Smart Maintenance: Key Performance Indicators

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

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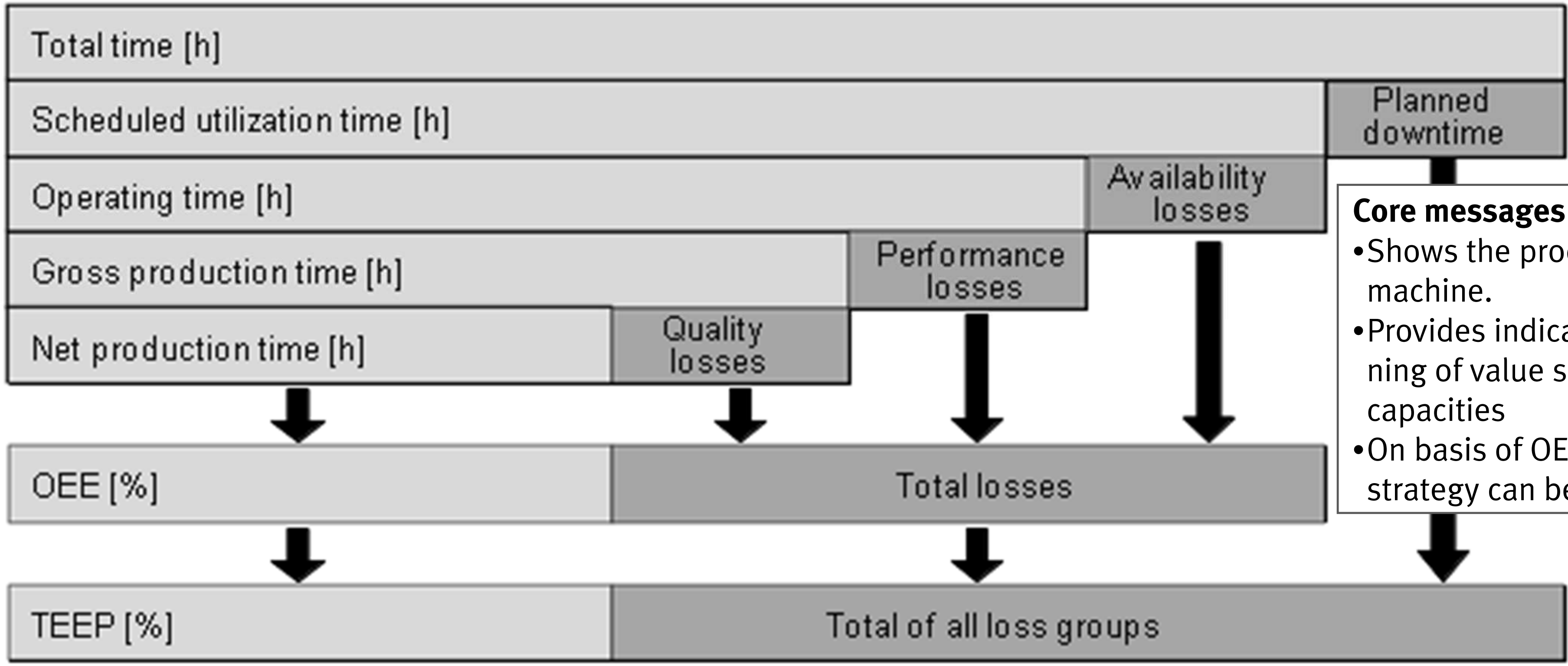
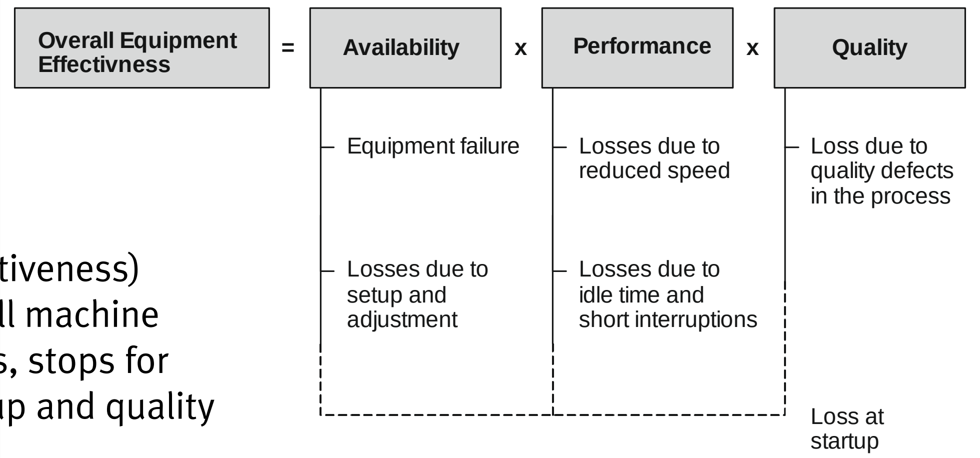
The relation between losses and OEE or TEEP



Core messages of OEE:

- Shows the productivity of a machine.
- Provides indications for the plan-ning of value streams and capacities
- On basis of OEE the maintenance strategy can be defined.

Overall Equipment Effectivness (OEE)



Explanation

The KPI (key performance indicator) OEE (Overall Equipment Effectiveness) gives a complete overview on equipment availability. It captures all machine and equipment downtimes resulting from unscheduled downtimes, stops for setup or adjustment, minor stoppages, reduced speeds and startup and quality losses.

OEE comprises three elements: availability, performance and quality. “Availability” is the ratio of machine runtime (T_{net}) to scheduled utilization time (T_{sched}). “Performance” calculates the ratio between actual processing speed (n_{total} x t_{cycle}) and net processing time (T_{net}). Finally, “Quality” captures the relationship between good parts and total parts.

Formula:

OEE = AR x PR x QR x 100%

$OEE = (T_{Net} / T_{Sched}) \times ((n_{total} \times t_{cycle}) / TL) \times ((n_{total} - n_{rew} - n_{defects}) / n_{total}) \times 100\%$

This formula can be simplified:

$OEE = t_{cycle} \times (n_{total} – n_{rew} – n_{defects}) / T_{sched} \times 100\%.$

Overall Equipment Effectivness (OEE) – Example

Initial situation:

The weekly work time of a turning centre is 10 shifts of 8 hours each. A total of 572 parts were manufactured, of which 2 were rejects and 3 had to be reworked. The cycle time was 6.12 minutes.

$$OEE = \frac{t_{cycle} \cdot \left(n_{total} - n_{rejects} - n_{rework}\right)}{T_{plan}} \cdot 100\%$$

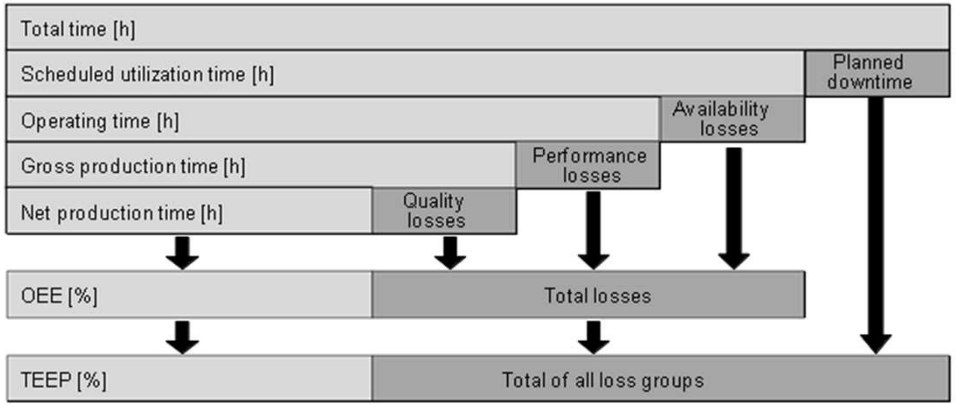
$$OEE = \frac{372\ s \times \left(572 - 3 - 2\right)}{288{,}000\ s} \cdot 100\% = 73.24\%$$

The results of the more detailed OEE formula are more interesting, as they identify the key loss areas. Let us assume that the week under review required 8.5 hours for troubleshooting and job changes.

Availability =	$T_{net} / T_{plan} = 0.89375$
Performance =	$(n_{total} \cdot t_{cycle}) / T_{net} = 0.8266$
Quality level =	$(n_{total} - n_{rejects} - n_{rework}) / n_{total} = 0.99126$
OEE =	$NG \cdot LG \cdot QG \cdot 100\% = 73.24\ \%$

Total Effective Equipment Productivity (TEEP)

Explanation:
TEEP stands for Total Effective Equipment Productivity. TEEP extends the KPI Overall Equipment Effectiveness (OEE) by the scheduled utilization time and, thus, constitutes the ratio between the actual productive time and the theoretically possible productive time for a machine or system.



TEEP is calculated by multiplying the scheduled utilization time by utilization, performance and quality. The scheduled utilization time is calculated as follows:

$$\text{Scheduled time} = \frac{(\text{Total time} - \text{Scheduled downtime})}{\text{Total time}}$$

So, the formula is as follows:

$$\text{TEEP} = \frac{(\text{Total time} - \text{Scheduled downtime})}{\text{Total time}} \cdot \text{OEE}$$

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Total Effective Equipment Productivity (TEEP) – Example

Initial situation:

A turning centre is used for 10 shifts per week, each of 8 hours. The maximum weekly work time is 24 hours x 7 days. The OEE has been calculated as 73.24%.

$$\text{TEEP} = \frac{(\text{Total time} - \text{Scheduled downtime})}{\text{Total time}} \cdot \text{OEE}$$

$$\text{TEEP} = \frac{7\text{ days} \cdot 24\text{ h} - (7\text{ days} \cdot 24\text{ h} - 10\text{ shifts} \cdot 8\text{ h})}{7\text{ days} \cdot 24\text{ h}} \cdot 73.24\%$$

$$\text{TEEP} = \frac{(168\text{ h} - [168 - 80\text{ h}])}{168\text{ h}} \cdot 73.24\% = 34.88\%$$

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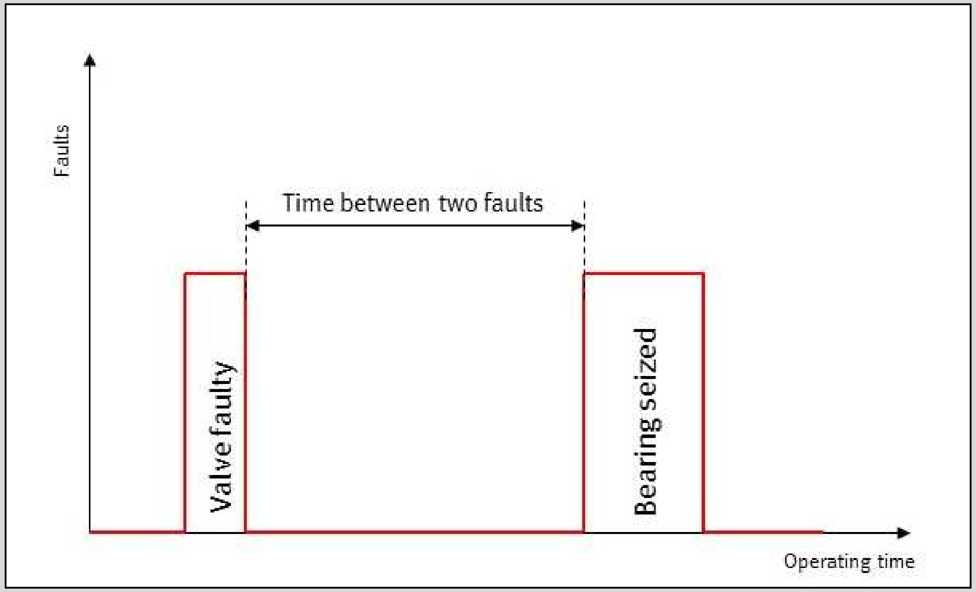
Exercise: Please calculate OEE and TEEP

• Number of shifts:	15 per week
• Production time per shift:	440 min (480 min – 40 min break)
• Cycle time:	0,72 min
• Produced pieces last week:	473 goods
• Reworking:	1 piece
• Quality problems:	4 pieces
• Unplaned stopps:	71 min

Mean Time between Failures (MTBF)



Explanation

The Mean Time Between Failures (MTBF) figure determines the value of fault-free production time of a machine or plant. It thus represents the time between two failures. Using this figure, it is possible to assess the reliability of a machine or plant. The figure can be graphically represented as follows.

Formula:

$$MTBF = \Sigma (T_{\text{failure } n} - T_{\text{failure } n\text{-}1}) / n$$

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Mean Time between Failures (MTBF) – Example

Example:

Occurred on: Date / time	Fault	Cause	Fault index	Resolved on: Date / time	Resolved by	Downtime in min	Fault-free production time in min
13.10.04 6:00	Welding machine transport	Sensor misaligned	m	13.10.05 6:30	Müller	30	1010
13.10.05 23:20	Roll loader unhinged	Hinge worn	m	13.10.05 23:50	Lustlich	30	864
14.10.05 14:14	Air pressure loss	Valve V17 faulty	P	14.10.05 22:10	Hedwig	476	670
15.10.05 9:20	Rotary table not switching	Relay R34 faulty	e	15.10.05 10:00	Augustin	40	520
15.10.05 18:40	Control crashed	Operator error	b	15.10.05 19:50	Hedwig	70	550
16.10.05 5:00	Band tear	Wear	m	16.10.05 6:50	Lustlich	110	
	Total:					**756**	**3614**

$$MTBF = \Sigma\,(T_{Fault\ n} - T_{Fault\ n-1})\ /\ n = (1010 + 864 + 670 + 520 + 550)\ /\ n = 722.8\ \text{min}$$

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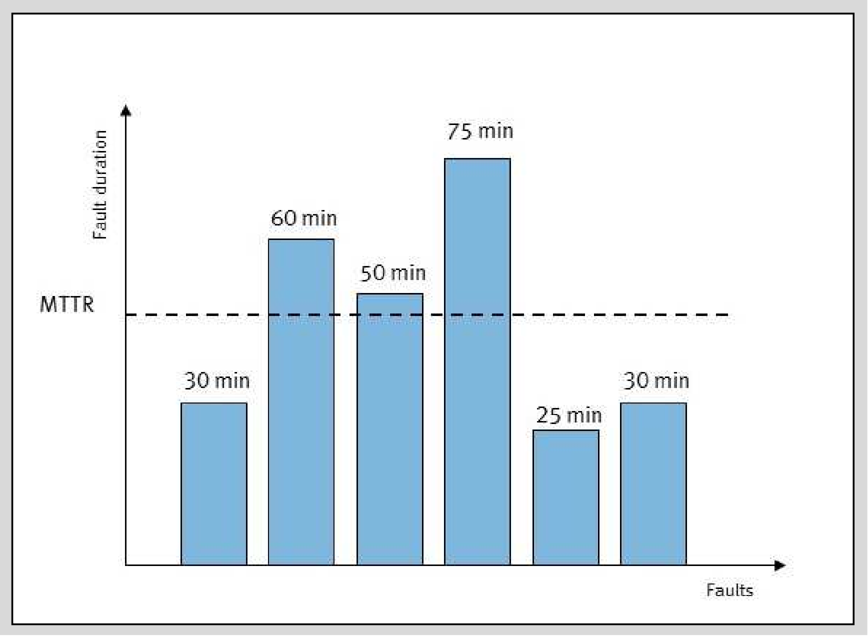
Mean Time to Repair (MTTR)



Explanation:

MTTR is the abbrevation for Mean Time to Repair. The figures shows the avarage time from the moment of fault till the resart of the machine. On basis of this figure, the quality of the repair process can described. On the first hand how fast the information reachs the maintenance operator. On the second hand how fast it is able to repair the machine.

Formula:

MTTR = $(\Sigma_{tr1} + t_{r2} + t_{r3} \ldots + \ldots t_{rn}) / n$

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Mean Time to Repair (MTTR) – Example

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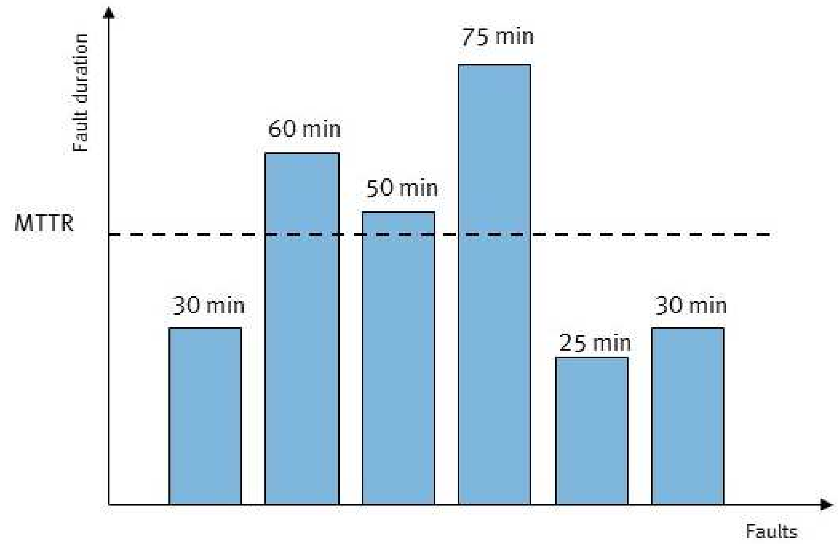

Calculation:

$$MTTR = \Sigma(t_{r1} + t_{r2} + \ldots + t_{rn}) / n_{\text{Number of faults}}$$

$$MTTR = (30 + 60 + 50 + 75 + 25 + 30) / 6$$

$$MTTR = 45 \text{ min}$$

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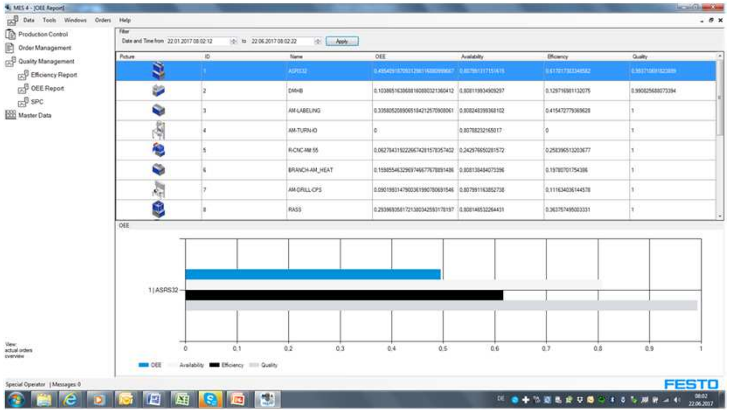
Exercise: Identification of losses with the right maintenance KPI´s



Learning objectives:
Once you have completed this task,
- you know the most important maintenance figures.
- you can determine the values required for this.
- you can calculate them.
- you are able to derive measures to improve the figures.

Problem:
The respective maintenance figures are to be determined for a CP Lab / CP Factory.

Work orders:
1. Read the OEE report (Overall Equipment Effectiveness) and interpret it.
2. Calculate the TEEP (Total Effective Equipment Productivity).
3. Determine the MTTR (mean time to repair).
4. Determine the MTBF (mean time between failures).

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