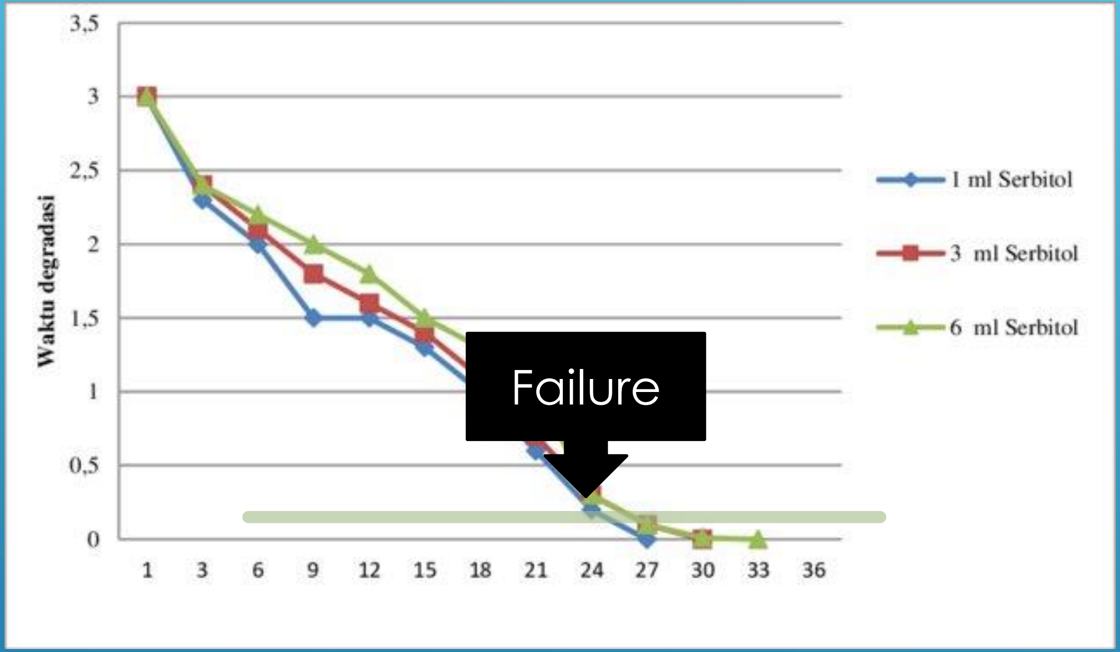
RELIABILITY DEGRADATION AND OPTIMAL MAINTENANCE FOR INFORMATION EQUIPMENT INSTALLED ON RAILWAY CARS

Purpose

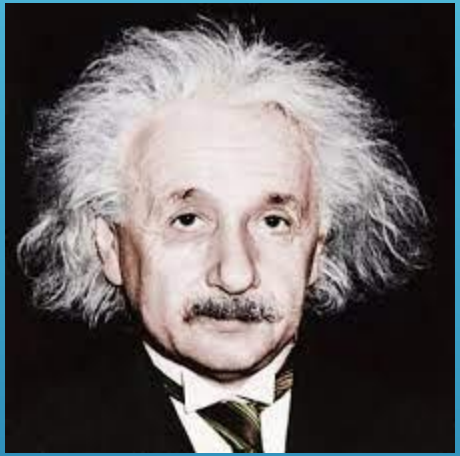
1. Scope
2. Brownian Motion - cause of many degradation processes
3. Analyzing Degradation Data
4. Resulting Reliability functions
5. Maintenance Costs

Typical degradation curve



Analyzed : Luminosity of Screen on Railway

Albert Einstein



- Ph D Thesis : Brownian Motion
- Noble Prize : photoelectric effect
- LED’s : Reverse Photoelectric Effect

THE RENDEZ-VOUS

- See Peskir
- 1905 Einstein : Heat equation (Brownian Motion)
- 1914 Fokker , 1917 Planck add non constant drift :
- 1924 Wiener proves the existence of a stochastic process satisfying the Einstein's postulates
- 1931 – Kolmogorov systematic study of the above forward equation
-

$$p_t = D p_{xx}$$

$$p_t = -(\mu p)_y + (D p)_{yy}$$

Ott & Gua

HISTORY OF AN EQUATION

WHY BROWNIAN

Definition 1. A *standard (one-dimensional) Wiener process* (also called *Brownian motion*) is a stochastic process $\{W_t\}_{t\geq 0+}$ indexed by nonnegative real numbers t with the following properties:

(1) $W_0 = 0$.
(2) With probability 1, the function $t \to W_t$ is continuous in t.
(3) The process $\{W_t\}_{t\geq 0}$ has *stationary, independent increments*.
(4) The increment $W_{t+s} - W_s$ has the $\text{NORMAL}(0, t)$ distribution.

- A particular case :
- Degradation of normally distributed parameters
- Continuous
- Increments :IID, Normally distributed

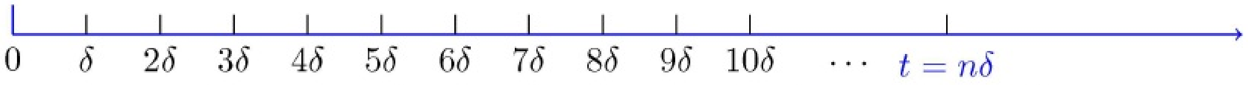


Figure 11.30 - Dividing the half-line $[0, \infty)$ to tiny subintervals of length δ.

$$X_i = \begin{cases} \sqrt{\delta} & \text{with probability } \frac{1}{2} \\ -\sqrt{\delta} & \text{with probability } \frac{1}{2} \end{cases}$$

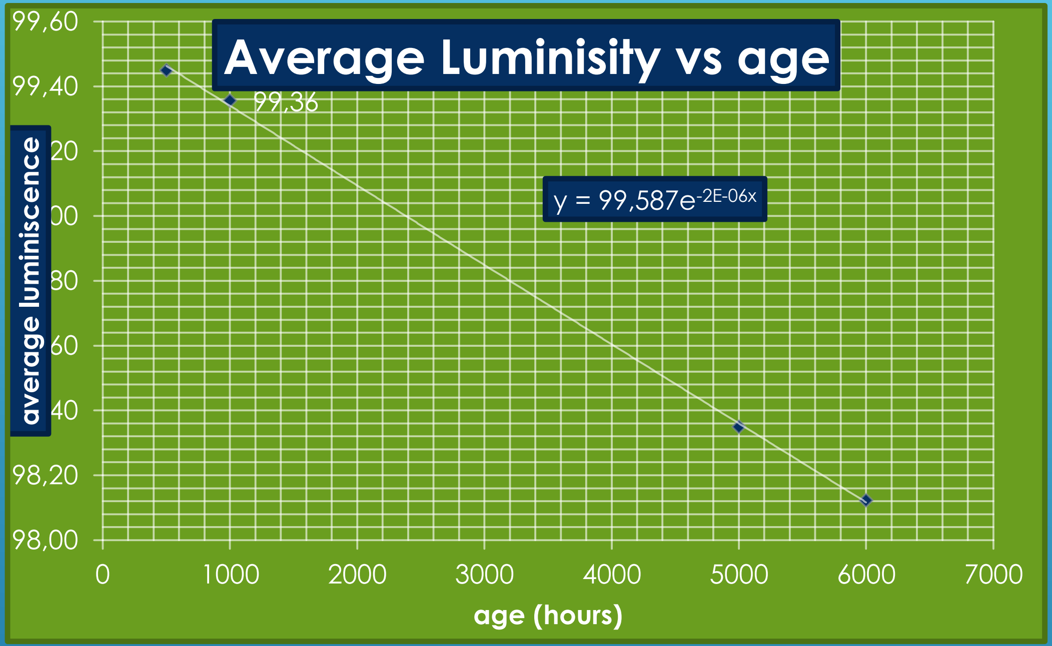
$$W(t) = W(n\delta) = \sum_{i=1}^{n} X_i.$$

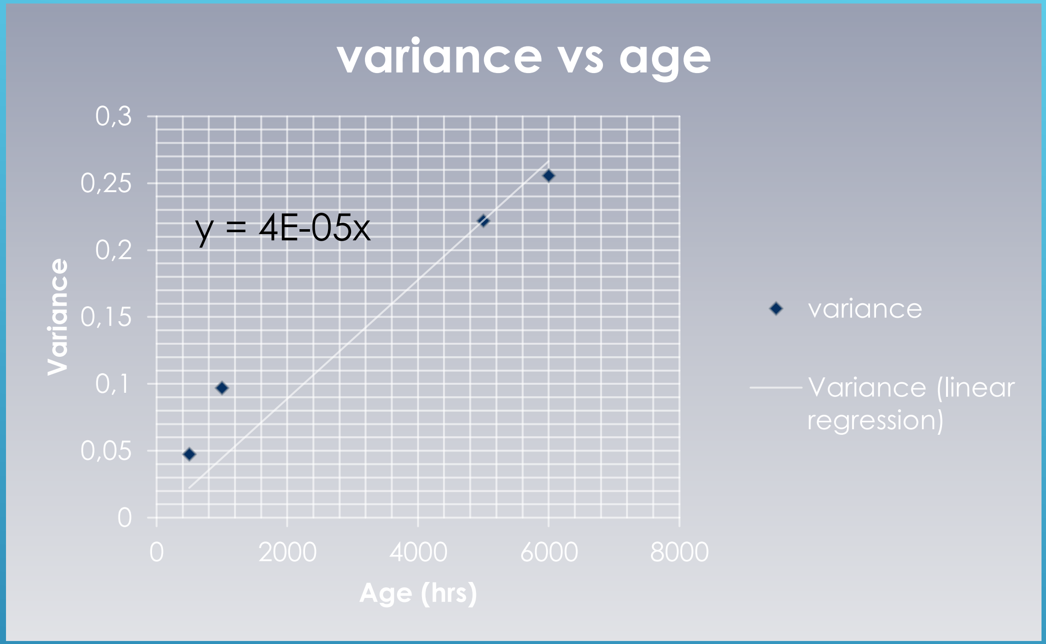
$$\begin{aligned} E[W(t)] &= \sum_{i=1}^{n} E[X_i] \quad) \\ &= 0, \\ \mathrm{Var}(W(t)) &= \sum_{i=1}^{n} \mathrm{Var}(X_i \\ &= n\mathrm{Var}(X_1) \\ &= n\delta \\ &= t. \end{aligned}$$

EXPECTATION AND VARIANCE OF A RANDOM WALK

Head / tails

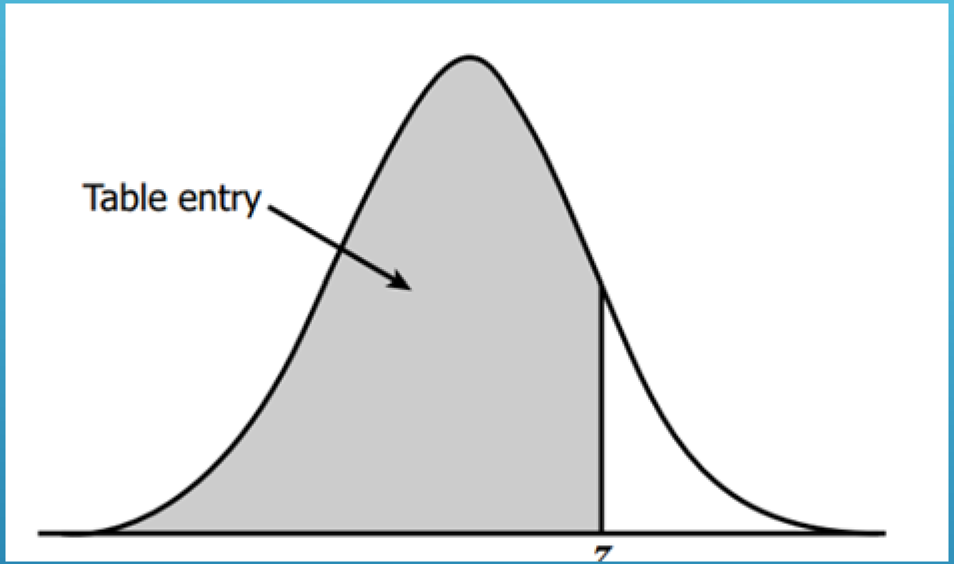
S. E. L. B. quality team, \Report no. : Sled-13-007 lm80 test report," Samsung Electronics LED Business,Korea, Tech. Rep., 2018.

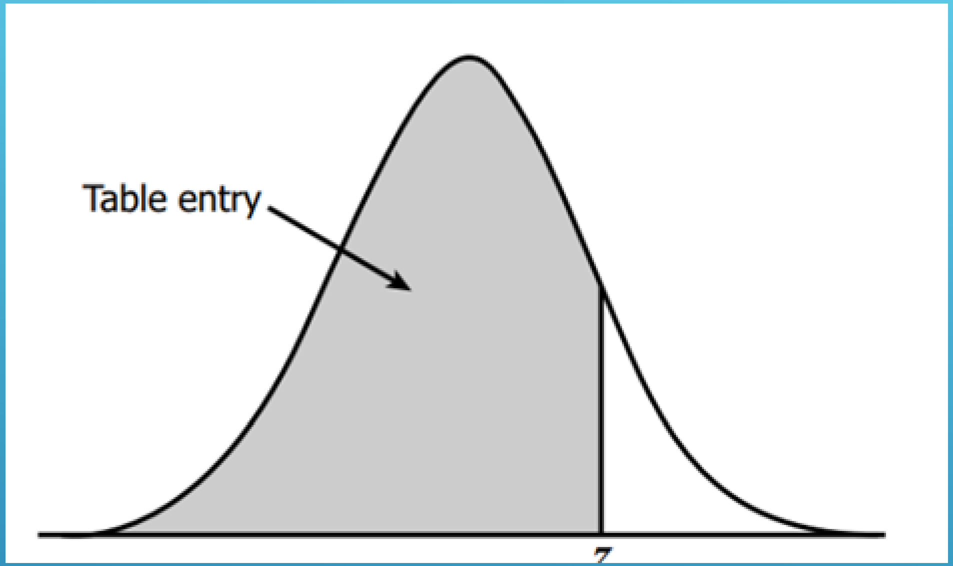




ANALYSIS OF SAMSUNG'S REPORT

Approaches by average Ott,Guo



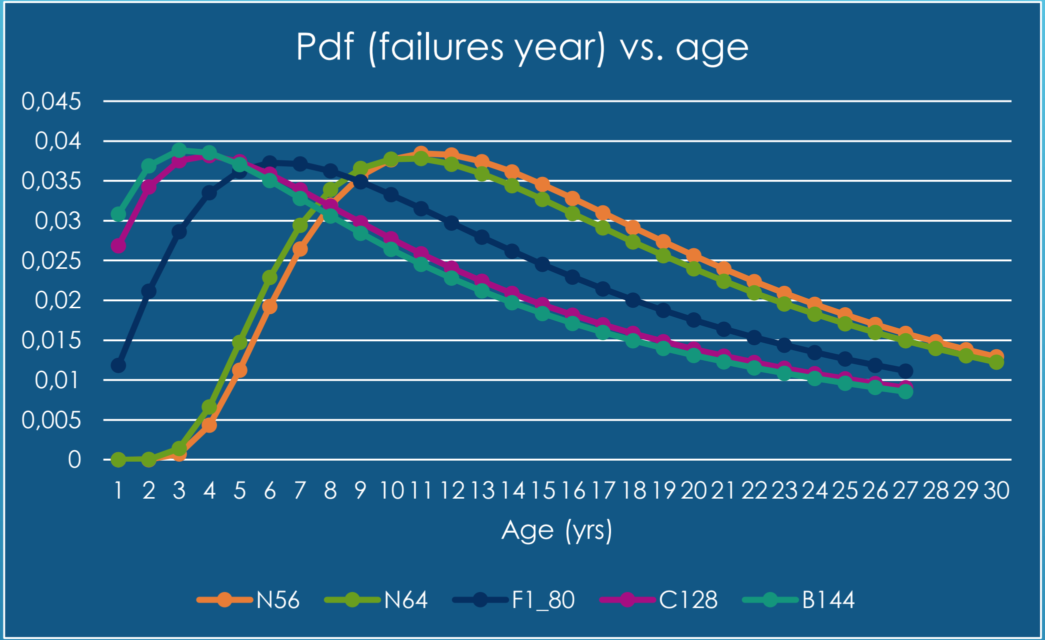


Z –SCORE

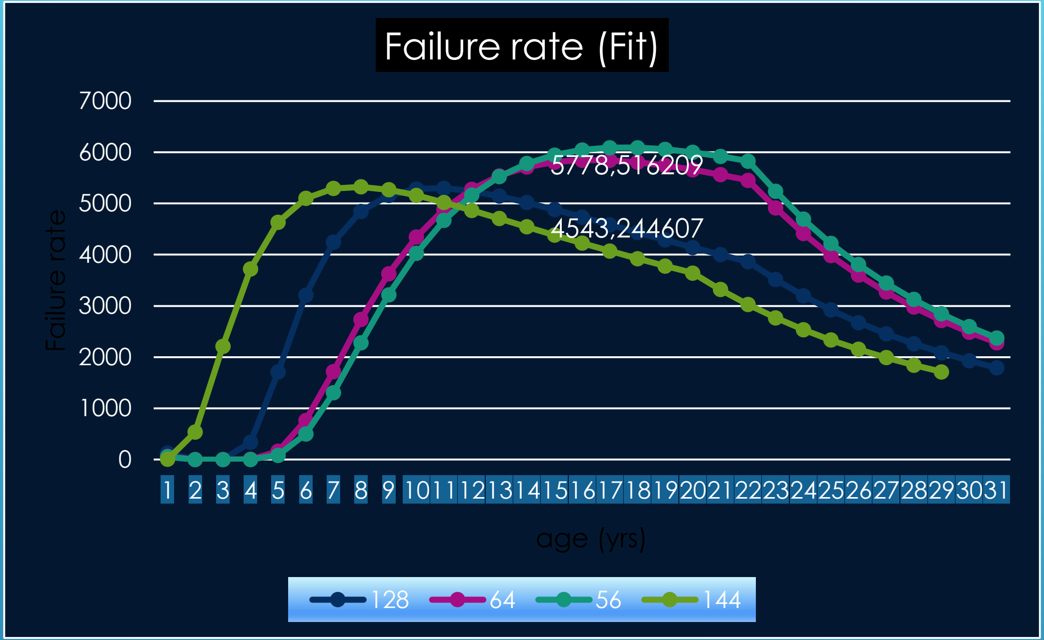
RELIABILITY FUNCTIONS

yrs	zN	R(t)	cdf	pdf	FR
1	6.272566324	1	1.77573E-10	1.77573E-10	1.77573E-10
2	4.164280423	0.999984383	1.56168E-05	1.56166E-05	1.56169E-05
3	3.182617828	0.999270249	0.000729751	0.000714134	0.000714655
4	2.571136232	0.994931728	0.005068272	0.004338522	0.004360622
5	2.13701834	0.98370175	0.01629825	0.011229978	0.011416039
6	1.80489899	0.964454755	0.035545245	0.019246995	0.019956348
7	1.538259693	0.938007435	0.061992565	0.02644732	0.028195214
8	1.316888649	0.906062024	0.093937976	0.03194541	0.035257421
9	1.128529518	0.870451821	0.129548179	0.035610203	0.040910022
10	0.965235744	0.832786626	0.167213374	0.037665195	0.045227905
11	0.821584015	0.794343155	0.205656845	0.038443471	0.048396554
12	0.693719686	0.756070991	0.243929009	0.038272164	0.050619802
13	0.578811178	0.718641706	0.281358294	0.037429285	0.052083374
14	0.474720788	0.682507001	0.317492999	0.036134705	0.05294408
15	0.379797038	0.647951959	0.352048041	0.034555041	0.053329635
16	0.292738712	0.615139061	0.384860939	0.032812898	0.053342245
17	0.21250297	0.584142669	0.415857331	0.030996392	0.05306305
18	0.138241532	0.554975234	0.445024766	0.029167436	0.052556284
19	0.069255288	0.527606792	0.472393208	0.027368441	0.051872799

Xiao-sheng ' s approach



Pdf (failures year) vs. age
0,045
0,04
0,035
0,03
0,025
0,02
0,015
0,01
0,005
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Age (yrs)
N56 N64 F1_80 C128 B144



Failure rate (Fit)
7000
6000
5000
4000
3000
2000
1000
0
Failure rate
5778,516209
4543,244607
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
age (yrs)
128 64 56 144

MAINTENANCE & SPARE STORE

AVERAGE NO OF FAILURES IN AN INTERVAL

Definition: Uj(t)

- $U_j(t)$= Prob of j or more failures until t
- $U_1(t)$= 1-R(t)

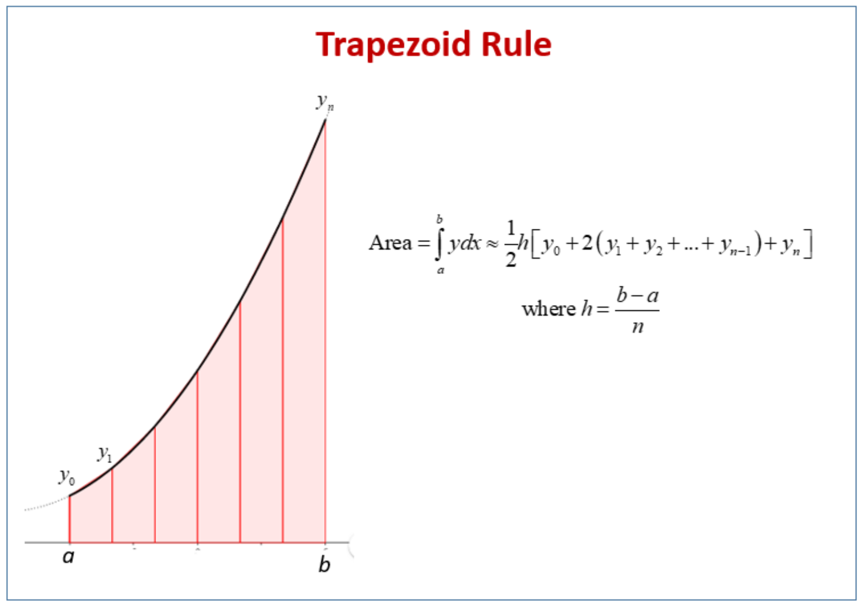
$r(t) = \sum_{i=1}^{n} U_j(t)$

Iterative calculation of Uj(t) Feller

$$\mathrm{U}_j(t) = \int_{\tau=0}^{t} \mathrm{U}_{j-1}(t-\tau) f(\tau) d\tau$$

Convolusion

Integral evaluated by trapezoidal rule
n must be large enough to ensure quasi linearity of the integrand



Correction for Non Linearity

Poisson For each Δt

For small fleets a correction is needed because λ is not constant and not linear

γ=TAT/Δt

Use $D = N$r(t)(γ + $\frac{\sqrt{\gamma(1/4+\epsilon\%)}}{\sqrt{N}}$)

For large fleets (N -> Q_p) use :

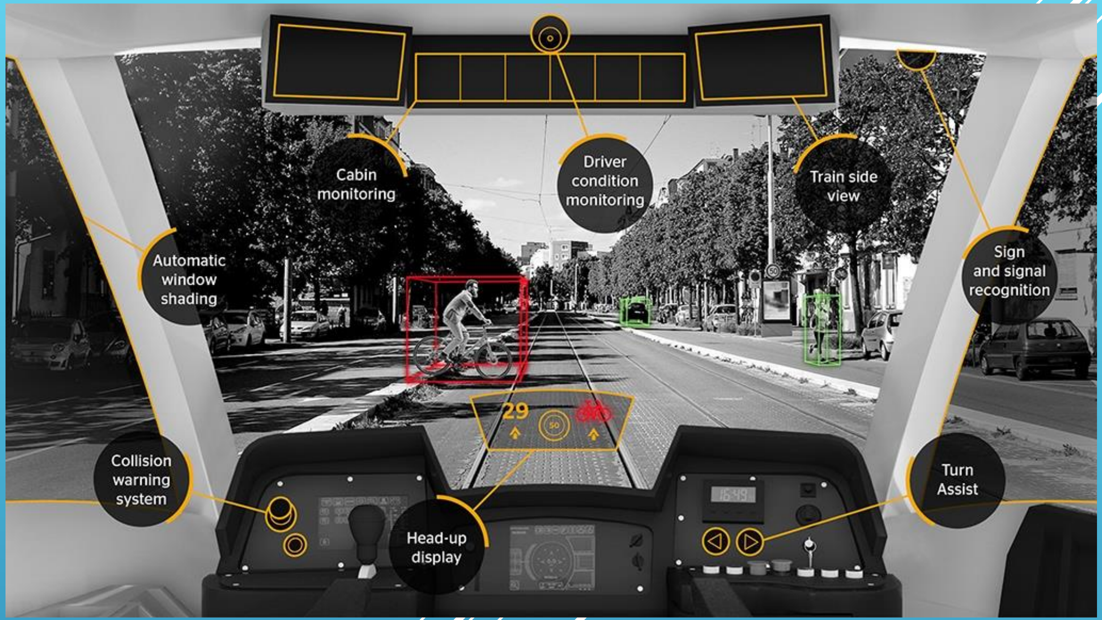
D= Nr(t) γ

Find k , so that :

P(D)= $\sum_{j=1}^{k} \frac{D^j}{j!} e^{-D}$< 1-έ

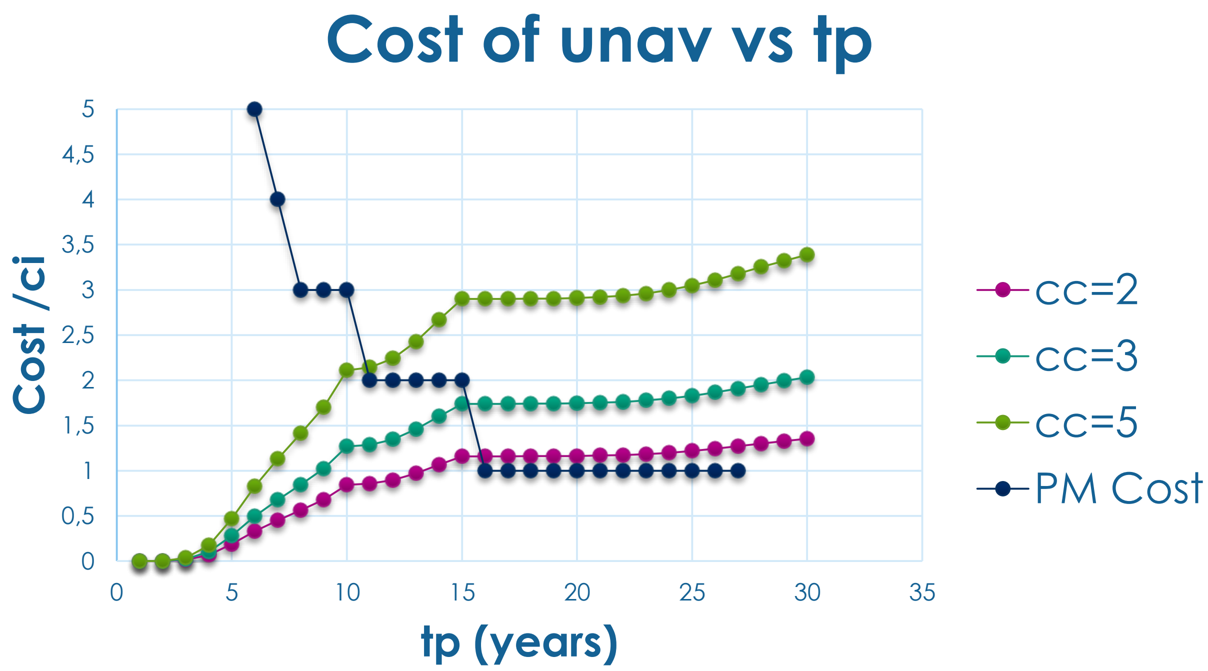
RECOMMENDED SPARE PARTS

Info system



Head up display

Optimal Maintenance



Optimal Maintenance

DEFINITIONS

$t_P \equiv$ *time for initiated replacement*

$n \equiv Int(\frac{t_L}{t_P})$

$t_r \equiv \mathrm{mod}(t_L, t_P)$

$F(t) \equiv 1 - R(t)$, *prob of failure, with no initiated replacement*

$F_p(t) \equiv 1 - R_p(t)$, *prob of failure, with initiated replacement*

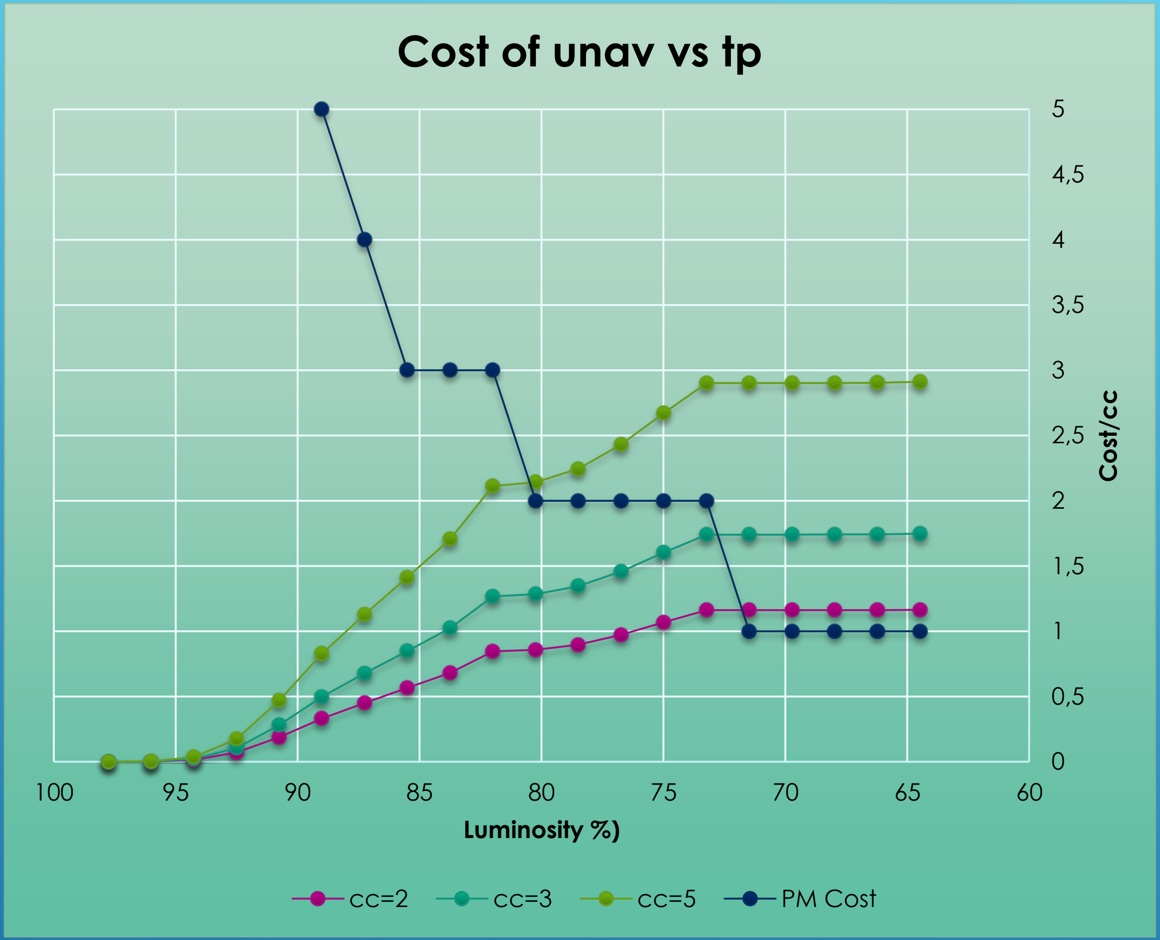
$ci \equiv$ cost *of an initiated replacement*

$cu \equiv$cost *unavailability, given it happened*

$CU \equiv$ expected unavailaility cost

$CI \equiv$ *total cost of initiated replacement during* t_L

$cc \equiv \frac{cu}{ci}$



If on the horizontal line we replace time, by the relative loss in luminosity , we get a similar graph, but the decision point on optimal maintenance is by luminosity instead of time

The advantage: The decision on replacement of the component takes in account the individual history of the compenent (production lot, environment, actual use etc.)

The cost : Need for periodic luminosity measurement

If the gain from the advantage is higher than the cost – the individual monitoring is beneficial.

Optimal Maintenance individual monitoring

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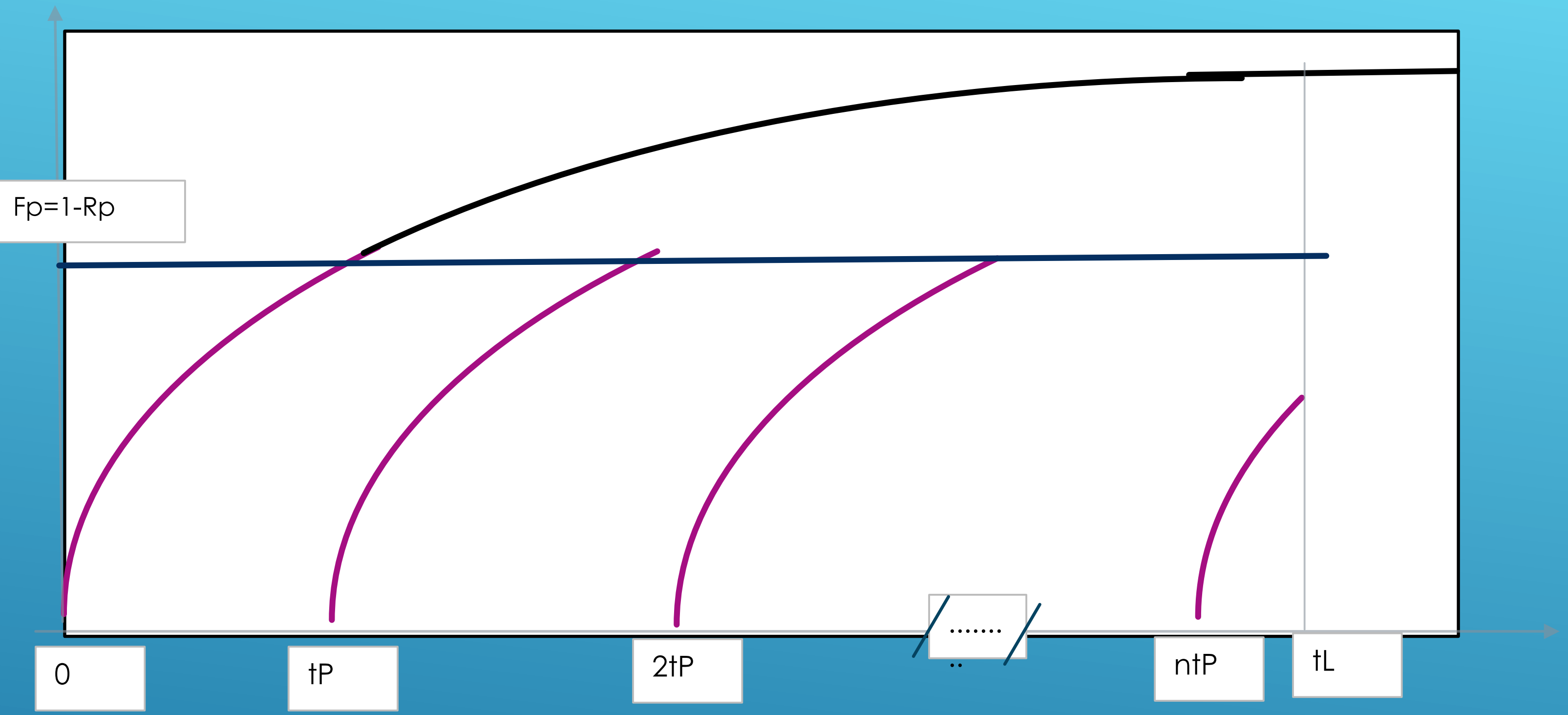

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CALCULATIONS

$$F_p(t_L) = F(t_P) + R(t_P)F(t_P) + \ldots + \ldots R(t_P)^n F(t_P) + R(t_P)^n F(t_r)$$

$$F_p(t_L) = F(t_P)\frac{1 - R(t_P)^n}{F(t_P)} + R(t_P)^n F(t_r)$$

$$CU = F_p(t_L)\ [(1 - R(t_P)^n) + R(t_P)^n * F(t_r)] * cc * ci$$

$$CI \equiv n * cu$$