Dynamic grouping exercise

We consider a train bogie. There are 20 components. A snapshot of the FMECA for these components are shown in Table 1.

Table 1 Snapshot of FMECA for bogie components

#	**Component**	**Function**	**Failure type**	**Failure effect**
1	Torsions bar and Lever, Motor Bogie	Anti roll device	Crack	Potential reduction of anti tilting
2	ZF-Ecomat 5HP600	Transmission between motor and axle gear	Wear and tear	Defect of gear
3	Flexible coupling bearing (CENTA)	Coupling between diesel engine / gear	Wear and tear	Worn out bearing -> vibrations
4	Deep Groove Ball Bearing	Power transfer	Wear and tear	Worn out bearing
5	Aeration Valve	Pressure balance	Locked	Problems with fuel oil filling
6	Torque Reaction Arm	Torque reaction link	Wear and tear	Fissure and demaged rubber of silent blocks
7	Diesel Engine Cummins	Actuation of half train set	Wear and tear	Functional failure or lower compression of engine
8	Engine attachment	Engine seat	Wear and tear	Worn out bearing
9	Plant frame bearing	Damping of vibrations	Wear and tear	Worn out bearing
10	Primary Damper	Absorbing the vibration between axle box and bogie	Functional failure	Reduced dynamic characteristics
11	Horizontal Damper, Motor Bogie	Absorbing the vibration between bogie and car body	Functional failure	Reduced dynamic characteristics
12	Horizontal Damper, Motor Bogie	Absorbing the vibration between bogie and car body	Functional failure	Reduced dynamic characteristics
13	Vertical Damper, Motor Bogie	Absorbing the vibration between bogie and car body	Functional failure	Reduced dynamic characteristics
14	Vertical Damper, Motor Bogie	Absorbing the vibration between bogie and car body	Functional failure	Reduced dynamic characteristics
15	Longitudinal Car Body Damper	Absorbing vibrations between car bodies	Functional failure	Reduced dynamic characteristics
16	Break Beam Support Bush	Fixing pin for break beam	Wear and tear	Increased gap between pin and bush
17	Bush for Brake Pad Link	Reduction of wear between bolts brake support	Wear and tear	Increased gap between pin and bush
18	Bush for Brake Unit	Reduction of wear between bolts and brake unit support	Wear and tear	Increased gap between pin and bush
19	Cylindrical roller bearing actuation side	Bearing rotor of generator	Wear and tear	Rotor of generator blocks
20	Cardan Shaft	Power transmission from gear box to bogie	Wear and tear	Fracture joint bearing

Table 2 shows reliability and cost figures. All failure times are assumed to be Weibull distributed, where we specify the mean time to failure (MTTF, given in million kilometres), and the aging (shape) parameter α. Set-up costs are assumed to be 3 000 € for all activities. In step 0 of the algorithm we first assess $k_{i,\mathrm{Av}} = 13$ for all activities, meaning that we initially believe that in average more than half of the activities are included in each execution of a maintenance group. The time horizon is set to $T = 15$ million kilometres.

Table 2 Cost figures and reliability parameters

#	C^P (€)	C^U(€)	MTTF (10^6 kilometres)	Aging, α
1	960	6 740	2.56	3.5
2	9 600	22 400	3.33	3
3	680	6 230	33.33	3.5
4	632	5 960	40.40	3.5
5	720	6 320	10.00	2
6	400	5 720	2.11	3.5
7	37 000	72 500	2.00	3.5
8	520	5 960	4.17	3.5
9	780	6 440	12.50	3.5
10	664	6 236	1.60	3.5
11	424	5 786	1.61	3.5
12	384	5 711	1.61	3.5
13	384	5 711	1.78	3.5
14	184	5 336	1.78	3.5
15	600	6 116	1.78	3.5
16	1 440	7 580	2.67	3.5
17	4 060	12 590	2.67	3.5
18	1 160	7 130	2.67	3.5
19	6 080	16 220	1.61	2.5
20	6 400	16 700	1.33	3.5

Problem 1

Assume that we start from scratch, i.e., all components are new at time t_0. Establish the first group, and the corresponding time of execution.

Problem 2

Find subsequent groups for $T = 15$ million kilometres. Calculate the $k_{i,\mathrm{Av}}$ for all activities. Rerun the procedure with the new value of $k_{i,\mathrm{Av}}$. Calculate the expected savings by using a better estimate for $k_{i,\mathrm{Av}}$.