APPENDIX

#R programming to optimize the cost function of chapter 2.

```
F = function(T, Co, Cd, alpha, beta, gamma, k, x, y)
sum((Co/T),
((k*Cd/T)*(T+(gamma*T*T/2)+(alpha*T^(beta+1)/(beta+1))+(alp
ha*gamma*T^(beta+2)/(beta+2)))),
-((k*Cd/(gamma*T))*(exp(gamma*T)-1)),
((x*k/T)*((T*T/2)+((gamma*T^3)/3)+(alpha*beta*T^(beta+2)/((
beta+1)*(beta+2)))+(alpha*gamma*T^(beta+3)/(beta+3)))),
((y*k/T)*((T*T*T/6)+((gamma*T^4)/8)+(alpha*beta*T^(beta+3)/
(2*(beta+2)*(beta+3)))+(alpha*gamma*T^(beta+4)/(2*(beta+4))
))))
Optim<-
optimize(F,c(0,2),tol=0.000001,Co=500,Cd=15,alpha=0.04,
beta=2,gamma=-0.02,k=250,x=5,y=0.05)
print(Optim)
```

Output:

```
$minimum
[1] 0.837232
$objective
[1] 1155.314
```

#R programming to optimize the cost function of chapter 3.

#Case-1 (Example 1):

```
F = function(T, Co, C, Cd, P, alpha, beta, k, gamma, x, y,
Ic, Ie, M)
```

```
sum((Ch/T),(k*Cd/T)*(T+(gamma*T*T/2)+(alpha*T^(beta+1)/(bet
a+1))+(alpha*gamma*T^(beta+2)/(beta+2))),(-k*Cd/(gamma*T))*
(exp(gamma*T)-1),

(x*k/T)*((T^2/2)+(gamma*T^3/3)+(alpha*beta*T^(beta+2)/((bet
a+1)*(beta+2)))+(alpha*gamma*T^(beta+3)/(beta+3))),
(y*k/T)*((T^3/6)+(gamma*T^4/8)+(alpha*beta*T^(beta+3)/(2*(b
eta+2)*(beta+3)))+(alpha*gamma*T^(beta+4)/(2*(beta+4)))),
(k*C*Ic/T)*((T^2/2)+(gamma*T^3/3)+(alpha*beta*T^(beta+2)/((
beta+1)*(beta+2)))+(alpha*gamma*T^(beta+3)/(beta+3))),

 (-k*C*Ic/T)*(T*M-(M^2/2)+(gamma/2)*(T*T*M-(M^3/3))

+(alpha/(beta+1))*(T^(beta+1)*M-(M^(beta+2)/(beta+2)))

+(alpha*gamma/(beta+2))*(T^(beta+2)*M-
(M^(beta+3)/(beta+3)))

+(alpha*M^(beta+2)/(beta+2))-
(alpha*T*M^(beta+1)/(beta+1))),

((-k*P*Ie/T)*((M^2/2)+(gamma*M^3/3))))

xmin=optimize(F,c(0.01,5),tol=0.000001,Ch=250,C=200,Cd=180,
P=245,alpha=0.04,beta=2,k=500,gamma=0.02,x=4,y=0.05,

Ic=0.15,Ie=0.09,M=0.1644)

xmin
```

Output:

```
xmin
$minimum
[1] 0.1840637
$objective
[1] 788.1295
```

#Case-2 (Example 2):

```
F = function(T, Co, C, Cd, P, alpha, beta, k, gamma, x, y,
Ic, Ie, M)

sum((Ch/T),(k*Cd/T)*(T+(gamma*T*T/2)+(alpha*T^(beta+1)/(bet
a+1))+(alpha*gamma*T^(beta+2)/(beta+2))),

(-k*Cd/(gamma*T))* (exp(gamma*T)-1),

(x*k/T)*((T^2/2)+(gamma*T^3/3)+(alpha*beta*T^(beta+2)/((bet
a+1)*(beta+2)))+(alpha*gamma*T^(beta+3)/(beta+3))),

(y*k/T)*((T^3/6)+(gamma*T^4/8)+(alpha*beta*T^(beta+3)/(2*(b
eta+2)*(beta+3)))+(alpha*gamma*T^(beta+4)/(2*(beta+4)))),

 ((-k*P*Ie/T)*(M*T+(gamma*M*T^2/2)-(T^2/2)-(gamma*T^3/6))))

xmin=optimize(F,c(0.01,5),tol=0.000001,Ch=500,C=200,Cd=6,P=
245,

a=0.06,b=4, k=500, gamma=0.06, x=4, y=0.5, Ic=0.15,
Ie=0.05, M=0.4)

xmin
```

Output:

```
$minimum
[1] 0.3493937
$objective
[1] 392.72
```

#R programming to optimize the profit function of chapter 4.

#Case-1 (Example 1):

```
library(DEoptimR)

Funtions <- list(obj=function(x){
```

```
  T1 <- x[1]

  T <- x[2]

  P<- x[3]

M=0.0822;   alpha=0.4;   beta=2;   a=500000;   b=2;
m=0.04;   delta=0.5;   C=10; Co=300;   Ca=80;   Ch=1.5;
Cd=1;  Cs=4;  A=4;   Ic=0.12;   Ie=0.09;
D=A^m*a*P^(-b)

#Sales Revenue

  Sales_Revenue<-(P*D)*(T1+1/delta-(exp(-delta*(T-
T1)))/delta)

#Purchase Cost

  I0=D*(T1+(alpha*T1^(beta+1))/(beta+1))

  Ib=(D/delta)*(1-(exp(-delta*(T-T1))))

  Purchase_Cost=C*(I0+Ib)

#Deterioration Cost

  Deterioration_Cost=Cd*D*(alpha*T1^(beta+1))/((beta+1))

#Lost Sales Cost

  Lost_Sales_Cost=Cs*D*(T-T1-(1/delta)+(exp(-delta*(T-
T1)))/delta)

#Holding Cost

  Holding_Cost=Ch*D*((T1^2/2)-(alpha*T1^(beta+2))/(beta+1)

   -(alpha^2*T1^(2*beta+2))/(2*(beta+1)^2))

#Ordering Cost

  Ordering_Cost=Co

#Advertisement Cost
```

```
  Advertisement_Cost=Ca*A
#Interest Charged
  Interest_Charged=C*D*Ic*(((T1-M)^2)/2
  -(alpha*T1^(beta+1)*(T1-M))/(beta+1)
  -alpha*(T1^(beta+2)-M^(beta+2))/(beta+1)
  -alpha^2*(T1^(beta+1)-M^(beta+1))^2/(2*(beta+1)^2) )
#Interest Earned
  Interest_Earned=P*D*Ie*(M^2/2)
TC1=(1/T)*(-Sales_Revenue +Purchase_Cost
+Deterioration_Cost+Lost_Sales_Cost+Holding_Cost+Ordering_C
ost+Advertisement_Cost+Interest_Charged-Interest_Earned)
return(TC1)},
  con = function(x){
    T1 <- x[1]
    T <- x[2]
    P<-x[3]
    c(T1-T)  })
JDEoptim(c(0.01,0.1,0.01), c(2,5,50), fn = Funtions$obj,
constr = Funtions$con, tol = 1e-4)
```

#Output:

```
$par
[1]  0.3942556  0.6092284  20.9852371
$value
[1] -11350.87
$iter
[1] 99
```

```
$convergence
[1] 0
```

#Case-2 (Example 2):

```
library(DEoptimR)
Funtions <- list(obj=function(x){
  T1 <- x[1]
  T <- x[2]
  P<- x[3]
  M=0.411; alpha=0.4; beta=2; a=500000; b=2; m=0.04;
  delta=0.5; C=10; Co=300; Ca=80; Ch=1.5; Cd=1; Cs=4
  A=3; Ic=0.12; Ie=0.09
  D=A^m*a*P^(-b)
  #Sales Revenue
  Sales_Revenue<-(P*D)*(T1+1/delta-(exp(-delta*(T-
T1)))/delta)
  #Purchase Cost
  I0=D*(T1+(alpha*T1^(beta+1))/(beta+1))
  Ib=(D/delta)*(1-(exp(-delta*(T-T1))))
  Purchase_Cost=C*(I0+Ib)
  #Deterioration Cost
  Deterioration_Cost=Cd*D*(alpha*T1^(beta+1))/((beta+1))
  #Lost Sales Cost
  Lost_Sales_Cost=Cs*D*(T-T1-(1/delta)+(exp(-delta*(T-
T1)))/delta)
```

```
  #Holding Cost
  Holding_Cost=Ch*D*((T1^2/2)-(alpha*T1^(beta+2))/(beta+1)
  -(alpha^2*T1^(2*beta+2))/(2*(beta+1)^2))
  #Ordering Cost
  Ordering_Cost=Co
  #Advertisement Cost
  Advertisement_Cost=Ca*A
  #Interest Charged
  Interest_Charged=0
  #Interest Earned
  Interest_Earned=P*D*Ie*T1*(M - T1^2/2)
TC1=(1/T)*(-Sales_Revenue+Purchase_Cost+Deterioration_Cost
+Lost_Sales_Cost+Holding_Cost+Ordering_Cost
+Advertisement_Cost+Interest_Charged-Interest_Earned)
return(TC1)},
  con = function(x){
    T1 <- x[1]
    T <- x[2]
    P<-x[3]
    c(T1-T)
  })
JDEoptim(c(0,0,0),c(2,5,50),fn=Funtions$obj,
         constr =Funtions$con, tol = 1e-4)
```

#Output:

```
$par
[1]  0.3875274  0.5102778 20.3512916
$value
[1] -11979.7
$iter
[1] 93
$convergence
[1] 0
```

#R programming to optimize the profit function of chapter 5.

#Case-1 (Example-1):

```
library(DEoptimR)
Funtions <- list(obj=function(x){
  t1 <- x[1]
  T <- x[2]
  z <- x[3]
  alpha=0.5;  beta=4;  delta=0.4;  p=80;  C=50;  Cs=10;
Ch=1;  D=500
  eta=0.03;  Co=400
  #Sales Revenue
  SR<-(p*D/T)*(t1+1/delta-(exp(-delta*(T-t1)))/delta)
  #Purchase cost
  PC<-(C*D/T)*(t1+(alpha*(exp(-
eta*z))*t1^(beta+1))/(beta+1)+1/delta-(exp(- delta*(T-
t1)))/delta)
  #Lost Sales Cost
```

```
  LSC<-(Cs*D/T)*(T-t1-(1/delta)+(exp(-delta*(T-t1)))/delta)
  #Holding Cost
  HC<-(Ch*D/T)*((t1^2)/2+(alpha*beta*t1^(beta+2)*exp(-
eta*z))/((beta+1)*(beta+2))
                +((alpha^2*(exp(-
2*eta*z))*t1^(2*beta+2)))/(2*(beta+1)^2))
    #Ordering cost
  CO<-Co/T
  #Preservation Technology Investment cost
  PTC<-(t1)*z/T
  return(-SR+PC+LSC+HC+CO+PTC)
  },
  con = function(x){
    t1 <- x[1]
    T <- x[2]
    z <- x[3]
    c(t1-T,z-500)
  })
JDEoptim(c(0,0,0),c(5,10,500),fn=Funtions$obj,
         constr =Funtions$con, tol = 1e-4)
```

Output:

```
$par
[1]   0.962889   1.063386 139.287825
$value
[1] -14212.07
$iter
```

```
[1] 117
$convergence
[1] 0
```

#Case-2(Example-2):

```
library(DEoptimR)
Funtions <- list(obj=function(x){
  T1 <- x[1];  T <- x[2];  z <- x[3];  Td=0.2;  alpha=0.5
  beta=4;  delta=0.4;  eta=0.03;  D=500;  A=400;  Ch=1;
Cs=10
  C=50;  p=80
  #Sales Revenue
  Sales_Revenue<-(p*D/T)*(T1+1/delta-(exp(-delta*(T-
T1)))/delta)
  #Purchase Cost
  I0=D*(T1+(alpha*exp(-eta*z)*((T1-Td)^(beta+1)))/(beta+1))
  Ib=(D/delta)*(1-(exp(-delta*(T-T1))))
  Purchase_Cost=(C/T)*(I0+Ib)
  #Lost Sales Cost
  Lost_Sales_Cost=(Cs*D/T)*(T-T1-(1/delta)+(exp(-delta*(T-
T1)))/delta)
  #Holding Cost
  Holding_Cost=(Ch*D/T)*((T1^2/2)+((alpha*exp(-
eta*z)*Td*(T1-Td)^(beta+1))/(beta+1))
                          +(alpha*beta*T1^(beta+2)*exp(-
eta*z))/((beta+1)*(beta+2))
```

```
                          -(alpha^2*(exp(-
2*eta*z))*T1^(2*beta+2))/(2*(beta+1)^2))
  #Ordering Cost
  Ordering_Cost=A/T
  #Preservation Technology Cost
  Preservation_Cost= (T1-Td)*z/T
  return(-
Sales_Revenue+Purchase_Cost+Lost_Sales_Cost+Holding_Cost+Or
dering_Cost+Preservation_Cost)},
  con = function(x){
    Td=0.2
    T1 <- x[1]
    T <- x[2]
    z<-x[3]
    c(T1-T,z-500)
  })
JDEoptim(c(0,0,0),c(2,10,500),fn=Funtions$obj,
         constr =Funtions$con, tol = 1e-4)
```

Output:

```
$par
[1]   0.9280495   1.0214640 103.0737115
$value
[1] -14266.63
$iter
[1] 133
$convergence
[1] 0
```

#R programming to optimize the profit function of chapter 6.

#Case-1 (Example-1):

```
library(DEoptimR)
Td=0.15; M=0.0822
Funtions <- list(obj=function(x){
  T1 <- x[1]
  T <- x[2]
  P<- x[3]
  xi <- x[4]
  Td=0.15; M=0.0822; alpha=0.4; beta=2; a=500000; b=2
  m=0.04; delta=0.5; eta=0.03; C=10; Co=300; Ca=80; Ch=1.5
  Cd=0.5; Cs=8; A=4; Ic=0.12; Ie=0.09; D=A^m*a*P^(-b)
  H=((alpha*exp(-eta*xi))/(beta+1))

  Sales_Revenue<-(P*D)*(T1+1/delta-(exp(-delta*(T-
T1)))/delta)
  I0=D*(T1+H*(T1-Td)^(beta+1))
  Ib=(D/delta)*(1-(exp(-delta*(T-T1))))
  Purchase_Cost=C*(I0+Ib)
  Deterioration_Cost=Cd*D*H*(T1-Td)^(beta+1)
  Lost_Sales_Cost=Cs*D*(T-T1-(1/delta)+(exp(-delta*(T-
T1)))/delta)
```

```
  Holding_Cost=Ch*D*((T1^2/2)+(H*Td*(T1-
Td)^(beta+1))+(H*beta*(T1-Td)^(beta+2))/(beta+2)-
((H^2/2)*(T1-Td)^(2*beta+2)))

  Ordering_Cost=Co

  Preservation_Cost= (T1-Td)*xi

  Advertisement_Cost=Ca*A

  Interest_Charged=C*D*Ic*((T1-M)^2/2+H*(Td-M)*(T-
Td)^(beta+1)+(H*beta*(T1-Td)^(beta+2))/(beta+2)-(H^2/2*(T1-
Td)^(2*beta+2)))

  Interest_Earned=P*D*Ie*(M^2/2)

TC1=(1/T)*(-Sales_Revenue+Purchase_Cost+Lost_Sales_Cost

+Deterioration_Cost+Holding_Cost+Ordering_Cost+Preservation
_Cost+Advertisement_Cost+Interest_Charged

-Interest_Earned)

 return(TC1)},

  con = function(x){

    T1 <- x[1]

    T <- x[2]

    P<-x[3]

    xi <- x[4]

    c(T1-T,xi-500)

  })

JDEoptim(c(0,0,0,0),c(5,5,100,500),fn=Funtions$obj,

         constr =Funtions$con, tol = 1e-4)
```

Output:

```
$par
[1]  0.5203819  0.6778396 21.1125665 66.9478621
$value
[1] -11459.13
$iter
[1] 132
$convergence
[1] 0
```

#Case-2 (Example-2):

```
library(DEoptimR)
M=0.2740 ; Td=0.15
Funtions <- list(obj=function(x){
  T1 <- x[1]
  T <- x[2]
  P<- x[3]
  xi <- x[4]
A=4;  Td=0.15;  M=0.2740;  alpha=0.4;  beta=2;  a=500000;
b=2; m=0.04; delta=0.5; eta=0.03; C=10;  Co=300;  Ca=80;
Ch=1.5; Cd=0.5;  Cs=8;  Ic=0.12;  Ie=0.09;  D=A^m*a*P^(-b)
  H=((alpha*exp(-eta*xi))/(beta+1))
  Sales_Revenue<-(P*D)*(T1+1/delta-(exp(-delta*(T-
T1)))/delta)
  I0=D*(T1+H*(T1-Td)^(beta+1))
  Ib=(D/delta)*(1-(exp(-delta*(T-T1))))
  Purchase_Cost=C*(I0+Ib)
```

```
  Deterioration_Cost=Cd*D*H*(T1-Td)^(beta+1)

  Lost_Sales_Cost=Cs*D*(T-T1-(1/delta)+(exp(-delta*(T-
T1)))/delta)

 Holding_Cost=Ch*D*((T1^2/2)+(H*Td*(T1-
Td)^(beta+1))+(H*beta*(T1-Td)^(beta+2))/(beta+2)-
(H^2/2*(T1-Td)^(2*beta+2)))

 Ordering_Cost=Co

 Preservation_Cost= (T1-Td)*xi

 Advertisement_Cost=Ca*A

 Interest_Charged=C*D*Ic*((T1-M)^2/2-H*(T1-M)*((T1-
Td)^(beta+1)+(M-Td)^(beta+1))-(2*H/(beta+2))*((T1-
Td)^(beta+2)-(M-Td)^(beta+2))

-(H^2/2)*(((T1-Td)^(beta+1)-(M-Td)^(beta+1)))^2)

Interest_Earned=P*D*Ie*(M^2/2)

TC2=(1/T)*(-Sales_Revenue+Purchase_Cost+Deterioration_Cost

+Lost_Sales_Cost+Holding_Cost+Ordering_Cost+Preservation_Co
st+Advertisement_Cost+Interest_Charged-Interest_Earned)

 return(TC2)},

con = function(x){

    T1 <- x[1]

    T <- x[2]

    P<-x[3]

    xi <- x[4]

    c(Td-M,M-T1,T1-T,xi-500)

  })

JDEoptim(c(0,0,0,0),c(5,5,100,500),fn=Funtions$obj,
```

```
        constr =Funtions$con, tol = 1e-4)
```

#Output:

```
$par
[1]  0.5179912  0.6505492 20.7617397 64.6868479
$value
[1] -11720.11
$iter
[1] 137
$convergence
[1] 0
```

#Case-3(Example-3):

```
library(DEoptimR)
M=0.5754; Td=0.15
Funtions <- list(obj=function(x){
T1 <- x[1]
  T <- x[2]
  P<- x[3]
  xi <- x[4]
  Td=0.15; M=0.5754; alpha=0.4; beta=2; a=500000; b=2
  m=0.04; delta=0.5; eta=0.03; C=10; Co=300; Ca=80
  Ch=1.5; Cd=0.5; Cs=8; A=4; Ic=0.12; Ie=0.09
D=A^m*a*P^(-b); H=((alpha*exp(-eta*xi))/(beta+1))
Sales_Revenue<-(P*D)*(T1+1/delta-(exp(-delta*(T-
T1)))/delta)
I0=D*(T1+H*(T1-Td)^(beta+1))
```

```
Ib=(D/delta)*(1-(exp(-delta*(T-T1))))

Purchase_Cost=C*(I0+Ib)

Deterioration_Cost=Cd*D*H*(T1-Td)^(beta+1)

Lost_Sales_Cost=Cs*D*(T-T1-(1/delta)+(exp(-delta*(T-
T1)))/delta)

Holding_Cost=Ch*D*((T1^2/2)+(H*Td*(T1-
Td)^(beta+1))+(H*beta*(T1-Td)^(beta+2))/(beta+2)-
(H^2/2*(T1-Td)^(2*beta+2)))

Ordering_Cost=Co

Preservation_Cost= (T1-Td)*xi

Advertisement_Cost=Ca*A

Interest_Charged=0

Interest_Earned=P*D*Ie*T1*(M-T1/2)

TC3=(1/T)*(-Sales_Revenue+Purchase_Cost+Deterioration_Cost

+Lost_Sales_Cost+Holding_Cost+Ordering_Cost

+Preservation_Cost+Advertisement_Cost-Interest_Earned)

return(TC3)},

  con = function(x){
    T1 <- x[1]
    T <- x[2]
    P<- x[3]
    xi <- x[4]
    c(T1-M,M-T,xi-500)
  })
JDEoptim(c(0,0,0,0),c(5,10,100,500),fn=Funtions$obj,
         constr =Funtions$con, tol = 1e-4)
```

#Output:

```
$par
[1]  0.4981376  0.5804786 20.2097210 64.3494058
$value
[1] -12261.01
$iter
[1] 108
$convergence
[1] 0
```