Chapter 8

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APPENDIX A

SAS PROGRAMS DEVELOPED FOR THIS STUDY

Appendix A1

SAS Programme for finding Control Limits for the EWMA Chart for Monitoring the Process Mean based on Standardized Sample Mean for Different In-control ARLs

The program given in appendix A 1 is for finding the control limit for the EWMA Chart for Monitoring the Process Mean based on Standardized Sample Mean for in-control ARL of 250 when λ_M= 0.65. For simulated data, for different control limits, the ARLs were found. Using iteration, the control limit that give the in-control ARL of 250 is taken as the control limit for the particular λ_M= 0.65 and ARL 250 combination. The simulations were run 1,000,000 times and the result was found as 1.99. Like this, programs were run for different combination of $\lambda_M$and in-control ARLs to find the control limits.

```
datacontrollimitsmean;
mu0 = 0;
sigma=1.0;
sigmasq =sigma*sigma;
nnn = 5;
nnnsqrt = sqrt(nnn);
nnn1 = nnn -1;
totalrun = 100000;
maxsamp = 1000000;
seed = 97287416;
lam = 0.65;
onelm= 1.0 - lam;
bigd = 0;
smalld =1 ;
```

```
do bigh = 1.97,1.98,1.99,2.00,2.01;
smallh = -bigh;
actuals = smalld*sigma;
actualm = mu0 + bigd*sigma/nnnsqrt;
message ='OK';
do runnum = 1 to totalrun;
zzz = 0;
runlen = 0;
do sample = 1 to maxsamp;
x1 = actualm + actuals*rannor(seed);
x2 = actualm + actuals*rannor(seed);
x3 = actualm + actuals*rannor(seed);
x4 = actualm + actuals*rannor(seed);
x5 = actualm + actuals*rannor(seed);
xsum = x1+x2+x3+x4+x5;
x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
xbar = xsum/nnn;
s = x2sum - xsum*xsum/nnn;
s = s/nnn1;
ut = (xbar - mu0)/sigma*nnnsqrt;
runlen =runlen +1;
zzz = onelm*zzz + lam*ut;
if zzz > bigh or zzz < smallh then do;
output;
goto DONE1;
end;
keep runlen bigh ;
```

```
end;
Message = 'Maximum # of smaple Exceeded';
output;
DONE1:
end;
end;
procmeans data = controllimitsmean;
by bigh ;
run;
```

The Sample out-put for this program is as follows:

```
The SAS System     09:13 Thursday, January 3, 2014  34

-------------------------------- bigh=1.97 --------------------------------
                              The MEANS Procedure
                          Analysis Variable : runlen

              N              Mean           Std Dev
ffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
        1000000       228.3777167       227.2598430
ffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
----------------------------- bigh=1.98 -----------------------------
              N              Mean           Std Dev
ffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
         300000       239.3720567       238.5905870
ffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
----------------------------- bigh=1.99 -----------------------------
              N              Mean           Std Dev
ffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
         300000       249.6155900       248.8675031
ffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
              N              Mean           Std Dev
ffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
         300000       260.6662367       260.3776291
ffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
```

Appendix A2

SAS Programme for finding Optimum λ_MValues for the EWMA Chart for Monitoring the Process Mean based on Standardized Sample Meanfor different in-control ARLs

The program given in appendix A 2 is for finding the optimum $\lambda_M$value for the EWMA Chart for 2.7 Δ shift in mean. Out-of-control ARLs were obtained for different λ_M values after knowing the control limits. The $\lambda_M$value which gives the smallest out-of-control ARL is taken as the optimum λ_M value for quick detection of 2.7 Δ shift in mean. The simulations were run 1,000,000 times and when there is 2.7 Δ shift in mean, the smallest out-of-control ARL was obtained for λ_M= 0.65. Like this, programs were run for different combination of Δ, and in-control ARLs to find the optimum $\lambda_M$values for different shift in mean Δ

```
dataoptimumlamdam;
mu0 = 0;
sigma=1.0;
sigmasq =sigma*sigma;
nnn = 5;
nnnsqrt = sqrt(nnn);
nnn1 = nnn -1;
totalrun = 1000000;
maxsamp = 1000000;
seed = 972885918;
lam = 0.65;
onelm= 1.0 - lam;
bigd = 2.7;
smalld =1 ;
do bigh = 1.99;
```

```
smallh = -bigh;
actuals = smalld*sigma;
actualm = mu0 + bigd*sigma/nnnsqrt;
message ='OK';
do runnum = 1 to totalrun;
zzz = 0;
runlen = 0;
do sample = 1 to maxsamp;
x1 = actualm + actuals*rannor(seed);
x2 = actualm + actuals*rannor(seed);
x3 = actualm + actuals*rannor(seed);
x4 = actualm + actuals*rannor(seed);
x5 = actualm + actuals*rannor(seed);
xsum = x1+x2+x3+x4+x5;
x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
xbar = xsum/nnn;
s = x2sum - xsum*xsum/nnn;
s = s/nnn1;
ut = (xbar - mu0)/sigma*nnnsqrt;
runlen =runlen +1;
zzz = onelm*zzz + lam*ut;
if zzz > bigh or zzz < smallh then do;
output;
goto DONE1;
end;
keep runlen  lam bigh ;
 end;
Message = 'Maximum # of smaple Exceeded';
output;
DONE1:
end;
end;
```

```
procmeans data = optimumlamdam;
by bigh ;
run;
```

Appendix A3

SAS Programme for finding Control Limits for the one sided EWMA Chart for Monitoring the Process variance Mean based on Standardized Sample variance for different in-control ARLs

```
data controllimitvar;
mu0 = 0;
sigma=1.0;
sigmasq =sigma*sigma;
nnn = 5;
nnnsqrt = sqrt(nnn);
nnn1 = nnn -1;
totalrun = 3000;
maxsamp = 1000000;
seed = 9287016;
lamv = 0.1;
onelamv= 1.0 - lamv;
bigd = 0;
smalld =1 ;
do bigh = 0.548182;
smallh = -bigh;
actuals = smalld*sigma;
actualm = mu0 + bigd*sigma/nnnsqrt;
message ='OK';
do runnum = 1 to totalrun;
mmm = 0;
runlen = 0;
do sample = 1 to maxsamp;
x1 = actualm + actuals*rannor(seed);
x2 = actualm + actuals*rannor(seed);
x3 = actualm + actuals*rannor(seed);
x4 = actualm + actuals*rannor(seed);
```

```
x5 = actualm + actuals*rannor(seed);
xsum = x1+x2+x3+x4+x5;
x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
xbar = xsum/nnn;
s = x2sum - xsum*xsum/nnn;
s = s/nnn1;
 v =  nnn1*s/sigmasq;
            vv= CDF('CHISQUARE',v,nnn1 );
            if vv > 0.00000000000001 and vv < 0.999999999999999 then
            vvv = probit(vv);else
            vvv = 8.21;
            runlen = runlen + 1;
            mmm = onelamv*mmm + lamv*vvv;
            if mmm>bigh  then do;
output;
goto DONE1;
end;
keep runlen bigh xbar qqq rrr vvv uuu message   x1 x2 x3 x4 x5 s ;
end;
Message = 'Maximum # of smaple Exceeded';
output;
DONE1:
end;
end;
proc print data = controllimitvar;
proc means data = controllimitvar;
by bigh ;
run;
```

AppendixA4

SAS Programme for finding Optimum λ_VValues for the EWMA Chart for Monitoring the Process Variance based on Standardized Sample variancefor different in-control ARLs

```
data optimumlamdv;
mu0 = 0;
sigma=1.0;
sigmasq =sigma*sigma;
nnn = 5;
nnnsqrt = sqrt(nnn);
nnn1 = nnn -1;
totalrun = 100000;
maxsamp = 1000000;
seed = 9287016;
lamv = 0.01;
onelamv= 1.0 - lamv;
bigd = 0, 0.5, 0.75, 1, 1.5;
smalld = 0.5, 0.75, 0.95, 1, 1.10, 1.25, 1.5, 3 ;
do bigh = 0.7482;
smallh = -bigh;
actuals = smalld*sigma;
actualm = mu0 + bigd*sigma/nnnsqrt;
message ='OK';
do runnum = 1 to totalrun;
mmm = 0;
runlen = 0;
do sample = 1 to maxsamp;
x1 = actualm + actuals*rannor(seed);
x2 = actualm + actuals*rannor(seed);
x3 = actualm + actuals*rannor(seed);
x4 = actualm + actuals*rannor(seed);
```

```
x5 = actualm + actuals*rannor(seed);
xsum = x1+x2+x3+x4+x5;
x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
xbar = xsum/nnn;
s = x2sum - xsum*xsum/nnn;
s = s/nnn1;
 v =  nnn1*s/sigmasq;
        vv= CDF('CHISQUARE',v,nnn1 );
        if vv > 0.00000000000001 and vv < 0.999999999999999 then
        vvv = probit(vv);else
        vvv = 8.21;
        runlen = runlen + 1;
        mmm = onelamv*mmm + lamv*vvv;
                                if mmm>bigh  then do;
        output;
goto DONE1;
end;
keep runlen bighxbar qqq rrr vvv uuu message x1 x2 x3 x4 x5  ;
end;
Message = 'Maximum # of smaple Exceeded';
output;
DONE1:
end;
end;
proc print data = optimumlamdv;
proc means data = optimumlamdv;
by bigh ;
run;
```

Appendix A5

SAS Programme for finding Optimum Chart Parameters for the SEEWMA Schemefor different in-control ARLs

```
data SEEWMA;
 mu = 0;
 sigma=1.0;
 sigmasq =sigma*sigma;
 nnn = 5;
 lim = 1.148;
 nnnsqrt = sqrt(nnn);
 nnn1 = nnn -1;
 totalrun = 10000;
 maxsamp = 1000000;
 seed = 857799;
 lam = 0.134;
 lamv = 0.141;
 onelm= 1.0 - lam;
 onelmv =1.0-lamv;
 bigh= (0.7737 + 0);
 sqbigh = (bigh**2);
 * smallh = -bigh;
 bighv = (0.734 + 0);
 sqbighv = (bighv**2);
* sf = sqbigh/sqbighv;
 *cf = 1.442401;
 *bigr =sqbigh*cf;
* Hre is sqrt of this;
*  bigd = 0;
* smalld =1 ;
```

```
do bigd = 0.6;
    do smalld = 1.5;
     actuals = smalld*sigma;
     actualm = mu + bigd*sigma/nnnsqrt;
     message='Ok';
       do runnum = 1 to totalrun;
       qqqm = 0;
       qqqv=0;
       runlen = 0;
         do sample = 1 to maxsamp;
         x1 = actualm + actuals*rannor(seed);
         x2 = actualm + actuals*rannor(seed);
         x3 = actualm + actuals*rannor(seed);
         x4 = actualm + actuals*rannor(seed);
         x5 = actualm + actuals*rannor(seed);
         xsum = x1+x2+x3+x4+x5;
         x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
         xbar = xsum/nnn;
         s = x2sum - xsum*xsum/nnn;
         s = s/nnn1;
         uu = (xbar - mu)/sigma*nnnsqrt;
         v =  nnn1*s/sigmasq;
         vv= CDF('CHISQUARE',v,nnn1 );
         if vv > 0.00000000000001 and vv < 0.99999999999999 then
         vvv = probit(vv);else
         vvv = 8.21;
         runlen =runlen +1;
         qqqm = onelm*qqqm + lam*uu;
         qqqv = onelmv*qqqv + lamv*vvv;

                   if qqqv < 0.00000 and nnn > 1  then
                   aat = qqqv; else
```

```
aat= 0.00000;
sqqqm = qqqm*qqqm;
sqaat = aat*aat;
*sqqqv = qqqv*qqqv;
*rrr= sqqqm + sf*sqqqv;
ct = (sqqqm/sqbigh) +(sqaat/sqbighv);
* if qqqm > bigh or qqqm < smallh or qqqv > bighv then do;
if ct > lim then do;
output;
goto DONE1;
end;
keep runlen bigd smalld xbar qqqm qqqv rrr vv uu v vvv vvv
x1 x2 x3 x4 x5 ;
end;
message ='Maximum # of samples Exceeded';
output;
DONE1:
end;
end;
end;
proc print data = SEEWMA ;
proc means data = SEEWMA;
by bigd smalld;
run;
```

Appendix A6

SAS Programme for finding Optimum Chart Parameters for the CS_r Scheme for different in-control ARLs

```
data csr;
 sigma =1;
 mu0 = 0;
 nnn = 5;
 nnnsq = sqrt(nnn);
 nnn1 = nnn -1;
 totalrun = 100000;
 maxsamp = 1000;
 seed = 967302006;
 km=0.224;
 kvu =0.055;
 kvl = 0.666;
 bighm = 2.268;
 smallhm= -bighm;
  bighv = 4.006;
 smallhv =-5.054;
 *bigd = 0;
 *smalld = 1;
do bigd = 0, 0.2, 0.40,0.5,1,1.5,3;
do smalld = 0.50, 0.75,0.95, 1, 1.05,1.10, 1.25,1.5, 3;
 actuals = smalld*sigma;
 actualm = mu0 + bigd*sigma/sqrt(nnn);
do runnum = 1 to totalrun;
        ssm=0;
        ttm =0;
        ssv=0;
        ttv=0;
        *qqqm = 0;
```

```
runlen = 0;
do sample = 1 to maxsamp;
x1 = actualm + actuals*rannor(seed);
x2 = actualm + actuals*rannor(seed);
x3 = actualm + actuals*rannor(seed);
x4 = actualm + actuals*rannor(seed);
x5 = actualm + actuals*rannor(seed);
xsum = x1+x2+x3+x4+x5;
x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
xbar = xsum/nnn;
s = x2sum - xsum*xsum/nnn;
s = s/nnn1;
runlen = runlen + 1;
ssm = max(0,ssm+xbar-km);
ttm = min(0,ttm+xbar+km);
ssv = max(0,ssv+log(s)-kvu);
ttv = min(0,ttv+log(s)+kvl);
if ssm > bighm or ttm < smallhm or ssv>bighv or ttv<smallhv then
do;
output;
goto DONE1;
end;
keep bigd smalld xbar ssm ttm ssv ttv s mu0 runlen;
end;
output;
DONE1:
end;
end;
end;
proc means data = csr;
by bigd smalld;
run;
```

Appendix A7

SAS Programme for finding Optimum Chart Parameters for the ES_escheme for different in-control ARLs

```
dataese;
 mu0 = 0;
 sigma=1.0;
 logsigma = -0.270;
 nnn = 5;
 nnnsq = sqrt(nnn);
 nnn1 = nnn -1;
 totalrun = 10;
 maxsamp = 1000000;
 seed = 23405701;
 lamm = 0.134;
 lamv =0.106;
 onelm = 1.0 - lamm;
 onelv = 1.0 - lamv;
   bighm = 0.372;
 smallhm = -bighm;
 bighv = 0.250;
 smallhv =-0.92;
 sqsmallhm=smallhm*smallhm;
 bhvmls = bighv-logsigma;
 sqbhvmls =bhvmls*bhvmls;
 shvmls = -smallhv-logsigma;
 sqshvmls=shvmls*shvmls;
 bigd = 0;
 smalld = 1;
  *do bigd = 0,0.2,.40,1,3;
 *do smalld = 0.5,0.75,0.95,1,1.05,1.25,3;
     actuals = smalld*sigma;
```

```
actualm = mu0 + bigd*sigma/sqrt(nnn);
    do runnum = 1 to totalrun;
    qqqm = 0;
            qqqv = -0.270;
    runlen = 0;
            do sample = 1 to maxsamp;
                    x1 = actualm + actuals*rannor(seed);
                    x2 = actualm + actuals*rannor(seed);
                    x3 = actualm + actuals*rannor(seed);
                    x4 = actualm + actuals*rannor(seed);
                    x5 = actualm + actuals*rannor(seed);
                    xsum = x1+x2+x3+x4+x5;
                    x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
                    xbar = xsum/nnn;
                    s = x2sum - xsum*xsum/nnn;
                    s = s/nnn1;
                    lgs = log(s);
                            runlen = runlen + 1;
            qqqm = onelm*qqqm + lamm*xbar;
                    qqqv = onelv*qqqv + lamv*lgs;
                    hhha = (qqqm-mu0)*(qqqm-mu0)/sqsmallhm;
                    hhhb = (qqqv-logsigma)*(qqqv-logsigma);
                    if (qqqv > logsigma)then ttt = hhha +
    hhhb/sqbhvmls;
                    else
                            ttt = hhha + hhhb/sqshvmls;
                            if ttt >1 then do;

output;
goto DONE1;
end;
  keep bigd smalld xbar lgs qqqm qqqv mu0 runlen bhvmls
    sqbhvmls shvmls sqshvmls hhha hhhb ttt;
```

```
        end;
    output;
    DONE1:
        end;
        *end;
        *end;
procprint data = ese;
procmeans data = ese;
by bigd smalld;
run;
```

Appendix A8

SAS Programme for finding Optimum Chart Parameters for the ES_r scheme for different in-control ARLs

```
data esr;
 mu0 = 0;
 sigma=1.0;
 sigmasq =sigma*sigma;
  nnn = 5;
 nnnsqrt = sqrt(nnn);
 nnn1 = nnn -1;
 totalrun = 30000;
 maxsamp = 1000000;
 seed = 97257416;
 lam = 0.08;
 onelm= 1.0 - lam;
 bigh = 3.01;
 *bigd = 0;
 *smalld =1 ;
do bigd = 0,1;
 do smalld = 1,1.25;
    actuals = smalld*sigma;
    actualm = mu0 + bigd*sigma/nnnsqrt;
      message ='OK';
        do runnum = 1 to totalrun;
                qqq = 2;
        runlen = 0;
        do sample = 1 to maxsamp;
        x1 = actualm + actuals*rannor(seed);
        x2 = actualm + actuals*rannor(seed);
        x3 = actualm + actuals*rannor(seed);
        x4 = actualm + actuals*rannor(seed);
```

```
x5 = actualm + actuals*rannor(seed);
xsum = x1+x2+x3+x4+x5;
x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
xbar = xsum/nnn;
s = x2sum - xsum*xsum/nnn;
s = s/nnn1;
uu = (xbar - mu0)/sigma*nnnsqrt;
uuu = uu*uu;
        h =  nnn1*s/sigmasq;
hhh= CDF('CHISQUARE',h,nnn1 );
  if  hhh>0.0000000000001  and  hhh<  0.999999999999999
then
     vv = probit(hhh);else
     vv = 8.21;
        vvv = vv*vv;
        rrr = uuu+vvv;
        runlen =runlen +1;
        qqq = onelm*qqq + lam*rrr;
        if qqq > bigh then do;
 output;
 goto DONE1;
 end;
keep runlen bigd smalld ;
 *xbar qqq rrr vvv uuu message
        x1 x2 x3 x4 x5 s ;
end;
Message = 'Maximum # of smaple Exceeded';
output;
DONE1:
end;
end;
end;
```

```
proc print data = esr;
proc means data = esr;
by bigd smalld;
run;
```

Appendix A9

SAS Programme for finding Optimum Chart Parameters for the SS_r scheme for different in-control ARLs

```
data ssr;
 mu0 = 0;
 sigma=1.0;
 nnn = 5;
 nnnsq = sqrt(nnn);
 nnn1 = nnn -1;
 totalrun = 100000;
 maxsamp = 1000000;
 seed = 98749706;
 bighm = 1.383;
 smallhm = -bighm;
 bighv = 1.531;
 smallhv =-3.789;
* bigd = 1.0;
* smalld = 1.05;
do bigd = 0,0.2,0.4,0.6,1,1.5,3;
    do smalld= 0.5,0.75,0.95,1,1.05,1.10,1.25,1.5,3;
  actuals = smalld*sigma;
  actualm = mu0 + bigd*sigma/sqrt(nnn);
    do runnum = 1 to totalrun;
   runlen = 0;
        do sample = 1 to maxsamp;
            x1 = actualm + actuals*rannor(seed);
            x2 = actualm + actuals*rannor(seed);
            x3 = actualm + actuals*rannor(seed);
            x4 = actualm + actuals*rannor(seed);
            x5 = actualm + actuals*rannor(seed);
```

```
            xsum = x1+x2+x3+x4+x5;
            x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
            xbar = xsum/nnn;
            s = x2sum - xsum*xsum/nnn;
            s = s/nnn1;
            loggs=log(s);
        runlen = runlen + 1;
            if xbar>bighm  or xbar< smallhm or loggs > bighv  or
      loggs < smallhv then do;
        output;
        goto DONE1;
        end;
    keep bigd smalld xbar loggs mu0 runlen;
  end;
  output;
  DONE1:
    end;
 end;
end;
 *proc print data = ssr;
proc means data = ssr;
by bigd smalld;
run;
```

Appendix A10

SAS Programme for finding Optimum Chart Parameters for the SS_escheme for different in-control ARLs

```
data sse;
  mu0 = 0;
  sigma=1.0;
  logsigma = -0.270;
  nnn = 5;
  nnnsq = sqrt(nnn);
  nnn1 = nnn -1;
  totalrun = 10;
  maxsamp = 1000000;
  seed = 23497746;
  bighm = 1.500;
  smallhm = -bighm;
  bighv = 1.634;
  smallhv =-4.256;
  sqsmalhm=smallhm*smallhm;
  bhvmls = bighv-logsigma;
  sqbhvmls =bhvmls*bhvmls;
  shvmls = smallhv-logsigma;
  sqshvmls=shvmls*shvmls;
  do bigd = 0,0.2,.40,0.60,1,1.5,3;
   do smalld = 0.5,0.75,0.95,1,1.05,1.10,1.25,1.5,3;
      actuals = smalld*sigma;
      actualm = mu0 + bigd*sigma/sqrt(nnn);
          do runnum = 1 to totalrun;
               runlen = 0;
             do sample = 1 to maxsamp;
                x1 = actualm + actuals*rannor(seed);
                x2 = actualm + actuals*rannor(seed);
```

```
x3 = actualm + actuals*rannor(seed);
x4 = actualm + actuals*rannor(seed);
x5 = actualm + actuals*rannor(seed);
xsum = x1+x2+x3+x4+x5;
x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
xbar = xsum/nnn;
s = x2sum - xsum*xsum/nnn;
s = s/nnn1;
lgs=log(s);
runlen = runlen + 1;
hhha = (xbar-mu0)*(xbar-mu0)/sqsmalhm;
hhhb = (lgs-logsigma)*(lgs-logsigma);
if (lgs > logsigma)then T =  hhha + hhhb/sqbhvmls;
else
T = hhha + hhhb/sqshvmls;
if T > 1 then do;
output;
goto DONE1;
end;
keep bigd smalld runlenxbar lgs hhha hhhb T  runlen;
end;
output;
DONE1:
end;
end;
end;
proc print data = sse;
proc means data = sse;
by bigd smalld;
run;
```

Appendix A11

SAS Programme for finding Optimum Chart Parameters for the MS_mscheme for different in-control ARLs

```
data msm;
 mu = 0;
 sigma=1.0;
 sigmasq =sigma*sigma;
 nnn = 5;
 nnnsqrt = sqrt(nnn);
 nnn1 = nnn -1;
 totalrun = 10;
 maxsamp = 10000000;
 seed = 128452701;
 *lam = 0.134;
 *onelm= 1.0 - lam;
  bigh = 3.090189;
 * bigd = 0;
* smalld =1 ;
do bigd = 0,0.2,0.40,0.6,1,1.5,3;
    do smalld = 0.5,0.75,0.95,1,1.05,1.10,1.25,1.50,3;
    actuals = smalld*sigma;
    actualm = mu + bigd*sigma/nnnsqrt;
    message='Ok';
      do runnum = 1 to totalrun;
      qqqm = 0;
      qqqv=0;
      runlen = 0;
        do sample = 1 to maxsamp;
        x1 = actualm + actuals*rannor(seed);
        x2 = actualm + actuals*rannor(seed);
```

```
x3 = actualm + actuals*rannor(seed);
x4 = actualm + actuals*rannor(seed);
x5 = actualm + actuals*rannor(seed);
xsum = x1+x2+x3+x4+x5;
x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
xbar = xsum/nnn;
s = x2sum - xsum*xsum/nnn;
s = s/nnn1;
uu = (xbar - mu)/sigma*nnnsqrt;
v =  nnn1*s/sigmasq;
vv= CDF('CHISQUARE',v,nnn1 );
if vv > 0.00000000000001 and vv < 0.999999999999999 then
vvv = probit(vv);else
vvv = 8.21;
vvvv = abs(vvv);
uuuu = abs(uu);
if vvvv > uuuu then mn= vvvv; else
mn = uuuu;
runlen =runlen +1;
          if mn > bigh then do;
    output;
    goto DONE1;
    end;
keep runlen bigd xbar qqqm qqqv rrr vv uu v vvv vvv
          x1 x2 x3 x4 x5 s ;
end;
message ='Maximum # of samples Exceeded';
output;
DONE1:
end;
end;
```

```
end;
proc print data = msm ;
 proc means data = msm;
 by bigd smalld;
 run;
```

Appendix A12

SAS Programme for finding Optimum Chart Parameters for the ES_{me} scheme for different in-control ARLs

```
data esme;
 mu = 0;
 sigma=1.0;
 sigmasq =sigma*sigma;
 nnn = 5;
 nnnsqrt = sqrt(nnn);
 nnn1 = nnn -1;
 totalrun = 100000;
 maxsamp = 100000000000;
 seed = 128452701;
 lam = 0.30;
 onelm= 1.0 - lam;
  bigh = 1.268;
  bigd = 0;
  smalld =1 ;
* do bigd = 0,0.2,0.40,0.6,1,1.5,3;
 *    do smalld = 0.5,0.75,0.95,1,1.05,1.10,1.25,1.50,3;
     actuals = smalld*sigma;
     actualm = mu + bigd*sigma/nnnsqrt;
     message='Ok';
        do runnum = 1 to totalrun;
        * qqqm = 0;
        * qqqv=0;
        y = 0;
        z = 0;
        runlen = 0;
           do sample = 1 to maxsamp;
```

```
x1 = actualm + actuals*rannor(seed);
x2 = actualm + actuals*rannor(seed);
x3 = actualm + actuals*rannor(seed);
x4 = actualm + actuals*rannor(seed);
x5 = actualm + actuals*rannor(seed);
xsum = x1+x2+x3+x4+x5;
x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
xbar = xsum/nnn;
s = x2sum - xsum*xsum/nnn;
s = s/nnn1;
uu = (xbar - mu)/sigma*nnnsqrt;
v =  nnn1*s/sigmasq;
vv= CDF('CHISQUARE',v,nnn1 );
if vv > 0.00000000000001 and vv < 0.999999999999999 then
vvv = probit(vv);else
vvv = 8.21;
 * vvvv = abs(vvv);
* uuuu = abs(uu);
* if vvvv > uuuu then mn= vvvv; * else
* mn = uuuu;
runlen =runlen +1;
y = onelm*y + lam*uu;
z = onelm*z + lam*vvv;
m = max(abs(y),abs(z));
          if m > bigh then do;
     output;
     goto DONE1;
     end;
keep runlen bigd smalld uu vvv y z m xbar qqqm qqqv rrr vv
uu v vvv vvv   x1 x2 x3 x4 x5 s ;
end;
message ='Maximum # of samples Exceeded';
```

```
output;
DONE1:
end;

proc print data = esme ;
proc means data = esme;
by bigd smalld;
run;
```

Appendix A13

SAS Programme for finding Optimum Chart Parameters for the ES_{sc} scheme for different in-control ARLs

```
data essc;
 mu0 = 0;
 sigma=1.0;
 sigmasq =sigma*sigma;
  nnn = 5;
 nnnsqrt = sqrt(nnn);
 nnn1 = nnn -1;
 totalrun = 100000;
 maxsamp = 1000000;
 seed = 97257416;
 lam = 0.150;
 onelm= 1.0 - lam;
 bigh = 1.84*2;
 do bigd = 0,0.2,.40,0.60,1,1.5,3;
 do smalld = 0.5,0.75,0.95,1,1.05,1.10,1.25,1.5,3;
     actuals = smalld*sigma;
     actualm = mu0 + bigd*sigma/nnnsqrt;
       message ='OK';
         do runnum = 1 to totalrun;
                 qqq = 2;
          runlen = 0;
          do sample = 1 to maxsamp;
          x1 = actualm + actuals*rannor(seed);
          x2 = actualm + actuals*rannor(seed);
          x3 = actualm + actuals*rannor(seed);
          x4 = actualm + actuals*rannor(seed);
          x5 = actualm + actuals*rannor(seed);
          xsum = x1+x2+x3+x4+x5;
```

```
x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
xbar = xsum/nnn;
s = x2sum - xsum*xsum/nnn;
s = s/nnn1;
uu = (xbar - mu0)/sigma*nnnsqrt;
uuu = uu*uu;
        h =  nnn1*s/sigmasq;

hhh= CDF('CHISQUARE',h,nnn1 );
  if  hhh>0.0000000000001  and  hhh<  0.999999999999999
then
    vv = probit(hhh);else
    vv = 8.21;
        vvv = vv*vv;
        rrr = uuu+vvv;
        runlen =runlen +1;
        qqq = onelm*qqq + lam*rrr;
        if qqq > bigh then do;
 output;
 goto DONE1;
 end;
keep runlen bigd smalld xbar qqq rrr vvv uuu message
           x1 x2 x3 x4 x5 s ;
end;
Message = 'Maximum # of smaple Exceeded';
output;
DONE1:
end;
end;
end;
proc print data =essc;
proc means data = essc;
```

```
by bigd smalld;
run;
```

Appendix A14

SAS Programme for finding Optimum Chart Parameters for the SS_d scheme for different in-control ARLs

```
data ssd;
 mu = 0;
 sigma=1.0;
 sigmasq =sigma*sigma;
 nnn = 5;
 nnnsqrt = sqrt(nnn);
 nnn1 = nnn -1;
 totalrun = 100000;
 maxsamp = 1000000;
 seed = 900452701;
 bigh = 3.323;
 smallh = - bigh;
 do bigd = 0,0.2,0.40,0.6,1,1.5,3;
     do smalld = 0.5,0.75,0.95,1,1.05,1.10,1.25,1.50,3;
     actuals = smalld*sigma;
     actualm = mu + bigd*sigma/nnnsqrt;
     message='Ok';
         do runnum = 1 to totalrun;
         qqqm = 0;
         qqqv=0;
         runlen = 0;
             do sample = 1 to maxsamp;
             x1 = actualm + actuals*rannor(seed);
             x2 = actualm + actuals*rannor(seed);
             x3 = actualm + actuals*rannor(seed);
             x4 = actualm + actuals*rannor(seed);
             x5 = actualm + actuals*rannor(seed);
             xsum = x1+x2+x3+x4+x5;
```

```
x2sum = x1*x1+x2*x2+x3*x3+x4*x4+x5*x5;
xbar = xsum/nnn;
s = x2sum - xsum*xsum/nnn;
s = s/nnn1;
uu = (xbar - mu)/sigma*nnnsqrt;
uuu = uu*uu;
v =  nnn1*s/sigmasq;
vv= CDF('CHISQUARE',v,nnn1 );
if vv > 0.00000000000001 and vv < 0.999999999999999 then
vvv = probit(vv);else
vvv = 8.21;
vvvv=vvv*vvv;
rrrsq = vvvv+ uuu;
rrr = sqrt(rrrsq);
runlen =runlen +1;
if rrr>bigh then do;
                output;
     goto DONE1;
     end;
keep runlen bigd smalldxbar qqqm qqqv rrr vv uu v vvv vvv
            x1 x2 x3 x4 x5 s ;
end;
message ='Maximum # of samples Exceeded';
   output;
   DONE1:
   end;
  end;
 end;
proc print data = ssd ;
 proc means data = ssd;
 by bigd smalld;
 run;
```

Appendix B

Piston ring data set. (Montgomery, 1996)

Sample t	X_{t1}	X_{1t2}	X_{t3}	X_{t4}	X_{t5}
1	74.030	74.002	74.019	73.992	74.008
2	73.995	73.992	74.001	74.011	74.004
3	73.988	74.024	74.021	74.005	74.002
4	74.002	73.996	73.993	74.015	74.009
5	73.992	74.007	74.015	73.989	74.014
6	74.009	73.994	73.997	73.985	73.993
7	73.995	74.006	73.994	74.000	74.005
8	73.985	74.003	73.993	74.015	73.988
9	74.008	73.995	74.009	74.005	74.004
10	73.998	74.000	73.990	74.007	73.995
11	73.994	73.998	73.994	73.995	73.990
12	74.004	74.000	74.007	74.000	73.996
13	73.983	74.002	73.998	73.997	74.012
14	74.001	74.001	73.999	74.002	74.003
15	74.012	74.014	73.998	73.999	74.007
16	74.000	74.002	74.005	73.998	73.996
17	73.994	74.012	73.986	74.005	74.007
18	74.006	74.010	74.018	74.003	74.000
19	73.984	74.002	74.003	74.005	73.997
20	74.000	74.010	74.013	74.020	74.003
21	73.988	74.001	74.009	74.005	73.996
22	74.004	73.999	73.990	74.006	74.009
23	74.010	73.989	73.990	74.009	74.014
24	74.015	74.008	73.993	74.000	74.010
25	73.982	73.984	73.995	74.017	74.013
26	74.012	74.015	74.030	73.986	74.000
27	73.995	74.010	73.990	74.015	74.001
28	73.987	73.999	73.985	74.000	73.990
29	74.008	74.010	74.003	73.991	74.006
30	74.003	74.000	74.001	73.986	73.997
31	73.994	74.003	74.015	74.020	74.004
32	74.008	74.002	74.018	73.995	74.005
33	74.001	74.004	73.990	73.996	73.998
34	74.015	74.000	74.016	74.025	74.000
35	74.030	74.005	74.000	74.016	74.012
36	74.001	73.990	73.995	74.010	74.024
37	74.015	74.020	74.024	74.005	74.019
38	74.035	74.010	74.012	74.015	74.026
39	74.017	74.013	74.036	74.025	74.026
40	74.010	74.005	74.029	74.000	74.020

Appendix C

Simulated data set consists of 40 samples

Sample t	X_{t1}	X_{1t2}	X_{t3}	X_{t4}	X_{t5}	Z_t	A_t	C_t
1	0.5073	1.2646	-0.0603	0.0007	-2.4717	-0.0425	0.1298	0.0406
2	0.2410	0.4434	-2.7532	0.0394	2.1952	-0.0279	0.3391	0.2560
3	-0.7315	-0.3195	-1.6033	-0.5485	0.9615	-0.1497	0.3080	0.2505
4	0.4672	0.4390	0.2885	0.4994	-0.2312	-0.0492	0.0604	0.0124
5	2.5121	-0.4961	1.1382	0.5740	0.2289	0.1782	0.1135	0.0859
6	-0.6717	0.5718	2.2080	2.7447	-0.5562	0.3961	0.2729	0.4484
7	0.8952	0.2057	1.3019	1.3277	0.2859	0.5711	0.1255	0.6243
8	1.0008	-0.6199	0.1641	-0.7039	1.1209	0.5535	0.0976	0.5746
9	1.7128	0.3820	0.4047	1.7047	1.1247	0.7822	0.0091	1.1058
10	0.4332	-0.5712	0.8744	0.3868	-1.2383	0.6780	0.0000	0.8306
11	-0.0380	1.0804	0.4137	-0.0562	1.6069	0.7613	0.0000	1.0474
12	0.0481	-0.1347	-1.3088	-2.2127	0.2572	0.4788	0.0000	0.4143
13	-1.3375	0.0465	-0.9593	-0.6832	0.8172	0.3007	0.0000	0.1634
14	1.1826	0.2444	1.4309	1.5445	-0.5157	0.4804	0.0000	0.4170
15	0.6356	0.6405	-0.7710	-0.0678	-2.0769	0.3287	0.0267	0.1968
16	0.5735	-0.2419	1.8311	-1.5479	0.2869	0.3380	0.1100	0.2332
17	-0.3612	2.1104	-0.3608	-0.0969	1.1816	0.4340	0.1520	0.3915
18	0.0381	1.9037	-0.0285	-0.9788	0.5396	0.4621	0.1755	0.4541
19	-0.9321	0.0646	-0.4937	0.3847	-0.3614	0.3296	0.0274	0.1980
20	1.3701	-0.6623	1.1551	0.1353	0.9892	0.4554	0.0042	0.3748
21	1.0814	2.0279	0.3719	0.4480	-2.6424	0.4704	0.2196	0.5066
22	0.7484	1.0014	-2.9943	0.4965	3.1913	0.5482	0.5237	1.1502
23	-0.4671	0.0479	-1.5569	-0.2385	1.6491	0.4480	0.5380	1.0035
24	1.0312	0.9959	0.8078	1.0715	0.1582	0.6193	0.3022	0.8951
25	3.5873	-0.1729	1.8700	1.1647	0.7333	0.9434	0.4045	1.9703
26	-0.3924	1.1620	3.2072	3.8781	-0.2481	1.2507	0.6285	3.7011
27	1.5662	0.7044	2.0745	2.1069	0.8045	1.5000	0.4914	4.6005
28	1.6982	-0.3277	0.6524	-0.4327	1.8483	1.5047	0.4878	4.6183
29	2.5882	0.9247	0.9531	2.5781	1.8530	1.8140	0.4118	6.3216
30	0.9887	-0.2668	1.5402	0.9307	-1.1007	1.7042	0.4151	5.6296
31	0.3997	1.7978	0.9643	0.3770	2.4559	1.8263	0.3717	6.3328
32	0.5074	0.2788	-1.1888	-2.3187	0.7687	1.4888	0.4433	4.4406
33	-1.2247	0.5053	-0.7519	-0.4068	1.4687	1.2799	0.4430	3.3944
34	1.9254	0.7527	2.2358	2.3778	-0.1974	1.5165	0.4518	4.6074
35	1.2417	1.2479	-0.5166	0.3625	-2.1489	1.3373	0.5421	3.8824
36	1.1641	0.1449	2.7361	-1.4877	0.8059	1.3582	0.6519	4.2741
37	-0.0043	3.0852	-0.0038	0.3261	1.9243	1.4862	0.7119	5.1135
38	0.4949	2.8268	0.4116	-0.7763	1.1217	1.5284	0.7491	5.4640
39	-0.7179	0.5279	-0.1699	0.9281	-0.0045	1.3689	0.5882	4.1523
40	2.1599	-0.3807	1.8911	0.6163	1.6837	1.5315	0.5691	4.9556