaction.

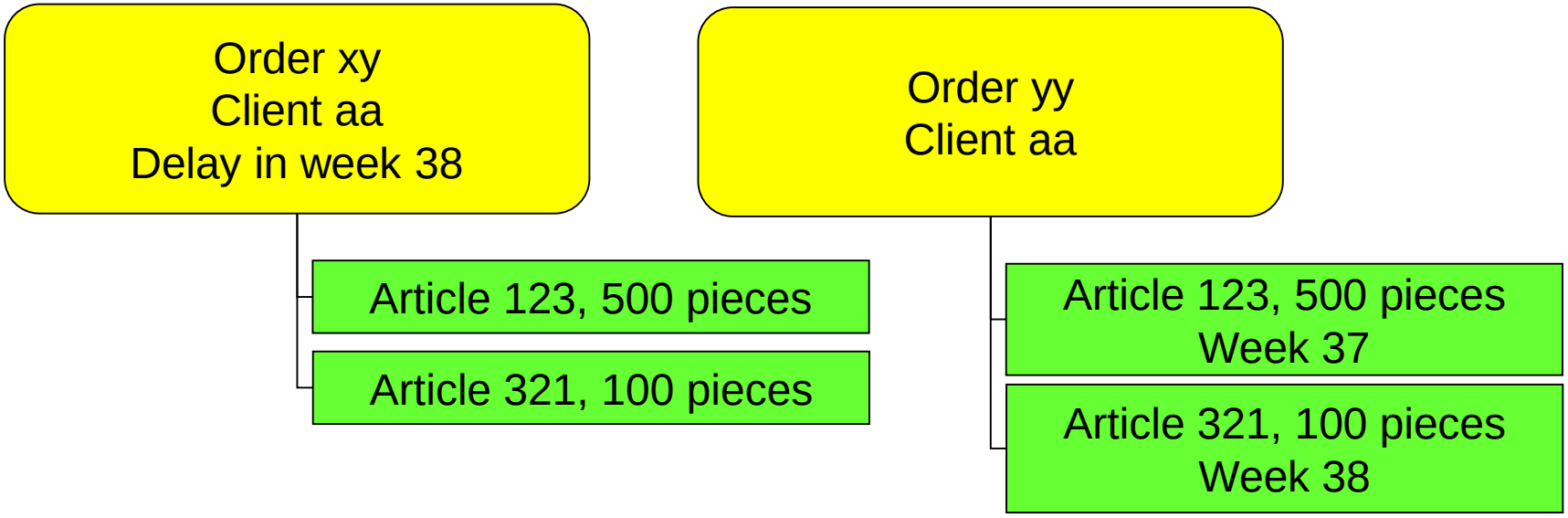
Why service is important: example



For a sample of firms in the household appliance sector, service performance are as much important as quality and price.

In a firm service performance measurements should be defined accordingly to what is assumed to be the “service for the client”:

- A complete *Order* or a single *Order Line/Row*
- Acceptable time *delays*



The structure of an order

ROSSO BIANCHI S.p.A

Milan, 25-11-2014

Dear GIALLO VERDI s.r.l.

Order n. 548/zz

Article aaa …… ……n° 3 pieces
Article bbb …… ……n° 7 pieces
Article ccc …… ……n° 9 pieces

Terms for delivery: . . . . . .
Place of delivery: ……
Payments terms: . . . . . .

ORDER ROWS or ORDER LINES

Service performance measurement – Accuracy (or Precision)

It evaluates the quality of the system of order preparation

(ref. wrong items sent)

The following indicators are used:

- Physical:
  - N° mistakes in the delivery / N° Orders (Order lines) managed
  - N° returns due to delivery mistakes
- Economic:
  - Cost of the penalty for inaccurate delivery
  - Cost of management and accounting activities duplication

The delivery mistakes can be of packaging, items, batches, etc…

Service performance measurement – Completeness

It evaluates the reduction in the level of service perceived by customers in terms of splitting of order fulfillment.

The following indicators are used:

- Physical:
  - N° of order rows fulfilled with the first delivery / N° total rows
  - Average N° of deliveries for each order
- Economic:
  - Value of order rows fulfilled with the first delivery / Total value of rows
  - Cost of fractioned deliveries.

Service performance measurement MTS – Availability (ref. stock-out)

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It takes into account the phenomenon of the stock-out.

Indicators:

- Physical:
  - N° items in stock-out / N° total items
  - N° order filled / N° total orders
  - N° order lines filled / N° total order lines
  - N° codes filled / N° codes requested
- Economic:
  - Cost of the lost margin* due to the stock-out (if not recoverable)
  - Cost of the penalty for delayed delivery (if any contractual clause considers and “back-log” concept takes place)
  - Cost of the loss of reputation …

Service performance measurement MTS – Stock out persistency (product unavailability)

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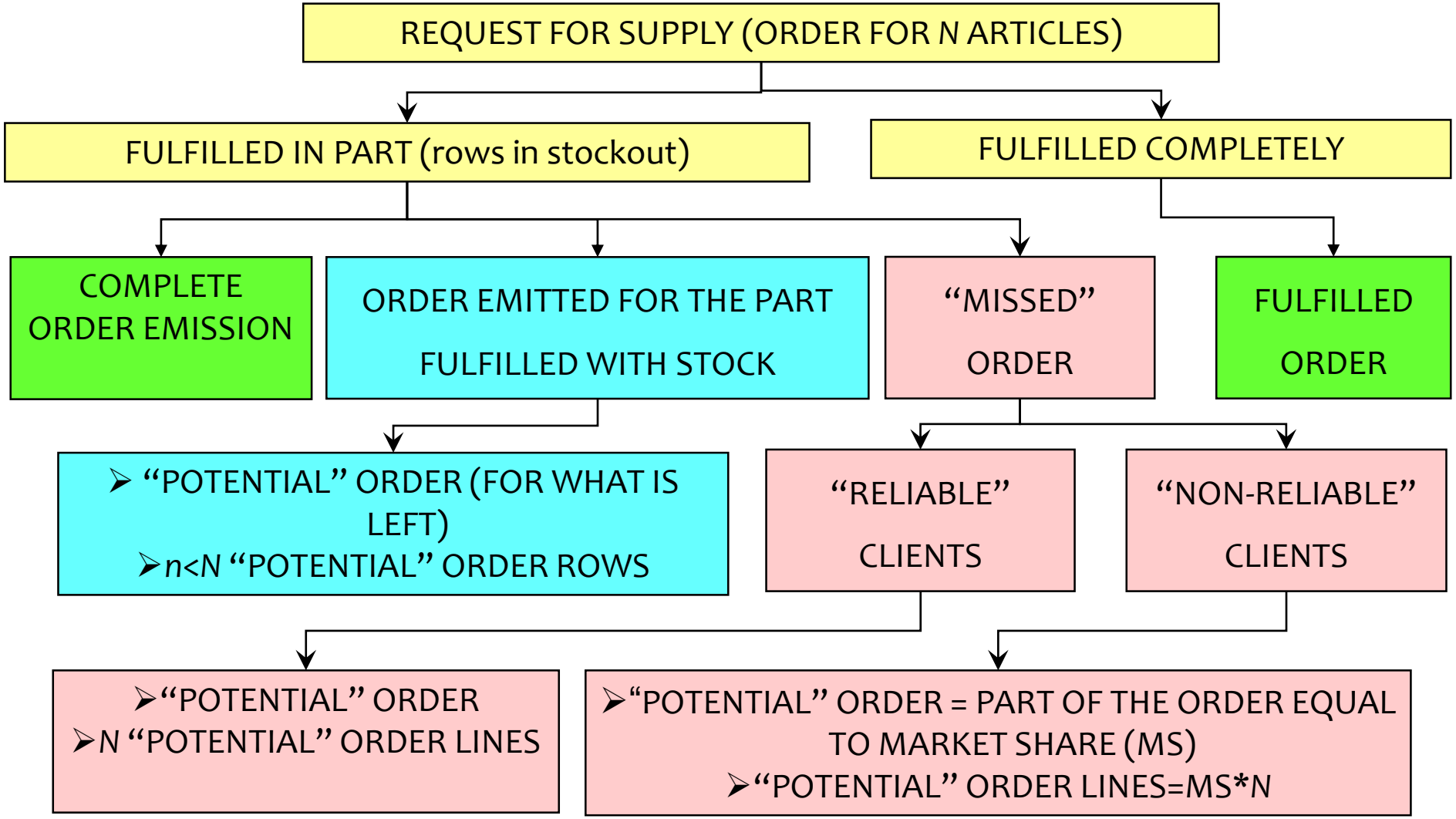
It measures the “going on of the stock-out issue”.

- Physical:
  - Average time of delivery of the orders delivered not “off-the-shelf”
  - N° periods in stock-out / N° total periods.

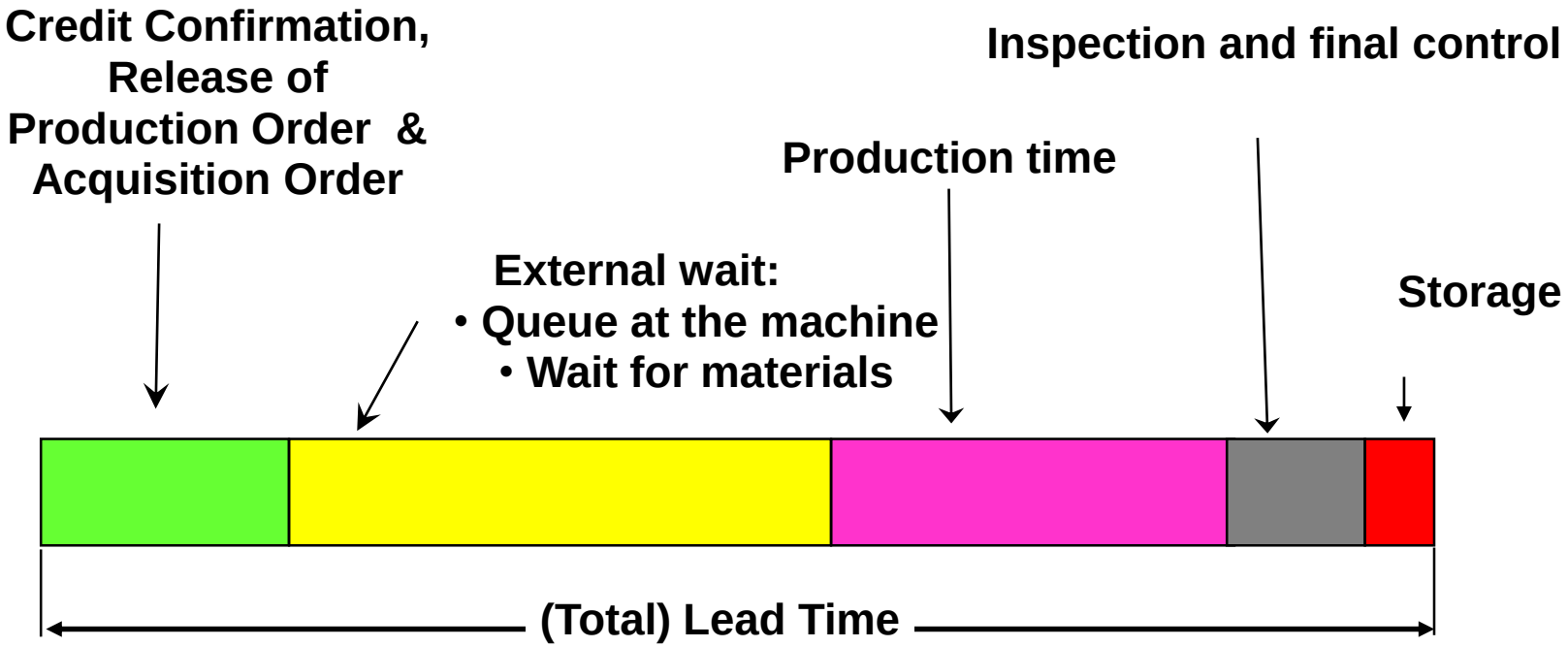
We should evaluate both the “actual” stock-out and the “potential” stock-out, especially in those situations in which it is actually difficult to control the real stock-out occurrence (e.g., the good is not available on the shelf)

The “potential” orders



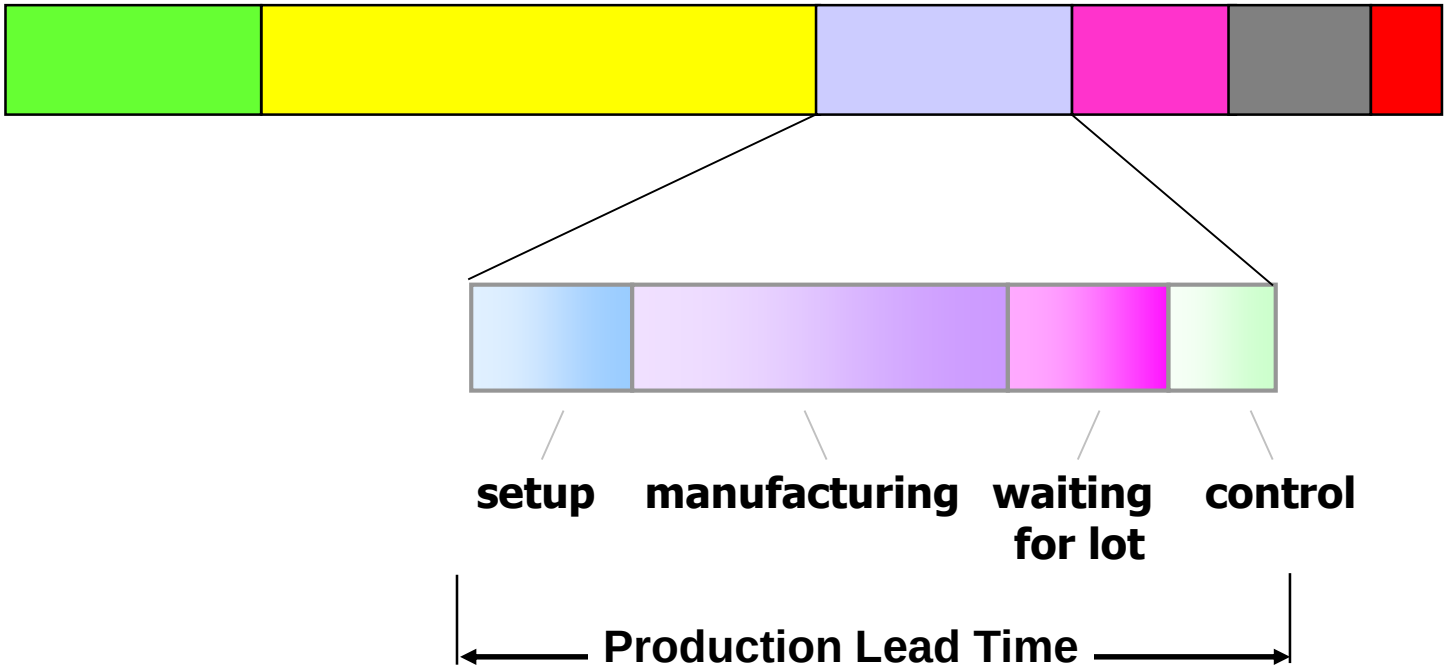
Service performance measurement – The concept of lead time

(Total) Lead Time (of a work order) is the time that is necessary to perform all the activities inside the factory from the customer order arrival to the moment in which the material is ready to be delivered.

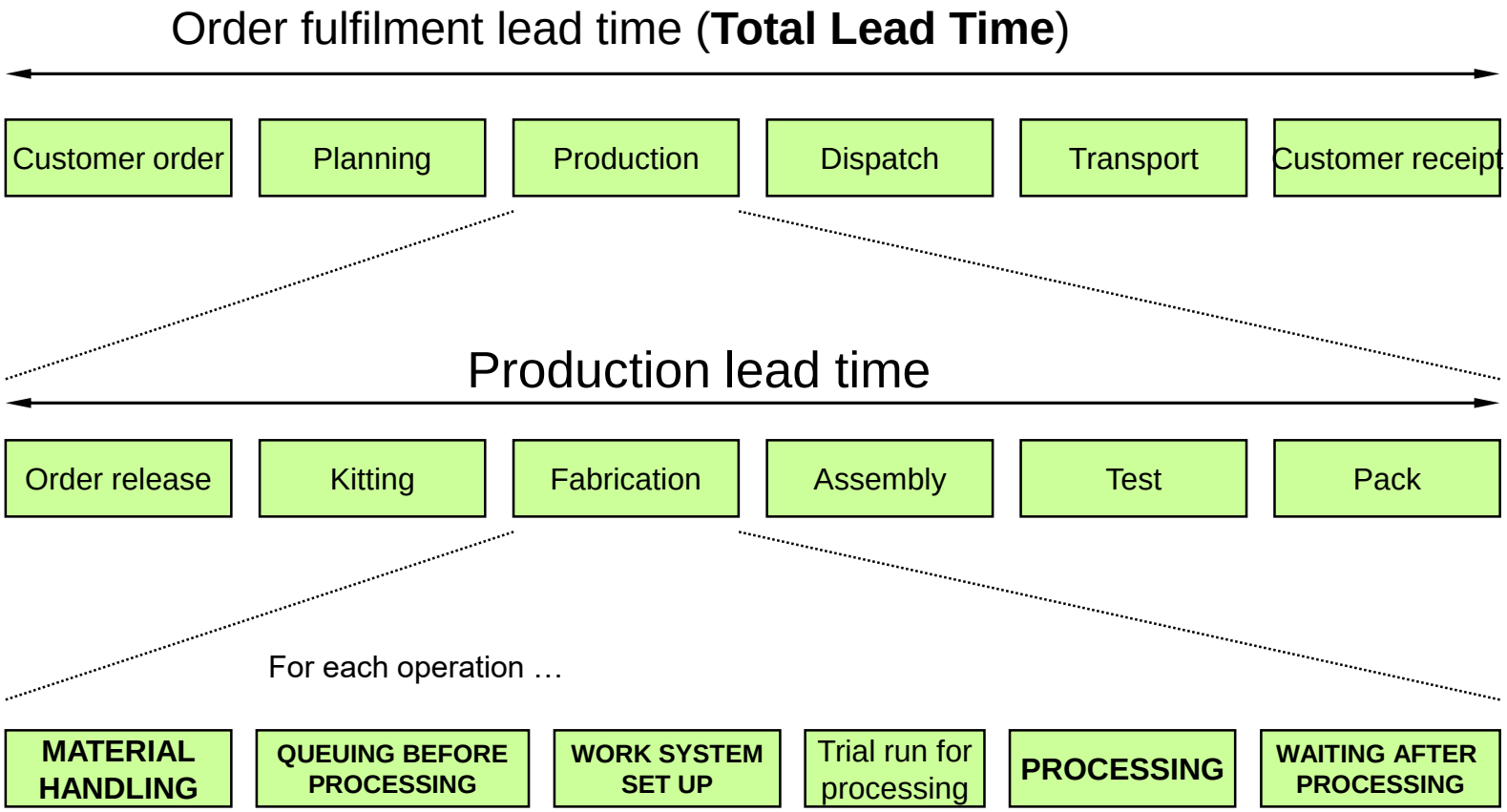


Service performance measurement – The concept of lead time

Also the “production time” is not entirely “productive”…

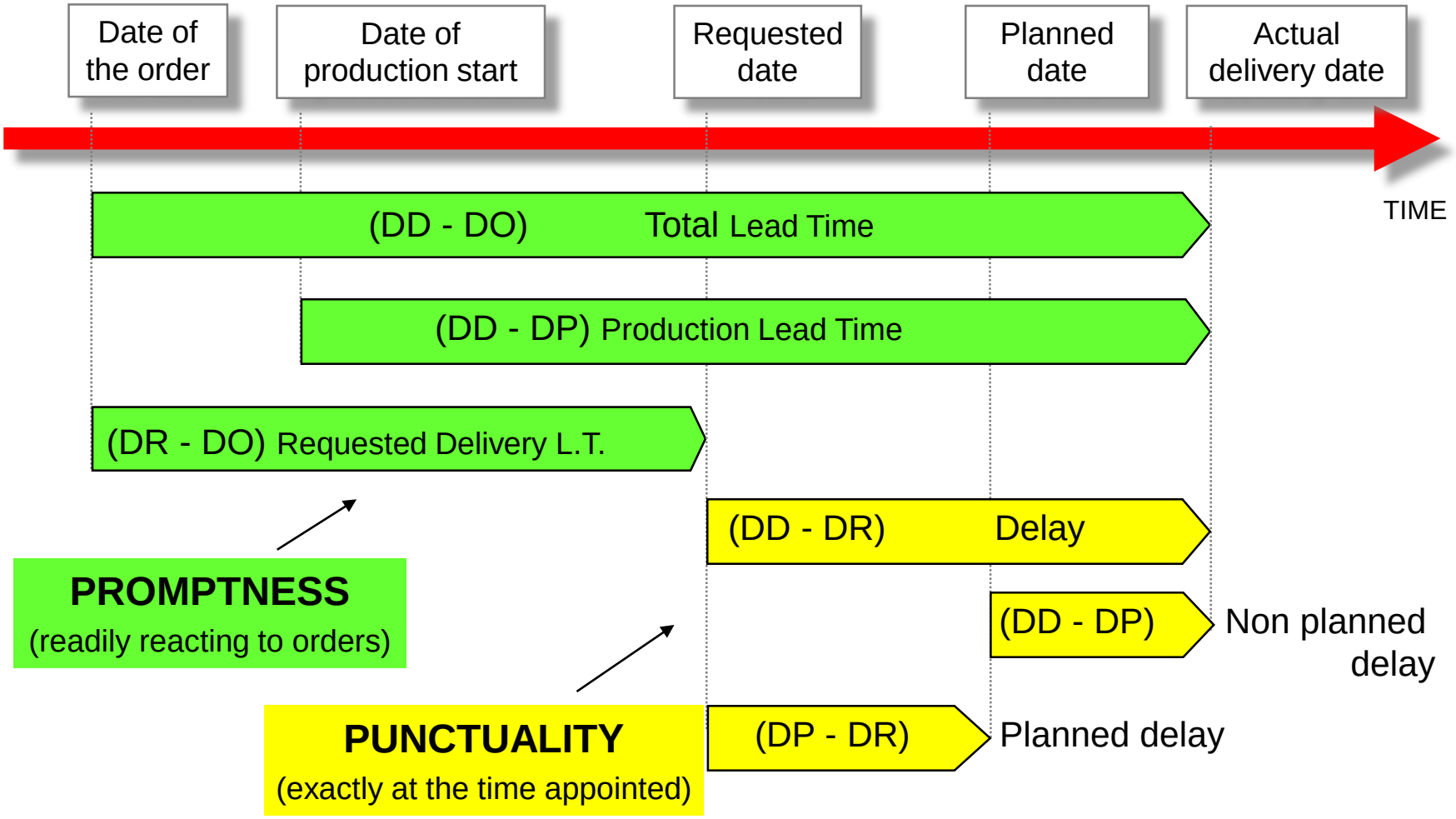


Service performance measurement – The concept of lead time



May also include quality control, setting up CNC programmes, machine breakdown, waiting for repair, repair, operator breaks, quality issues, shortages of parts, detailed planning and control, etc.

Service performance measurement – Performance related to LT: promptness and punctuality



Service performance measurement – Performance related to LT: promptness and punctuality

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The Lead Time is of fundamental importance, in particular with respect to the customer lead time (DLT, delivery lead time)

$$\textbf{Planning Index} = \frac{\text{Delivery Lead Time}}{\text{Total Lead Time}} \lessgtr 1$$

Se IP < 1, MTS (mandatory)

Se IP > 1, ATO/MTO (allowed)

The measure of promptness

It measures the responsiveness of the system, by observing the time elapsed between the date of the emission of the order and the date of the shipment / delivery of the goods to the client.

- Physical:
  - Σ (Delivery Date – Order date) / N° tot orders
  - Σ (Date of full delivery – Order date) / N° tot orders
  - N° orders filled within “x” days / N° total orders
  - N° lines filled within “x” days / N° total lines

The measure of punctuality

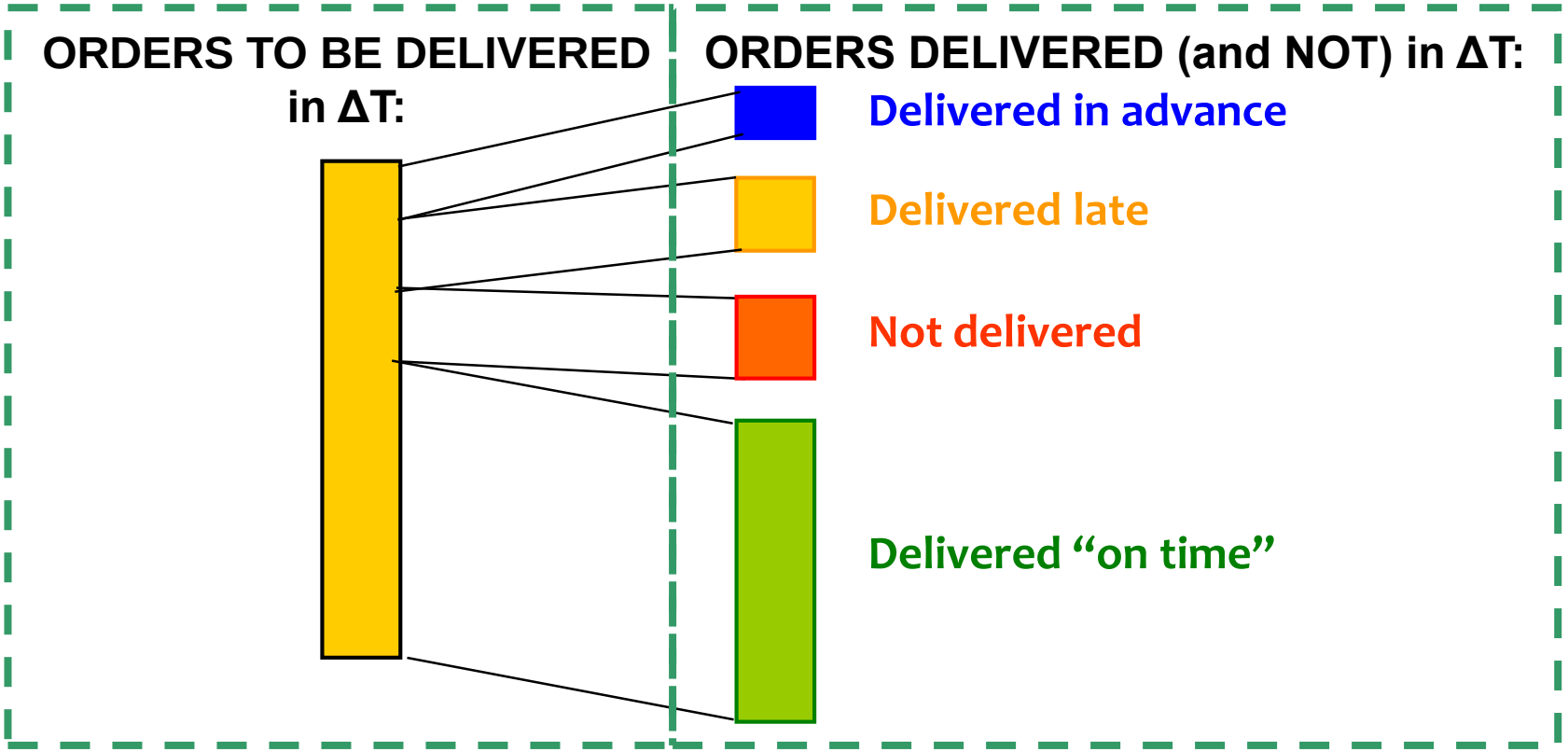
It measures the capability of the system to respect the date requested (or agreed) with the client.

It is the time elapsed from the date requested (or agreed, depending on the client perspective).

- Physical:
  - Number of orders / number of late order lines (absolute, relative)
  - Average delay (measured for all the orders; or only for those that are late)
- Economic:
  - Penalty cost
  - Cost of administrative and management activities duplication

Delivery punctuality

Taking as reference base the orders whose delivery has been promised in the reference period:



Delivery punctuality- performance calculated with respect to the orders to deliver in a certain period

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$$\%\ \text{orders delivered “on time”} = \frac{\#\ \text{orders delivered “on time”}}{\text{Tot orders to deliver in the period}} * 100$$

$$\%\ \text{orders delivered late} = \frac{\#\ \text{orders delivered late}}{\text{Tot orders to deliver in the period}} * 100$$

$$\%\ \text{orders delivered in advance} = \frac{\#\ \text{orders delivered in advance}}{\text{Tot orders to deliver in the period}} * 100$$

$$\%\ \text{orders not delivered} = \frac{\#\ \text{orders not delivered}}{\text{Tot orders to deliver in the period}} * 100$$

Delivery punctuality - performance calculated with respect to the orders to deliver in a certain period

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$$\text{Average delay of the orders delivered late} = \frac{\sum_i (\#\text{ orders delivered late of } i \text{ units of time}) * i}{\#\text{ orders delivered late}}$$

$$\text{Average advance of the orders delivered in advance} = \frac{\sum_i (\#\text{ orders delivered in advance of } i \text{ units of time}) * i}{\#\text{ orders delivered in advance}}$$