SOLUTION PROBLEM La

```
set
      DIST
                    ordered
                                                                        ; # Districts: North, South, East, West, Central
                                                                        ; # Schools: Addison, Beeks, Canfield, Dalcy
      SCH0
                    ordered
set
                    {i in DIST, j in SCHO}
                                                                        ; # Travel Time from each District to each School
param Ttm
                                                                        ; # Student Population per District
param Stp
                   {i in DIST}
                                                                        ; # Maximum Capacity per School
param Cap
      QS
                   {i in DIST, j in SCHO} integer >= 0
                                                                         ; # Quantity of Students per District per School
var
                                                                        ; # Total Travel Time for all Students
      TT
var
                                                                        ; # Average Travel Time per Student
      OA
var
minimize TotTtm
                   : TT
                                                                        ; # Minimize Total Travel Time
                    : TT = sum {i in DIST, j in SCHO} QS[i,j] * Ttm[i,j]; # Total Travel Time
s.t. TtmCon
s.t. StpCon
                   {i in DIST} : sum {j in SCHO} QS[i,j] = Stp[i]
                                                                       ; # Students per District = Sum of Students per School
s.t. CapCon
                   {j in SCHO} : sum {i in DIST} QS[i,j] <= Cap
                                                                        ; # Quantity of Students <= Capacity per School
                                                                        ; # Avg. Travel Time = Total Time / Student population
s.t. AvgCon
                    : QA = TT / sum {i in DIST} Stp[i]
data
                                                                                                   ;
set
      DIST
                    :=
                                 North
                                              South
                                                           East
                                                                        West
                                                                                      Central
set
      SCH0
                    :=
                                 Addison
                                              Beeks
                                                           Canfield
                                                                        Dalcv
                                                           Canfield
                                 Addison
                                              Beeks
param Ttm
                                                                        Dalcy
                                                                                                   :=
                                 12
                                              23
                                                           35
                   North
                                                                        17
                   South
                                 26
                                              15
                                                           21
                                                                        27
                                                           22
                    East
                                 18
                                              20
                                                                        31
                                 29
                                              24
                                                           35
                                                                        10
                   West
                                                           23
                   Central
                                 15
                                              10
                                                                        16
                                 North 250
param Stp
                                              South 340
                                                           East 310
                                                                        West 210
                                                                                      Central 290
                    :=
param Cap
                                 400
                    :=
option solver gurobi
solve
option display width 200, display 1col 0
display QS,QA
```

SOLUTION PROBLEM Lb

```
set
      DIST
                   ordered
                                                                        ; # Districts: North, South, East, West, Central
                                                                        ; # Schools: Addison, Beeks, Canfield, Dalcy
      SCH0
                   ordered
set
                   {i in DIST, j in SCHO}
                                                                        ; # Travel Time from each District to each School
param Ttm
                                                                        ; # Student Population per District
param Stp
                   {i in DIST}
                                                                        ; # Maximum Capacity per School
param Cap
      QS
                   {i in DIST, j in SCHO} integer >= 0
                                                                        ; # Quantity of Students per District per School
var
                                                                        ; # Total Travel Time for all Students
      TT
var
      OA
                                                                        ; # Average Travel Time per Student
var
minimize TotTtm
                   : TT
                                                                        ; # Minimize Total Travel Time
                   : TT = sum {i in DIST, j in SCHO} QS[i,j] * Ttm[i,j]; # Total Travel Time
s.t. TtmCon
s.t. StpCon
                   {i in DIST} : sum {j in SCHO} QS[i,j] >= Stp[i]
                                                                      ; # Students per District = Sum of Students per School
s.t. CapCon
                   {j in SCHO} : sum {i in DIST} QS[i,j] <= Cap
                                                                      ; # Quantity of Students <= Capacity per School
                                                                       ; # Avg. Travel Time = Total Time / Student population
s.t. AvgCon
                   : QA = TT / sum {i in DIST} Stp[i]
                   {i in SCHO} : sum {i in DIST} QS[i,i] >= sum {i in DIST} Stp[i] / 4 ; # Even Quantity of Students among Schools
      BalCon
s.t.
data
                                                                                                  ;
set
      DIST
                                 North
                                              South
                                                           East
                                                                        West
                                                                                     Central
                    :=
                                                           Canfield
      SCH0
                                 Addison
                                              Beeks
                                                                        Dalcy
set
                    :=
                                 Addison
                                              Beeks
                                                           Canfield
param Ttm
                                                                        Dalcv
                                                                                                  :=
                                              23
                   North
                                 12
                                                           35
                                                                        17
                                              15
                                                           21
                                                                        27
                   South
                                 26
                                 18
                                              20
                                                           22
                                                                        31
                   East
                   West
                                 29
                                              24
                                                           35
                                                                        10
                   Central
                                 15
                                              10
                                                           23
                                                                        16
param Stp
                                 North 250
                                              South 340
                                                           East 310
                                                                        West 210
                    :=
                                                                                     Central 290
param Cap
                    :=
                                 400
option solver gurobi
solve
option display width 200, display 1col 0
display QS,QA
```

SOLUTION PROBLEM M

```
set
      EUPT
                    ordered
                                                                    ; # EU Ports: Hamburg, Marseilles, Liverpool
                                                                    ; # US Cities: Norfolk, New York, Savannah
                    ordered
set
      CITY
                                                                    ; # Distribution Centers: Dallas, St Louis, Chicago
set
      DIST
                    ordered
param Cos
                    {i in EUPT, j in CITY}
                                                                    ; # Cost from each EU Port to each US City
                    {j in CITY, k in DIST}
                                                                    ; # Cost from each US City to each Distribution Center
param Cod
param Sup
                    {i in EUPT}
                                                                    ; # Maximum Capacity per EU Port
param Dmd
                    {k in DIST}
                                                                    ; # Demand per Distribution Center
      OC.
                    {i in EUPT, j in CITY} integer >= 0
                                                                   ; # Quantity Shipped from each Port to each City
var
      OD
                    {j in CITY, k in DIST} integer >= 0
                                                                   ; # Ouantity Shipped from each City to each Distribution Center
var
minimize TotCst
                    : sum {i in EUPT, j in CITY} QC[i,j] * Cos[i,j]
                           + sum {j in CITY, k in DIST} QD[j,k] * Cod[j,k] ; # Minimize Total Cost
s.t. SupCon
                    {i in EUPT} : sum {j in CITY} QC[i,j] <= Sup[i] ; # Quantity Shipped from each EU Port <= Supply Capacity
      DmdCon
                    {k in DIST} : sum {j in CITY} QD[j,k] >= Dmd[k]
                                                                         ; # Quantity Shipped from each City >= Demand
s.t.
                    \{i \text{ in CITY}\}: \text{ sum }\{i \text{ in EUPT}\} \text{ QC}[i,i] = \text{ sum }\{k \text{ in DIST}\} \text{ QD}[i,k]: \# \text{ QC} = \text{ QD for each City}
s.t.
      CitCon
data
                                                                                         ;
      EUPT
                                               Marseilles
                                                                    Liverpool
set
                    :=
                                  Hamburg
set
      CITY
                    :=
                                  Norfolk
                                               New York
                                                                    Savannah
set
      DIST
                    :=
                                  Dallas
                                               St Louis
                                                                    Chicago
                                  Norfolk
                                                New York
                                                                    Savannah
param Cos
                                                                                         :=
                    Hamburg
                                  420
                                                390
                                                                    610
                    Marseilles
                                  510
                                                590
                                                                    470
                    Liverpool
                                  450
                                                360
                                                                    480
param Cod
                                  Dallas
                                               St Louis
                                                                    Chicago
                                                                                         :=
                    Norfolk
                                  75
                                                63
                                                                    81
                    New York
                                  125
                                                                    95
                                               110
                                                                    95
                    Savannah
                                  68
                                               82
param Sup
                                  Hamburg 55
                                               Marseilles
                                                             78
                                                                    Liverpool
                                                                                  37
                    :=
                                                                                  50
param Dmd
                                  Dallas 60
                                               St Louis
                                                             45
                                                                    Chicago
                    :=
option solver gurobi
solve
option display width 200, display 1col 0
display OC
display QD
```

SOLUTION PROBLEM M 3dim

```
set
      EUPT
                    ordered
                                                                         ; # EU Ports: Hamburg, Marseilles, Liverpool
                                                                         ; # US Cities: Norfolk, New York, Savannah
                    ordered
set
      CITY
                                                                         ; # Distribution Centers: Dallas, St Louis, Chicago
set
      DIST
                    ordered
param Cos
                    {i in EUPT, j in CITY}
                                                                         ; # Cost from each EU Port to each US City
                    {j in CITY, k in DIST}
                                                                         ; # Cost from each US City to each Distribution Center
param Cod
                                                                         ; # Maximum Capacity per EU Port
param Sup
                    {i in EUPT}
param Dmd
                    {k in DIST}
                                                                         ; # Demand per Distribution Center
      0S
                    {i in EUPT, j in CITY, k in DIST} integer >= 0
                                                                         ; # Q Shipped from each Port to each City and Dist. Center
var
minimize TotCst
                    : sum {i in EUPT, j in CITY, k in DIST} QS[i,j,k] * Cos[i,j]
                    + sum {i in EUPT, j in CITY, k in DIST} QS[i,j,k] * Cod[j,k]
                                                                                       ; # Minimize Total Cost
      SupCon
                    {i in EUPT} : sum {j in CITY, k in DIST} OS[i,j,k] <= Sup[i]</pre>
                                                                                      ; # Total Quantity Shipped <= Supply Capacity
s.t.
      DmdCon
                    {k in DIST} : sum {i in EUPT, j in CITY} QS[i,j,k] >= Dmd[k]
                                                                                       ; # Total Quantity Shipped >= Demand
s.t.
data
                                                                                       ;
      EUPT
                                 Hamburg
                                              Marseilles
                                                                   Liverpool
set
                    :=
                                                                   Savannah
set
      CITY
                    :=
                                 Norfolk
                                              New York
set
      DIST
                    :=
                                 Dallas
                                               St Louis
                                                                   Chicago
                                 Norfolk
                                               New York
                                                                   Savannah
param Cos
                                                                                       :=
                    Hamburg
                                 420
                                               390
                                                                   610
                    Marseilles
                                               590
                                                                   470
                                 510
                    Liverpool
                                 450
                                               360
                                                                   480
param Cod
                                 Dallas
                                              St Louis
                                                                   Chicago
                                                                                       :=
                    Norfolk
                                 75
                                               63
                                                                   81
                    New York
                                 125
                                                                   95
                                              110
                                                                   95
                    Savannah
                                 68
                                              82
param Sup
                                 Hamburg 55
                                              Marseilles
                                                            78
                                                                   Liverpool
                                                                                37
                    :=
                                                                                50
param Dmd
                                 Dallas 60
                                              St Louis
                                                            45
                                                                   Chicago
                    :=
option solver gurobi
solve
option display_width 200, display 1col 0
display QS
```

SOLUTION PROBLEM M 3dim SumQ

```
set
      EUPT
                   ordered
                                                                 ; # EU Ports: Hamburg, Marseilles, Liverpool
set
      CITY
                   ordered
                                                                 ; # US Cities: Norfolk, New York, Savannah
      DIST
                   ordered
                                                                 : # Distribution Centers: Dallas, St Louis, Chicago
set
param Cos
                   {i in EUPT, j in CITY}
                                                                 ; # Cost from each EU Port to each US City
                   { in CITY, k in DIST}
                                                                 ; # Cost from each US City to each Distribution Center
param Cod
                   {i in EUPT}
                                                                 ; # Maximum Capacity per EU Port
param Sup
param Dmd
                   {k in DIST}
                                                                 ; # Demand per Distribution Center
      QS
                   {i in EUPT, j in CITY, k in DIST} integer >= 0; # Q Shipped from each Port to each City and Dist. Center
var
      QC
                   {i in EUPT, i in CITY} integer >= 0
                                                         : # Ouantity Shipped from each Port to each City
var
                   { in CITY, k in DIST} integer >= 0
                                                                ; # Ouantity Shipped from each City to each Distribution Center
      OD
var
minimize TotCst
                   : sum {i in EUPT, j in CITY, k in DIST} QS[i,j,k] * ( Cos[i,j] + Cod[j,k] ) ; # Minimize Total Cost
                   {i in EUPT} : sum {j in CITY, k in DIST} QS[i,j,k] <= Sup[i]
      SupCon
                                                                                     ; # Total Quantity Shipped <= Supply Capacity
s.t.
                   {k in DIST} : sum {i in EUPT, j in CITY} QS[i,j,k] >= Dmd[k]
      DmdCon
                                                                                     ; # Total Quantity Shipped >= Demand
s.t.
                   {i in EUPT, j in CITY} : QC[i,j] = sum {k in DIST} QS[i,j,k]
s.t.
      SumOC
                                                                                     ; # Total Quantity Shipped >= Demand
s.t.
      SumQD
                   {j in CITY, k in DIST} : QD[j,k] = sum {i in EUPT} QS[i,j,k]
                                                                                     ; # Total Quantity Shipped >= Demand
data
                                                                                     ;
set
      EUPT
                                Hamburg
                                              Marseilles
                                                                 Liverpool
                    :=
      CTTY
                                 Norfolk
                                              New York
                                                                 Savannah
set
                    :=
      DIST
                                              St Louis
set
                    :=
                                 Dallas
                                                                 Chicago
param Cos
                                 Norfolk
                                              New York
                                                                 Savannah
                                                                                     :=
                   Hamburg
                                 420
                                              390
                                                                 610
                   Marseilles
                                 510
                                              590
                                                                 470
                   Liverpool
                                 450
                                              360
                                                                  480
                                              St Louis
param Cod
                                Dallas
                                                                 Chicago
                                                                                     :=
                   Norfolk
                                75
                                              63
                                                                 81
                                                                 95
                   New York
                                125
                                              110
                                                                 95
                   Savannah
                                 68
                                              82
                                                                                     ;
param Sup
                                 Hamburg 55
                                             Marseilles
                                                           78
                                                                 Liverpool
                                                                               37
param Dmd
                                 Dallas 60
                                              St Louis
                                                           45
                                                                 Chicago
                                                                               50
                    :=
option solver gurobi
solve
option display width 200, display 1col 0
display OS
display OC
display QD
```

SOLUTION PROBLEM Na

```
set
      RESR
                   ordered
                                                          ; # Resources: Man.Mch.Hrs, Man.Manpow, Dist.Manpow
      PROD
                   ordered
                                                          ; # Products: A, B, C, D, E
set
                   {i in RESR, j in PROD}
                                                          ; # Hours required per Resource per Product
param Hrs
                                                          ; # Available Hours per Resource (Capacity)
param Cap
                   {i in RESR}
                   {j in PROD}
                                                          ; # Sale Price per unit per Product
param Spr
param Vco
                   {j in PROD}
                                                          ; # Variable Cost per unit per Product
                   { j in PROD} >= 0
var
      QΡ
                                                          ; # Quantity to be produced per Product
                   : sum {j in PROD} QP[j] * ( Spr[j] - Vco[j] )
maximize TotPrf
                                                                             ; # Maximize Total Profit
                   {i in RESR} : sum {j in PROD} QP[j] * Hrs[i,j] <= Cap[i] ; # Capacity Constraint for each resource
s.t. CapCon
data
                                                                                                         ;
      RESR
                                       Man.Mch.Hrs Man.Manpow
set
                                                                 Dist.Manpow
                   :=
      PROD
                                                                                           Е
set
                    :=
                                                                 C
                                                                              D
                                                    В
                                                                 C
                                                                              D
                                                                                           Е
param Hrs
                                                                                                         :=
                                                    3
                                                                              6
                                                                                           3
                   Man.Mch.Hrs
                                       4
                                                                 12
                   Man.Manpow
                                       6
                                                    10
                                                                 7
                                                                              8
                                                                                           12
                                                    2
                                                                 5
                                                                                           5
                   Dist.Manpow
                                       4
                                                                                                         ;
                                       Cap
param
                                                                                                         :=
                   Man.Mch.Hrs
                                       1000
                   Man.Manpow
                                       1100
                                        600
                   Dist.Manpow
param Spr
                   :=
                                       A 97
                                                    B 110
                                                                 C 142
                                                                              D 112
                                                                                              97
param Vco
                                       A 58
                                                    B 75
                                                                 C 72
                                                                              D 55
                                                                                           Е
                                                                                              40
                    :=
option solver gurobi
solve
option display width 200, display 1col 0
display QP
```

SOLUTION PROBLEM Nb

```
set
      RESR
                   ordered
                                                          ; # Resources: Man.Mch.Hrs, Man.Manpow, Dist.Manpow
      PROD
                   ordered
                                                          ; # Products: A, B, C, D, E
set
                   {i in RESR, j in PROD}
                                                          ; # Hours required per Resource per Product
param Hrs
                                                          ; # Available Hours per Resource (Capacity)
param Cap
                   {i in RESR}
                   {j in PROD}
                                                          ; # Sale Price per unit per Product
param Spr
param Vco
                   {j in PROD}
                                                          ; # Variable Cost per unit per Product
                   {i in PROD} integer >= 0
var
      QΡ
                                                          ; # Quantity to be produced per Product
                   : sum {j in PROD} QP[j] * (Spr[j] - Vco[j] ) ; # Maximize Total Profit
maximize TotPrf
                   {i in RESR} : sum {j in PROD} QP[j] * Hrs[i,j] <= Cap[i] ; # Capacity Constraint for each resource
s.t. CapCon
data
      RESR
                                       Man.Mch.Hrs Man.Manpow
set
                                                                 Dist.Manpow
                   :=
      PROD
                                                                                           Е
set
                   :=
                                                                 C
                                                                              D
                                                    В
                                                                 C
                                                                              D
                                                                                           Е
param Hrs
                                                                                                        :=
                                                    3
                                                                              6
                                                                                           3
                   Man.Mch.Hrs
                                       4
                                                                 12
                   Man.Manpow
                                       6
                                                    10
                                                                 7
                                                                              8
                                                                                           12
                                                    2
                                                                 5
                                                                                           5
                   Dist.Manpow
                                       4
                                                                                                        ;
                                       Cap
param
                                                                                                        :=
                   Man.Mch.Hrs
                                       1000
                   Man.Manpow
                                       1100
                                        600
                   Dist.Manpow
param Spr
                   :=
                                       A 97
                                                    B 110
                                                                 C 142
                                                                              D 112
                                                                                              97
param Vco
                                       A 58
                                                    B 75
                                                                 C 72
                                                                              D 55
                                                                                           Е
                                                                                              40
                   :=
option solver gurobi
solve
option display width 200, display 1col 0
display QP
```

SOLUTION PROBLEM NC

```
set
       RESR
                    ordered
                                                           ; # Resources: Man.Mch.Hrs, Man.Manpow, Dist.Manpow
       PROD
                                                           ; # Products: A, B, C, D, E
set
                    ordered
                    {i in RESR, j in PROD}
                                                           ; # Hours required per Resource per Product
param Hrs
                                                           ; # Available Hours per Resource (Capacity)
param Cap
                    {i in RESR}
                                                           ; # Sale Price per unit per Product
param Spr
                   {j in PROD}
                                                           ; # Variable Cost per unit per Product
param Vco
                    {j in PROD}
                    {j in PROD}
                                                           ; # Fixed Cost per Product
param Fco
                                                           ; # Represents a very large number
param M
                   {j in PROD} integer >= 0
                                                           ; # Quantity to be produced per Product
       OΡ
var
                   {i in PROD} binary
                                                           ; # 1 if the Product is produced, 0 otherwise
var
       PΡ
                  : sum {j in PROD} ( QP[j] * ( Spr[j] - Vco[j] ) - PP[j] * Fco[j] ) ; # Maximize Total Profit
maximize TotPrf
s.t. CapCon {i in RESR} : sum {j in PROD} QP[j] * Hrs[i,j] <= Cap[i] ; # Capacity Constraint for each resource</pre>
                                                                        : # OP equal zero for Products not produced
      FcoCon {j in PROD} : QP[j] <= PP[j] * M</pre>
s.t.
data
                                                                                                          ;
       RESR
                                       Man.Mch.Hrs Man.Manpow
set
                    :=
                                                                  Dist.Manpow
       PROD
                                                                  C
                                                                                             Ε
set
                    :=
                                                                               D
param Hrs
                                                                  C
                                                                               D
                                                                                             Е
                                                                                                          :=
                    Man.Mch.Hrs
                                                     3
                                                                               6
                                                                                             3
                                                                  12
                                        6
                                                     10
                                                                  7
                                                                               8
                                                                                            12
                    Man.Manpow
                                        4
                                                     2
                                                                  5
                                                                               5
                                                                                            5
                    Dist.Manpow
                                                                                                          ;
param
                                       Cap
                                                                                                          :=
                    Man.Mch.Hrs
                                       1000
                    Man.Manpow
                                       1100
                    Dist.Manpow
                                        600
                                       A 97
                                                     B 110
                                                                  C 142
                                                                               D 112
                                                                                             E 97
param Spr
                                                                  C 72
                                                                                             E 40
param Vco
                                       A 58
                                                     B 75
                                                                               D 55
                    :=
param Fco
                                       A 400
                                                     B 300
                                                                  C 700
                                                                               D 500
                                                                                             E 600
                    :=
                                       1000000
param M
                    :=
option solver gurobi
solve
option display width 200, display 1col 0
display QP,PP
                                              ;
```