Norwegian University of Science and Technology
Department of Production and Quality Engineering
Institutt for produksjons- og kvalitetsteknikk

EXAMINATION PAPER / EKSAMENSOPPGAVE FOR:

TPK4140 Maintenance Management / Driftssikkerhet - Vedlikeholdsstyring

Academic contact during examination / Faglig kontaktperson under eksamen:

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Examination date / Eksamensdato: 17 December 2012 / 17. desember 2012

Examination time / klokkeslett: 09.00 – 13.00

Studiepoeng: 7.5

Permitted examination aids:	**D: No printed or written aids allowed.**	
	Specified simple calculator allowed.	
	Note: Pencils are allowed, but do not use red coloured pencil!	
Tillatte hjelpemidler:	**D: Ingen trykte eller håndskrevne hjelpemidler tillatt.**	
	Bestemt, enkel kalkulator tillatt.	
	Merk: Blyant er tillatt, men ikke bruk rødfarget blyant!	
Language / Språk:	**English and (Norwegian) bokmål**	
Number of pages / Antall sider:	**Bokmål:**	**4** (starts on page 2)
Number of pages / Antall sider:	**Nynorsk:**	**0**
Number of pages / Antall sider:	**English**	**4** (starts on page 6)
Number of pages enclosed /Antall sider vedlagt:		**9 (including this front page / inclusive forsiden)**

Announcement of grades / Sensurfrist: **18 January 2013 / 18. januar 2013**

Solution, selected problems

Problem 3A

We use

$\lambda_E(\tau_{\mathrm{PM}}) = \left(\frac{\Gamma(1+1/\alpha)}{\mathrm{MTTF}}\right)^{\alpha} {\tau_{\mathrm{PM}}}^{\alpha-1}$ and PFD=PFD(τ_{FT}) = $\lambda\tau_{\mathrm{FT}}/2$

yielding the following cost equation:

$$\mathrm{C}(\tau_{\mathrm{PM}}, \tau_{\mathrm{FT}}) = \frac{C_{\mathrm{PM}}}{\tau_{\mathrm{PM}}} + \frac{C_{\mathrm{FT}}}{\tau_{\mathrm{FT}}} + \lambda_E(\tau_{\mathrm{PM}})[C_U(1 - \mathrm{PFD}(\tau_{\mathrm{FT}})) + \mathrm{PFD}(\tau_{\mathrm{FT}})(1-q)C_E + \mathrm{PFD}(\tau_{\mathrm{FT}})q \cdot C_H]$$

and the approximation

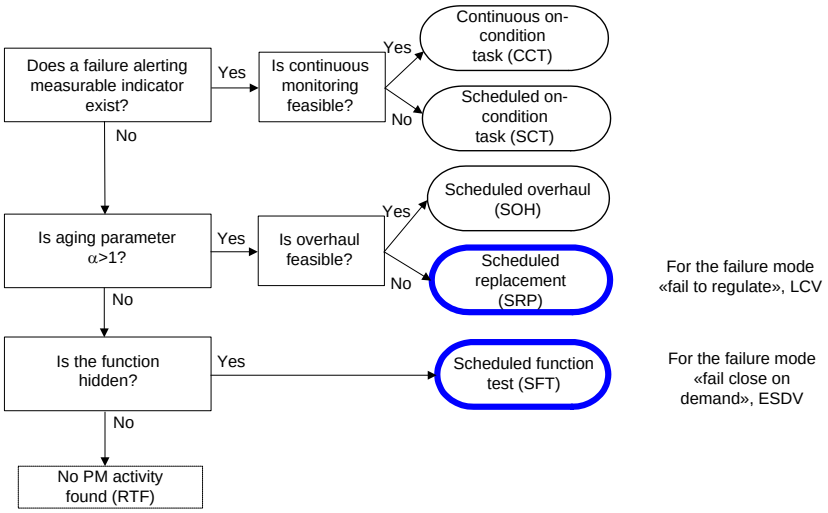
$$\mathrm{C}(\tau_{\mathrm{PM}}, \tau_{\mathrm{FT}}) \approx \frac{C_{\mathrm{PM}}}{\tau_{\mathrm{PM}}} + \frac{C_{\mathrm{FT}}}{\tau_{\mathrm{FT}}} + \lambda_E(\tau_{\mathrm{PM}})[C_U + \mathrm{PFD}(\tau_{\mathrm{FT}})(C_E + q \cdot C_H)]$$

B) Standard derivatives $\frac{\partial \mathrm{C}(\tau_{\mathrm{PM}},\tau_{\mathrm{FT}})}{\partial \tau_{\mathrm{PM}}} = 0 \Rightarrow \tau_{\mathrm{PM}} = \frac{\mathrm{MTTF}}{\Gamma(1+1/\alpha)} \sqrt[\alpha]{\frac{C_{\mathrm{PM}}}{(\alpha-1)[C_U+\mathrm{PFD}(\tau_{\mathrm{FT}}=12\ \mathrm{months})(C_E+q\cdot C_H)]}}$ =13.2 months

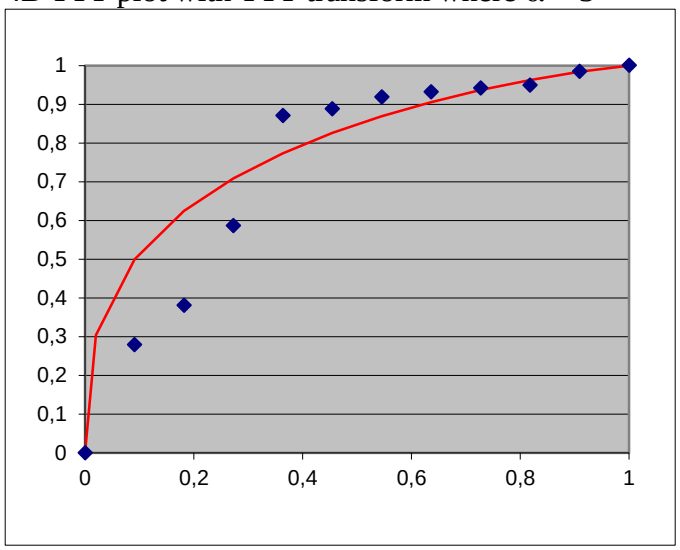
C) Standard derivatives $\frac{\partial \mathrm{C}(\tau_{\mathrm{PM}},\tau_{\mathrm{FT}})}{\partial \tau_{\mathrm{FT}}} = 0 \Rightarrow \tau_{\mathrm{FT}} = \sqrt{\frac{2C_{\mathrm{FT}}}{(C_E+q\cdot C_H)\cdot\lambda\cdot\lambda_E(\tau_{\mathrm{PM}}=13.2\ \mathrm{months})}}$ =15.7 months

D) Cost per hour with optimal intervals from B) and C) is approximately NOK 1150 per month. Inserting τ_{PM} = τ_{FT} = 12 months in the new cost equation (subtracting 1 000 NOK per activity) gives approximately NOK 750 per month, i.e., it pays off to combine with the turnaround.

Problem 4A



4B TTT plot with TTT transform where $\alpha = 3$



$T_{(i)}$	$\Sigma T_{(i)}$	$\Sigma T_{(i)+}(n-i)T_{(i)}$	i/n	TTT
10	10.00	110	0.09	0.28
14	24.00	150	0.18	0.38
23	47.00	231	0.27	0.59
37	84.00	343	0.36	0.87
38	122.00	350	0.45	0.89
40	162.00	362	0.55	0.92
41	203.00	367	0.64	0.93
42	245.00	371	0.73	0.94
43	288.00	374	0.82	0.95
50	338.00	388	0.91	0.98
56	394.00	394	1.00	1.00

$\alpha = 3$, and MTTF = 394/11 = 35. 8 is very good in relation to assumptions in Problem 3, however the "match" to the TTT transform is not that good.