

Supplementary Material for A Practical Approach to Industrial Engineering Discrete-Event Simulation with Free Mathematical and Programming Software

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1.1 State diagram

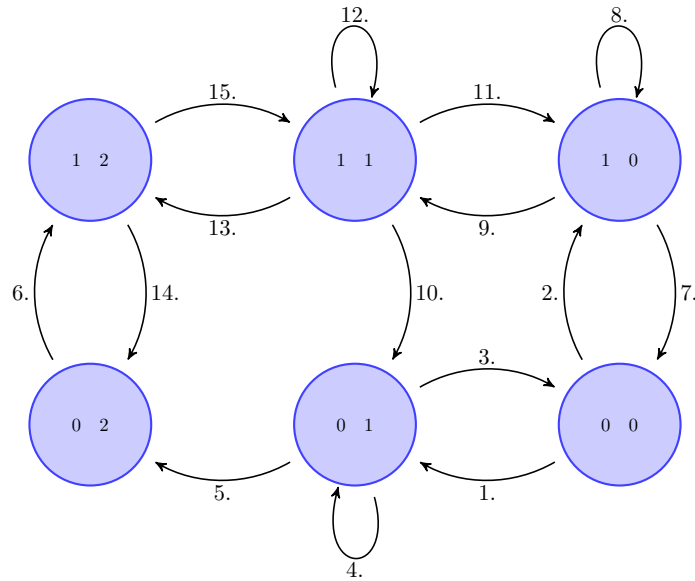


Figure S1: State diagram for the first exercise of practicing

- State '00' to...
 1. State '01': repair of M_2
 2. State '10': repair of M_1
- State '01' to...
 3. State '00': failure of M_2 || preventive maintenance of M_2
 4. State '01': setup || part produced on M_2 && (compliant product && (productType == "B" && Lsb > 0 || productType == "NC")) || (non compliant product && (Lsnc == Ksnc || productType == "B" && Lsb > 0 || productType == "NC"))

- 5. State '02': part produced on M_2 && productType == "B" && Lsb == 0
- State '02' to...
 - 6. State '12': repair of M_1
- State '10' to...
 - 7. State '00': failure of M_1 || preventive maintenance of M_1
 - 8. State '10': part produced on M_1
 - 9. State '11': repair of M_2
- State '11' to...
 - 10. State '01': failure of M_1 || preventive maintenance of M_1
 - 11. State '10': failure of M_2 || preventive maintenance of M_2
 - 12. State '11': setup || part produced on M_1 || part produced on M_2 && (compliant product && (productType == "B" && Lsb > 0 || productType == "NC")) || (non compliant product && (Lsnc == Ksnc || productType == "B" && Lsb > 0 || productType == "NC"))
 - 13. State '12': part produced on M_2 && productType == "B" && Lsb == 0
- State '12' to...
 - 14. State '02': failure of M_1 || preventive maintenance of M_1
 - 15. State '11': part produced on M_1

1.2 Octave code

Listing S1: Octave code for the first exercise in Practicing.

```

1 pkg load statistics;
2 clear
3 Dsim = 100000;
4 Ksnc = 20;
5 Dop1 = 4;
6 Dop2 = 4;
7 f1 = @(U) wblinv(U, 100,2);
8 f2 = @(U) wblinv(U, 100,2);
9 complianceRate = 0.08;
10 setup = 5;
11 muc = 5;
12 mup = 3;
13 mus = 1.5;
14 Cc = 300;
15 Cp = 100;
16 P = 275;
17 Cs = 0.05;
18 age1 = 70;
19 age2 = 70;
20
21
22 Tsim = 0;
23 state = 11;
24 Lsb = 10;
25 Lsnc = 0;
26 Lso = 0;
27 Tevent = 0;
28 Top1 = Dop1;
29 Top2 = Dop2;
30 Tttf1 = f1(rand());
31 Tttf2 = f2(rand());
32 Tpm1 = age1;
33 Tpm2 = age2;
34 Tsetup = realmax;
35
36 gain = 0;
37 productType = "B";

```

```

38
39
40 while Tsim < Dsim
41     switch state
42         case 00
43             Tevent = min([Tttr1, Tttr2]);
44             Tttr1 -= Tevent; Tttr2 -= Tevent;
45             gain -= Cs * (Lsb + Lsnc) * Tevent;
46
47             if Tttr1 == 0
48                 state = 10;
49                 Tttf1 = f1(rand());
50
51             elseif Tttr2 == 0
52                 state = 01;
53                 Tttf2 = f2(rand());
54             end
55
56             Tsim += Tevent;
57
58         case 01
59             Tevent = min([Tsetup, Tttr1, Top2, Tttf2, Tpm2]);
60             Tsetup -= Tevent; Tttr1 -= Tevent; Top2 -= Tevent; Tttf2 -= Tevent; Tpm2 -= Tevent
61             ;
62             gain -= Cs * (Lsb + Lsnc) * Tevent;
63
64             if Tsetup == 0
65                 Tsetup = realmax;
66
67             elseif Tttr1 == 0
68                 state = 11;
69                 Tttf1 = f1(rand());
70
71             elseif Top2 == 0
72                 if rand() >= complianceRate
73                     Lso += 1;
74                     gain += P;
75                     if productType == "B" && Lsb > 0
76                         Lsb -= 1;
77                         Top2 = Dop2;
78                     elseif productType == "B" && Lsb == 0
79                         state = 02;
80                     elseif productType == "NC" && Lsnc > 0
81                         Lsnc -= 1;
82                         Top2 = Dop2;
83                     else
84                         productType = "B";
85                         Tsetup = setup;
86                     end
87
88                 else
89                     Lsnc += 1;
90                     if Lsnc == Ksnc
91                         productType = "NC";
92                         Tsetup = setup;
93                         Lsnc -= 1;
94                         Top2 = Dop2;
95                     elseif productType == "B" && Lsb > 0
96                         Lsb -= 1;
97                         Top2 = Dop2;
98                     elseif productType == "B" && Lsb == 0
99                         state = 02;
100                     elseif productType == "NC"
101                         Lsnc -= 1;
102                         Top2 = Dop2;
103                     end
104                 end
105
106             elseif Tttf2 == 0
107                 state = 00;
108                 Tttr2 = muc + mus;
109                 gain -= Cc;

```

```

110         elseif Tpm2 == 0
111             state = 00;
112             Tttr2 = mup + mus;
113             gain -= Cp;
114             Tpm2 = age2;
115
116         end
117
118         Tsim += Tevent;
119
120     case 02
121         Tevent = Tttr1;
122         gain -= Cs * (Lsb + Lsnc) * Tevent;
123
124         state = 12;
125         Tttf1 = f1(rand());
126
127         Tsim += Tevent;
128
129     case 10
130         Tevent = min([Top1, Tttf1, Tpm1, Tttr2]);
131         Top1 -= Tevent; Tttf1 -= Tevent; Tpm1 -= Tevent; Tttr2 -= Tevent;
132         gain -= Cs * (Lsb + Lsnc) * Tevent;
133
134         if Top1 == 0
135             Lsb += 1;
136             Top1 = Dop1;
137
138         elseif Tttf1 == 0
139             state = 00;
140             Tttr1 = muc + mus;
141             gain -= Cc;
142
143         elseif Tpm1 == 0
144             state = 00;
145             Tttr1 = mup + mus;
146             gain -= Cp;
147             Tpm1 = age1;
148
149         elseif Tttr2 == 0
150             state = 11;
151             Tttf2 = f2(rand());
152         end
153
154         Tsim += Tevent;
155
156     case 11
157         Tevent = min([Tsetup, Top1, Top2, Tttf1, Tpm1, Tttf2, Tpm2]);
158         Tsetup -= Tevent; Top1 -= Tevent; Top2 -= Tevent; Tttf1 -= Tevent; Tpm1 -= Tevent;
159         Tttf2 -= Tevent; Tpm2 -= Tevent;
160         gain -= Cs * (Lsb + Lsnc) * Tevent;
161
162         if Tsetup == 0
163             Tsetup = realmax;
164
165         elseif Top1 == 0
166             Lsb += 1;
167             Top1 = Dop1;
168
169         elseif Top2 == 0
170             if rand() >= complianceRate
171                 Lso += 1;
172                 gain += P;
173                 if productType == "B" && Lsb > 0
174                     Lsb -= 1;
175                     Top2 = Dop2;
176                 elseif productType == "B" && Lsb == 0
177                     state = 12;
178                 elseif productType == "NC" && Lsnc > 0
179                     Lsnc -= 1;
180                     Top2 = Dop2;
181                 else
182                     productType = "B";

```

```

182         Tsetup = setup;
183     end
184
185     else
186         Lsnc += 1;
187         if Lsnc == Ksnc
188             productType = "NC";
189             Tsetup = setup;
190             Lsnc -= 1;
191             Top2 = Dop2;
192         elseif productType == "B" && Lsb > 0
193             Lsb -= 1;
194             Top2 = Dop2;
195         elseif productType == "B" && Lsb == 0
196             state = 12;
197         elseif productType == "NC"
198             Lsnc -= 1;
199             Top2 = Dop2;
200         end
201     end
202
203     elseif Tttf1 == 0
204         state = 01;
205         Tttr1 = muc;
206         gain -= Cc;
207
208     elseif Tpml == 0
209         state = 01;
210         Tttr1 = mup;
211         gain -= Cp;
212         Tpml = age1;
213
214     elseif Tttf2 == 0
215         state = 10;
216         Tttr2 = muc;
217         gain -= Cc;
218
219     elseif Tpm2 == 0
220         state = 10;
221         Tttr2 = mup;
222         gain -= Cp;
223         Tpm2 = age2;
224     end
225
226     Tsim += Tevent;
227
228     case 12
229         Tevent = min([Top1, Tttf1, Tpml]);
230         Top1 -= Tevent; Tttf1 -= Tevent; Tpml -= Tevent;
231         gain -= Cs * (Lsb + Lsnc) * Tevent;
232
233         if Top1 == 0
234             Top1 = Dop1;
235             state = 11;
236             Top2 = Dop2;
237
238         elseif Tttf1 == 0
239             state = 02;
240             Tttr1 = muc;
241             gain -= Cc;
242
243         elseif Tpml == 0
244             state = 02;
245             Tttr1 = mup;
246             gain -= Cp;
247             Tpml = age1;
248         end
249
250         Tsim += Tevent;
251     end
252 end
253
254

```

```
255 disp(["The_total_gain_is_", num2str(gain)]);
```

1.3 Results presentation

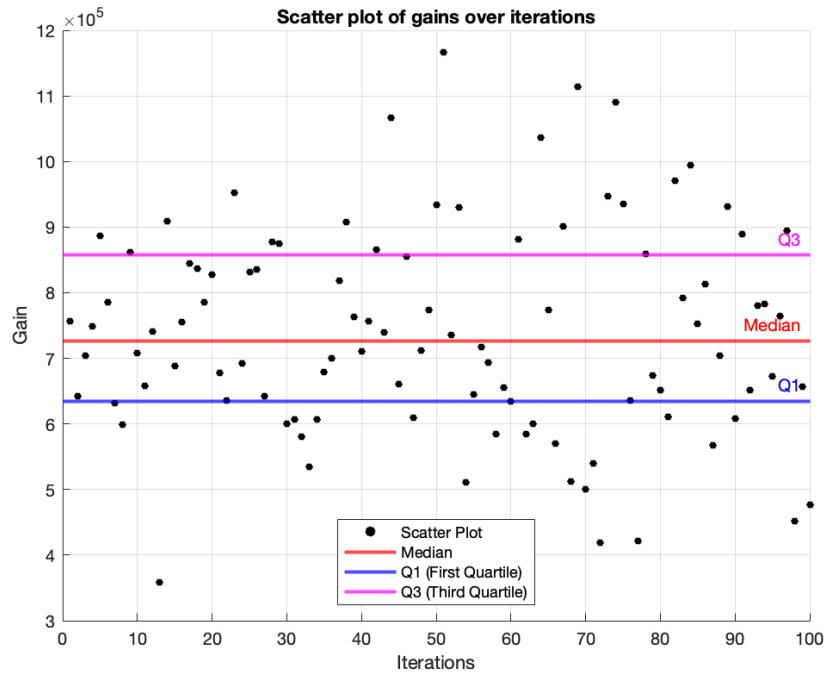


Figure S2: Scatter plot of gains over iterations