BỘ GIÁO DỤC VÀ ĐÀO TẠO

HCMC University of Technology and Education

HCMUTE

MAINTENANCE IN INDUSTRY

CHAPTER 4 RELIABILITY – AVAILABILITY – OEE

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1

2

Requirement

- Defects (khiếm khuyết) and Failure (hỏng hóc) classification
- Calculation
  - Reliability (độ tin cậy)
  - Availability (khả năng sẵn sàng)
  - Overall Equipment Effectiveness (hiệu suất tổng thể thiết bị)
- Can solve problems in the given situation

2

3

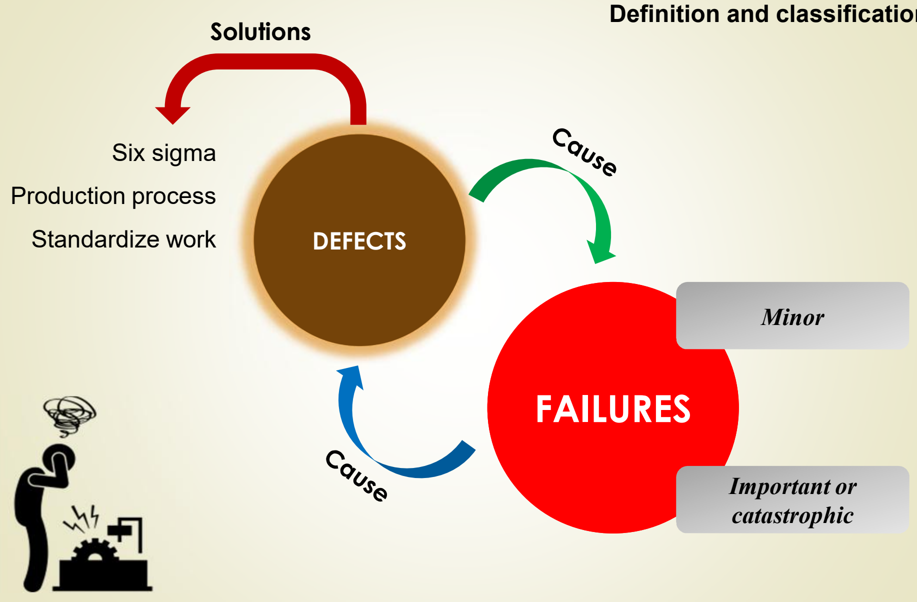
Contents

3

4

I. Defects and Failures

Definition and classification

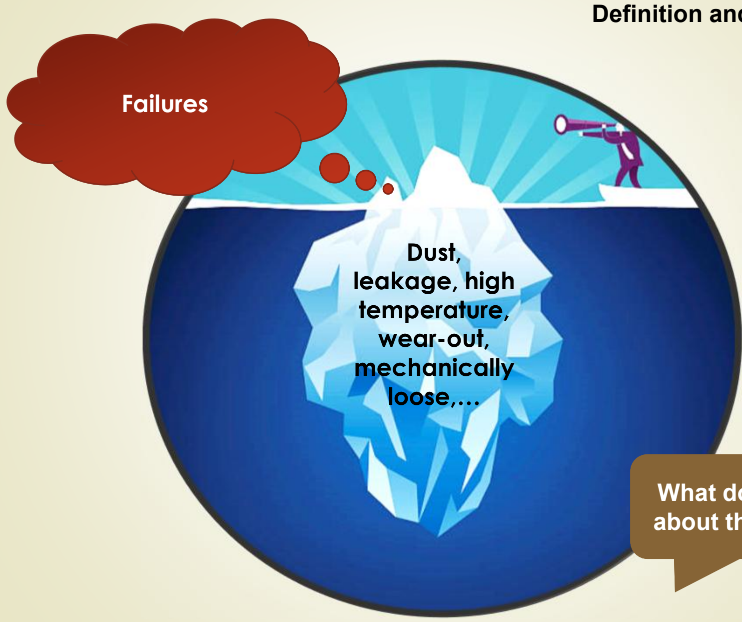


4

5

I. Defects and Failures

Definition and classification



What do you think about this picture?

5

6

Chapter 4

Reliability – Availability – Overall Equipment Effectiveness

6

7

III. Reliability & Availability

Definition

Reliability

Defining the probability that an item will continue to perform its intended function ***without failure*** for ***a specified period of time*** under stated conditions.

Reliability is a performance expectation

It's usually defined at design

Availability

Depends on upon ***Operation uptime*** and ***Operating cycle***.

Availability is a performance result

Equipment history will tell us the availability

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7

8

III. Reliability & Availability

Availability

Some math

$$\textit{Inherent Availability} = \frac{MTBF}{MTBF + MTTR}$$

- **Inherent Availability:** consider only corrective downtime (chỉ tính những lần sửa chữa không có kế hoạch)
- **MTBF:** Mean Time Between Failures (khoảng thời gian trung bình giữa các lần dừng máy đột xuất)
- **MTTR:** Mean Time To Repair (khoảng thời gian trung bình để khắc phục)

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8

III. Reliability & Availability

Availability

Some math

$$Inherent\ Availability = \frac{MTBF}{MTBF + MTTR}$$

$$Achieved\ Availability = \frac{MTBM}{MTBM + M}$$

$$Operational\ Availability = \frac{Uptime}{Operation\ Cycle}$$

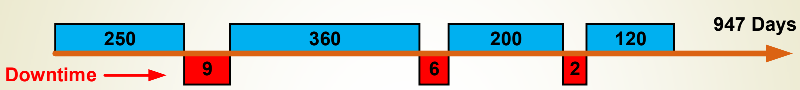
- **Operational Availability:** ratio of the system uptime and total time
- **Achieved Availability:** consider corrective and preventive maintenance (tính cả bảo trì sửa chữa và bảo trì có kế hoạch)
- **MTBM:** Mean Time Between Maintenance actions (khoảng thời gian trung bình giữa những lần dừng máy)
- **M:** Maintenance Mean Downtime (including preventive and planned corrective downtime)

III. Reliability & Availability

Availability

Example

Historically, an equipment has performance as shown in below Figure



$$. MTBF = \frac{250 + 360 + 200 + 120}{4} = 232.5\ (days)$$

$$. MTTR = \frac{9 + 6 + 2}{3} = 5.67\ (days)$$

$$. Inherent\ Availability = \frac{232.5}{(232.5 + 5.67)} = 97.62\%$$

$$. Operational\ Availability = \frac{250 + 360 + 200 + 120}{947} = 98.2\%$$

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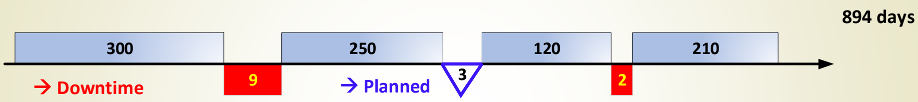
III. Reliability & Availability

11

Availability

Example

Historically, an equipment has performance as shown in below Figure



$$. \, MTBM = \frac{300+250+120+210}{4} = 220 \; (days)$$

$$. \, M = \frac{9+3+2}{3} = 4.67 \; (days)$$

$$. \, Achieved\ Availability = \frac{220}{(220+4.67)} = 97.92\%$$

$$. \, Operational\ Availability = \frac{300+250+120+210}{894} = 98.43\%$$

III. Reliability & Availability

12

Availability

$$Achieved\ Availability \uparrow = \frac{MTBM \uparrow}{MTBM + M \downarrow}$$

To improve Achieved Availability:

- **Improve MTBM:**
  - ✓ Reduce Preventive Programs to a minimum or have Preventive intervals as well defined as possible.
  - ✓ Using Predictive techniques whenever possible
  - ✓ Implementing Maintenance Engineering (RCM, TPM...)
- **Minimize M:**
  - ✓ Implementing Maintenance Engineering (Planning, Logistics...)
  - ✓ Improving personnel technical skills (training)
  - ✓ Developing Integrated Planning (Mntce + Ops + HSE + Inspection+...)

III. Reliability & Availability

Reliability

***Failure Rate* (λ)** (tần suất hư hỏng)

$Failure\ rate\ (\lambda)\ is\ defined\ as\ the\ reciprocal\ of\ MTBF:$

$$\boldsymbol{\lambda = \frac{1}{MTBF}}$$

***Reliability*: $R(t)$**

$Let\ P(t) be\ the\ probability\ of\ failure\ between\ 0\ and\ t;$
$reliability\ is\ defined\ as:$

$$\boldsymbol{R(t) = 1 - P(t)}$$

III. Reliability & Availability

Reliability

Considering rate failure (λ) constant, that R(t), meaning the probability of having operated until instant **t**, is given by:

$$\boldsymbol{R(t) = e^{-\lambda . t}}$$

This reinforces the idea that Reliability is **function of time, it is not a definite number.** So, it's incorrect to affirm: "This equipment has a 0.97 reliability factor…". We should rather say: "This equipment has **97%** reliability for running, let's say, **240 days**…"

15

III. Reliability & Availability

Reliability

Example

Historically, an equipment has 4 failures per year. Which is the reliability of this equipment for a 100 days run?

$$\lambda = \frac{4}{365} \leftrightarrow \lambda = 0.011/day \rightarrow R(100) = e^{-0.011x100} = 0.333 = 33.3\%$$

The probability of having no failure **until 100 days is 33.3%**

Some upgrades have been made, so failure rate now is 2 per year (meaning that MTBF has doubled). Which is the reliability for a 100 days run?

$$\lambda = \frac{2}{365} \leftrightarrow \lambda = 0.0055/day \rightarrow R(100) = e^{-0.0055x100} = 0.577 = 57.7\%$$

The probability of having no failure **until 100 days is 57.7%.**

→ As seen, doubling MTBF **doesn't double** reliability.

16

III. Reliability & Availability

Reliability

Example

Historically, an equipment has a MTBF = 200 days. To improve 10% its reliability to operate on a 100 days run, which percent should MTBF be improved?

$$\lambda = \frac{1}{200} = 0.005/day \rightarrow R(100) = e^{-0.005\,x\,100} = 0.607 = 60.7\%$$

To improve this reliability in 10%, new reliability should be:

$$R'(100) = 1.1\,x\,0.607 = 0.668 = e^{-\lambda\,x\,100}$$

$$\ln 0.668 = -\lambda' x\,100 \leftrightarrow -0.403 = -\lambda' x\,100 \leftrightarrow \lambda' = 0.00403$$

$$\frac{1}{MTBF'} = 0.00403 \leftrightarrow MTBF' = 248\ days$$

$$\rightarrow \frac{248}{200} = 1.24 \rightarrow MTBF\ should\ improve\ 24\%$$

17

III. Reliability & Availability

Reliability

Example

As per the manufacturer, an equipment has a 90% reliability to run over one year. If you want to have a 95% confidence that it will not fail, how long should it take until the equipment undergo a Preventive maintenance or some predictive technique?

$$0.9 = e^{-\lambda\, x\, 365} \leftrightarrow \ln 0.9 = -\lambda\, x\, 365 \leftrightarrow -0.1054 = -\lambda\, x\, 365 \leftrightarrow \lambda = 2.89\, x\, 10^{-4}/\text{day}$$

$$0.95 = e^{-\lambda\, x\, t} \leftrightarrow \ln 0.95 = -\lambda\, x\, t \leftrightarrow -0.0513 = -\, 2.89\, x\, 10^{-4}\, x\, \text{t} \leftrightarrow t = 177.5\ days$$

For practical purposes, this equipment could be in a semester preventive / predictive program.

17

18

III. Reliability & Availability

Reliability

SYSTEM

- Series (nối tiếp)
- Parallel (song song)
- Mixed (Series & Parallel)

18

19

III. Reliability & Availability

Reliability

SYSTEM IN SERIES

Let P_1 = 5%, P_2 = 10% and P_3 = 20% be the failure probability of each component of this system, in a certain period. Which is the reliability of this system, in series?

This system will run, provided that **ALL** its components **run**. So, their **reliabilities** are **multiplied**.

$R_1 = 1 - P_1 = 1 - 0.05 = 0.95$

$R_2 = 1 - P_2 = 1 - 0.10 = 0.90$

$R_3 = 1 - P_3 = 1 - 0.20 = 0.80$

$R = R_1 \times R_2 \times R_3 = 0.95 \times 0.90 \times 0.80 =$ **0.6840 = 68.4%**

System failure probability → **31.6%**

→ System failure probability is bigger than each individual component. System reliability is less than each component.

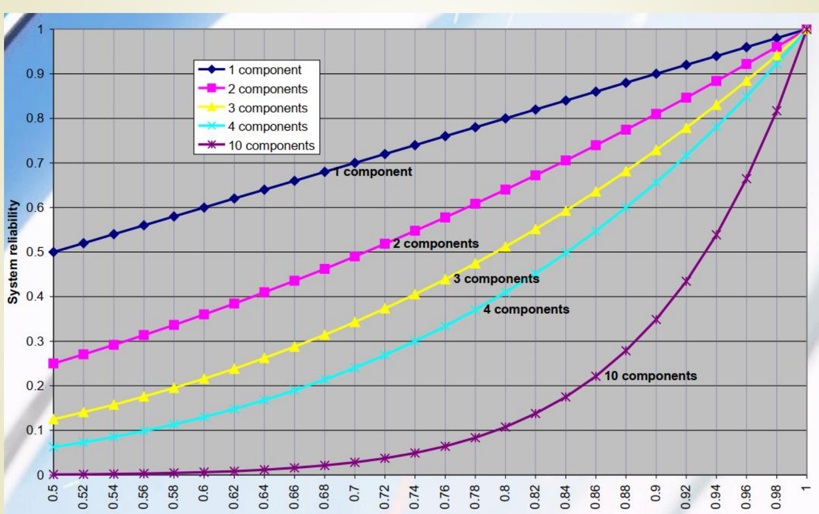
19

20

III. Reliability & Availability

Reliability

SYSTEM IN SERIES

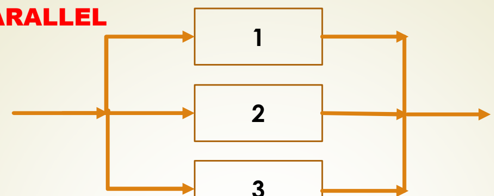


20

21

III. Reliability & Availability

SYSTEM IN PARALLEL **Reliability**



Let $P_1 = 5\%$, $P_2 = 10\%$ and $P_3 = 20\%$ be the failure probability of each component of this system, in parallel, in a given period. Which is the reliability of the system, in parallel?

This system will run until **ALL** components **fail**. In this case, the **failure probabilities** are **multiplied**.

$P = P_1 \times P_2 \times P_3 = 0.05 \times 0.10 \times 0.20 = 0.0010$

R = 1 – P = **0.999 = 99.9%**

System failure probability → **0.1%**

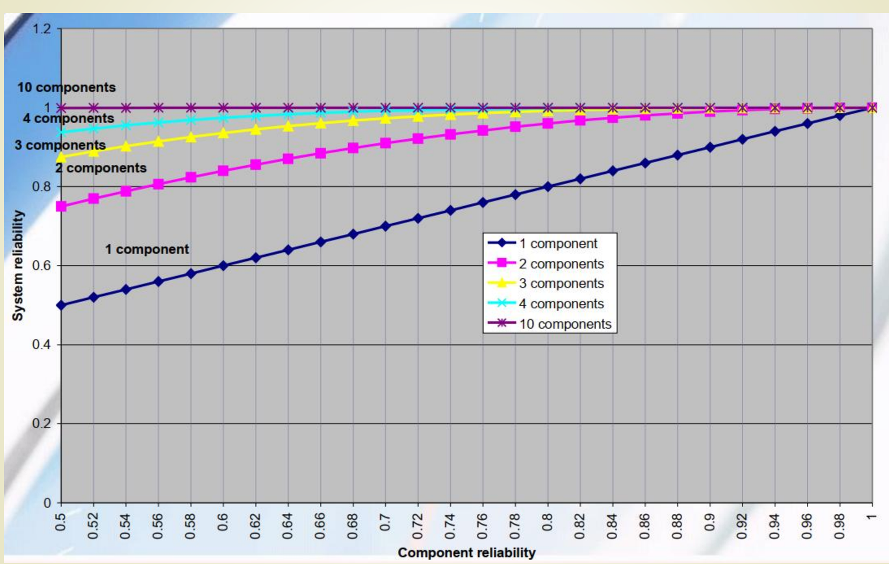
→ System failure probability is less than each component. System reliability is bigger than each component.

21

22

III. Reliability & Availability

SYSTEM IN PARALLEL **Reliability**



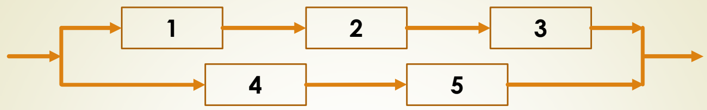
22

23

III. Reliability & Availability

Reliability

MIXED SYSTEM



If P_1 = 10%, P_2 = 5%, P_3 = 15%, P_4 = 2% and P_5 = 20%, which is the system reliability?

$R_1 = 1 – 0.10 = 0.90$

$R_2 = 1 – 0.05 = 0.95$

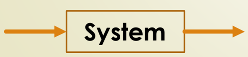
$R_3 = 1 - 0.15 = 0.85$

- $R_{123} = 0.9 \times 0.95 \times 0.85 = 0.7268$
- $P_{123} = 0.2733$

$R_4 = 1 – 0.02 = 0.98$

$R_5 = 1 – 0.20 = 0.80$

- $R_{45} = 0.98 \times 0.80 = 0.7840$
- $P_{45} = 0.2160$



$P_{system} = 0.2733 \times 0.2160 = 0.0590$

$R_{system} = 1 – 0.0590 = 0.941 =$ **94.1%**

24

Chapter 4

Reliability – Availability – Overall Equipment Effectiveness

I. Defects and Failures

II. **Reliability & Availability**

III. Overall Equipment Effectiveness

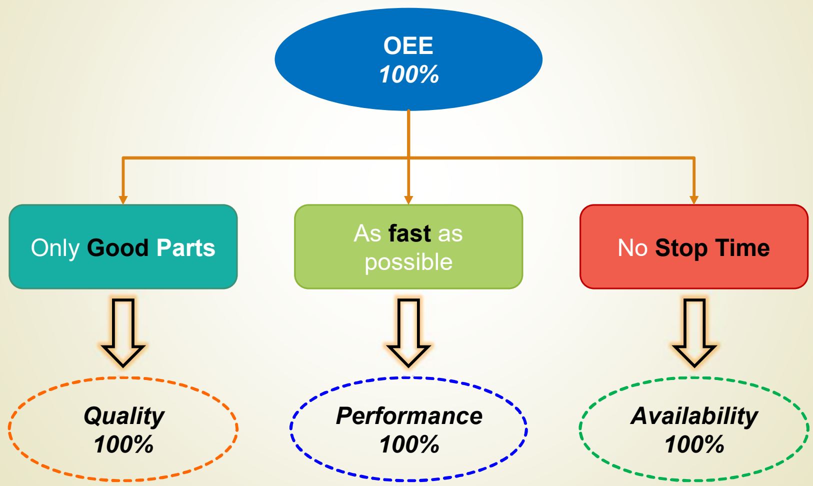
- Definition
- Calculating OEE
- World-class OEE

25

III. Overall Equipment Effectiveness - OEE

Definition

OEE (Overall Equipment Effectiveness) is the gold standard for measuring manufacturing productivity



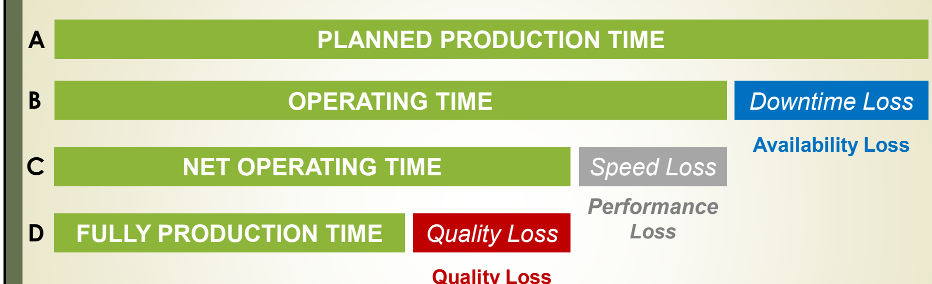
25

26

III. Overall Equipment Effectiveness - OEE

Calculating OEE

Understanding of waste in the manufacturing process



26

27

III. Overall Equipment Effectiveness - OEE

Calculating OEE

It is calculated as the ratio of **Actual Operating Time** *(thời gian hoạt động thực tế)* to **Planned Production Time** *(thời gian sản xuất theo kế hoạch)*:

$$Availability = \frac{Actual\ Operating\ Time}{Planned\ Production\ Time} = \frac{T-(T_1+T_2)}{T}$$

- ***Planned Production Time*** = *Plant Operating Hours – Planned Shut Down Time*
- ***Plant Operating Hours:*** Uptime of equipment
- ***Planned Shut Down Time:*** Periods when not scheduled (required) to produce (e.g. weekends , off-shifts, breaks, lunch, etc). If your scheduled to run during breaks and lunches this is not considered Planned Shutdown Time.
- ***T_1:*** Total Breakdown Time *(tổng thời gian dừng máy không kế hoạch)*
- ***T_2:*** Total Planned Shutdown Time *(tổng thời gian dừng máy có kế hoạch)*

27

28

III. Overall Equipment Effectiveness - OEE

Calculating OEE

It is calculated as the ratio of **Net Run Time** *(năng suất thực tế)* to **Run Time** *(năng suất thiết kế)*. In practice, it is calculated as:

$$Performance = \frac{Net\ Run\ Time}{Run\ Time} = \frac{\frac{q}{T-(T_1+T_2)}}{S}$$

- **q:** Total product.
- **S:** number of products that the machine can produce according to the design.

28

29

III. Overall Equipment Effectiveness - OEE

Calculating OEE

Quality is calculated as:

$$Quality = \frac{Good\ Parts}{Total\ Parts} = \frac{q - q_1}{q}$$

- q_1: Total not good count

29

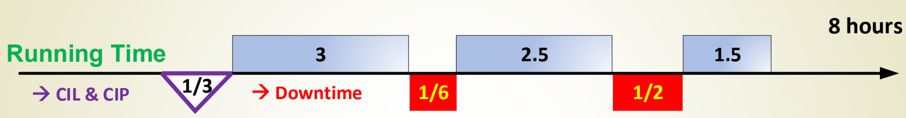
30

III. Overall Equipment Effectiveness - OEE

Calculating OEE

Example

Historically, an equipment has performance in the shift as shown in below Figure.



Equipment has produced total 20.000 products, whereas there are 1000 not good product. The rate capacity of equipment is 3000 pph (products per hours). Define OEE score

$$A = \frac{T - (T_1 + T_2)}{T} = \frac{8 - \left(\frac{1}{6} + \frac{1}{2} + \frac{1}{3}\right)}{8} = 87.5\% \qquad Q = \frac{Good\ Product}{Total\ Product} = \frac{20000 - 1000}{20000} = 95\%$$

$$P = \frac{\frac{q}{T - (T_1 + T_2)}}{S} = \frac{\frac{20000}{8 - \left(\frac{1}{6} + \frac{1}{2} + \frac{1}{3}\right)}}{3000} = 95.24\%$$

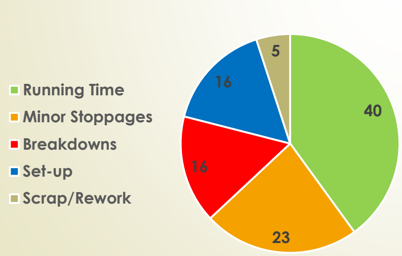
$$OEE = A \times P \times Q = 79\%$$

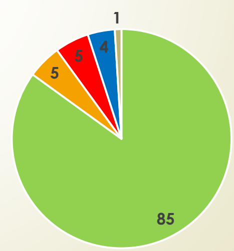
30

31

III. Overall Equipment Effectiveness - OEE

World-class OEE

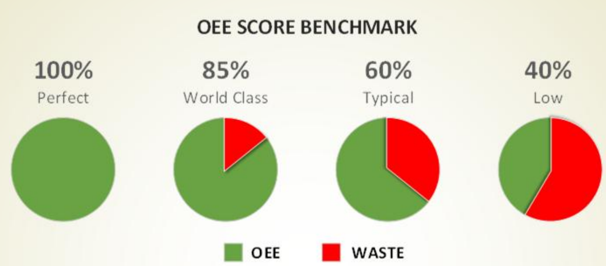




32

III. Overall Equipment Effectiveness - OEE

World-class OEE



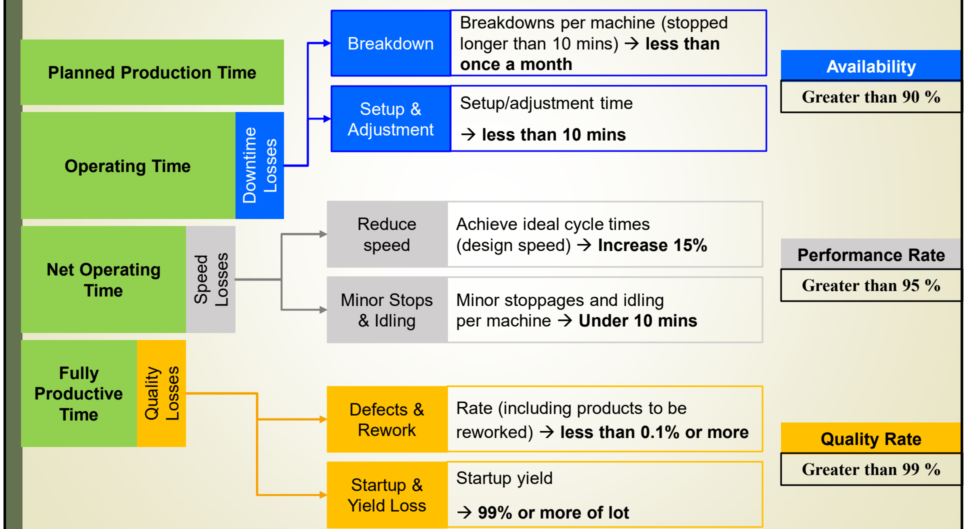
- An OEE score of ***100%*** is **perfect** production (hệ thống hoàn hảo)
- An OEE score of ***85%*** is **world class** for discrete manufacturers (tiêu chuẩn)
- An OEE score of ***60%*** is fairly **typical** for discrete manufacturers (phổ biến)
- An OEE score of ***40%*** is not uncommon for manufacturers without TPM and/or lean programs (thấp)

33

III. Overall Equipment Effectiveness - OEE

World-class OEE

Improving Six Big Losses



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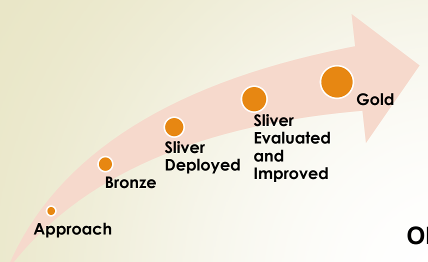
33

34

III. Overall Equipment Effectiveness - OEE

World-class OEE



OEE BASELINE

OEE baseline	Bronze	Sliver	Gold
0 – 30%	45%	60%	80%
31 – 49%	55%	65%	80%
50 – 59%	65%	75%	82%
60 – 69%	70%	80%	84%
70 – 79%	80%	83%	86%
80 – 85%	85%	86%	88%

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34

35