model

December 25, 2024

1 The OperationsResearch fall-2024 problem

1.1 Summary

The goal of project is to minimize the revenue of a factory which is producing metal alloys and sends them to markets using containers. we have some limitations in different levels of problem which you can see in project doc.

1.2 Pyomo formulation

We begin by importing the Pyomo package and creating a model abstract object:

[ ]:
```
from pyomo.environ import *
infinity = float('inf')
model = AbstractModel(name='OR1')
```

The sets *Ore*, *Alloys*, *Metals*, *Factories*, *Depots* and *Markets* are declared abstractly using the `Set` component:

[ ]:
```
model.Ore = Set()
model.Alloys = Set()
model.Metals = Set()
model.Factories = Set()
model.Depots = Set()
model.Markets = Set()
```

Similarly, we add parameters, the model parameters are defined abstractly using the `Param` component:

[ ]:
```
M = 999999999
epsilon = 1e-9
discount_percentage = 0.05

model.min_buy_fac = Param(model.Factories,within=NonNegativeReals, default=0.0)
model.max_buy_fac = Param(model.Factories,within=NonNegativeReals,␣
 ↪default=infinity)
model.discount_margin = Param(model.Factories, within=NonNegativeReals,␣
 ↪default=infinity)
model.contract_cost = Param(model.Factories,within= NonNegativeReals)
model.A_comb_min = Param(model.Metals, within=NonNegativeReals, default=0.0)
```

```
model.A_comb_max = Param(model.Metals, within=NonNegativeReals,␣
 ↪default=infinity)
model.B_comb_min = Param(model.Metals, within=NonNegativeReals, default=0.0)
model.B_comb_max = Param(model.Metals, within=NonNegativeReals,␣
 ↪default=infinity)
model.price_of_alloy_fac = Param(model.Factories, model.Alloys,␣
 ↪within=NonNegativeReals)
model.Max_ore = Param(model.Ore,within=NonNegativeReals)
model.Ore_cost = Param(model.Ore,within=NonNegativeReals)
model.Ore_combination = Param(model.Ore, model.Metals, within=NonNegativeReals)
model.container_cap = Param(within= NonNegativeIntegers)
model.Container_min_to_be_sent_depot = Param(model.Factories, model.Depots,␣
 ↪within=NonNegativeIntegers)
model.Container_Max_to_be_sent_depot = Param(model.Factories, model.Depots,␣
 ↪within=NonNegativeIntegers)
model.Container_cost_to_be_sent_depot = Param(model.Factories, model.Depots ,␣
 ↪within=NonNegativeReals)
model.depots_min_to_receive = Param(model.Depots, within=NonNegativeIntegers)
model.depots_Max_to_receive = Param(model.Depots, within=NonNegativeIntegers)
model.Container_min_to_be_sent_market = Param(model.Depots, model.Markets,␣
 ↪within= NonNegativeIntegers)
model.Container_Max_to_be_sent_market = Param(model.Depots, model.Markets,␣
 ↪within= NonNegativeIntegers)
model.Container_cost_to_be_sent_market = Param(model.Depots ,model.Markets,␣
 ↪within= NonNegativeReals)
model.Max_market_demand = Param(model.Markets,model.Alloys, within=␣
 ↪NonNegativeReals)
model.Market_price = Param(model.Markets , model.Alloys , within=␣
 ↪NonNegativeReals)
```

The `within` option here is used in these parameter declarations to define expected properties of the parameters. This information is used to perform error checks on the data that is used to initialize the parameter components.

The `Var` component is used to define the decision variables: the `binary` is `{0,1}` to be clear.

[ ]:
```
model.Z = Var(model.Ore,model.Alloys, within=NonNegativeReals)
model.F = Var(model.Ore,model.Alloys, within=NonNegativeReals)
model.A = Var(model.Ore,model.Alloys, within=NonNegativeReals)
model.C = Var(model.Ore,model.Alloys, within=NonNegativeReals)
model.U = Var(model.Alloys,within=NonNegativeReals)
model.t = Var(model.Alloys,model.Factories,model.Depots,␣
 ↪within=NonNegativeReals)
model.Extracted_ore = Var(model.Ore,within=NonNegativeReals) # defined as S in␣
 ↪report
model.h = Var(model.Factories,within= Binary)
model.B = Var(model.Factories, model.Depots, within=NonNegativeIntegers)
```

```
model.g = Var(model.Alloys, model.Depots, model.Markets,␣
 ↪within=NonNegativeReals)
model.G = Var(model.Depots, model.Markets, within= NonNegativeIntegers)
model.l = Var(model.Depots, model.Markets, within= Binary)
model.d = Var([1,2], within= Binary)
model.R = Var(model.Alloys,[1,2], within= NonNegativeReals, initialize=0)
```

Rule functions are used to define constraint expressions in the `Constraint` component: here we have rule for maximum extraction of Ore:

[ ]:
```
def Max_extracted_ore_rule(model,i):
    return model.Extracted_ore[i] <= model.Max_ore[i]
model.Max_extracted_ore_limit = Constraint(model.
 ↪Ore,rule=Max_extracted_ore_rule)
```

Rule for Alloy weight limit(alloy weight is sum of metals weights in it):

[ ]:
```
def Alloy_sum_rule(model,j):
    return model.U[j] == sum(model.Z[i,j] for i in model.Ore)+\
                         sum(model.C[i,j] for i in model.Ore)+\
                         sum(model.A[i,j] for i in model.Ore)+\
                         sum(model.F[i,j] for i in model.Ore)
model.Alloy_sum_limit = Constraint(model.Alloys,rule=Alloy_sum_rule)
```

Rule for Metals in alloys(should be less than (or equal to) extracted metals from Ore):

[ ]:
```
def Metal_sum_rule_Z(model,i):
    return sum(model.Z[i,j] for j in model.Alloys) <= model.
 ↪Extracted_ore[i]*model.Ore_combination[i,'Zinc']
model.Metal_sum_limit_Z = Constraint(model.Ore,rule=Metal_sum_rule_Z)
```

[ ]:
```
def Metal_sum_rule_F(model,i):
    return sum(model.F[i,j] for j in model.Alloys) <= model.
 ↪Extracted_ore[i]*model.Ore_combination[i,'Iron']
model.Metal_sum_limit_F = Constraint(model.Ore,rule=Metal_sum_rule_F)
```

[ ]:
```
def Metal_sum_rule_C(model,i):
    return sum(model.C[i,j] for j in model.Alloys) <= model.
 ↪Extracted_ore[i]*model.Ore_combination[i,'Copper']
model.Metal_sum_limit_C = Constraint(model.Ore,rule=Metal_sum_rule_C)
```

[ ]:
```
def Metal_sum_rule_A(model,i):
    return sum(model.A[i,j] for j in model.Alloys) <= model.
 ↪Extracted_ore[i]*model.Ore_combination[i,'Aluminum']
model.Metal_sum_limit_A = Constraint(model.Ore,rule=Metal_sum_rule_A)
```

Rule for limitation of percentage of Metals in Alloys(f is bottom limit and t is top limit):

[ ]:
```
def Metal_in_alloy_rule_A_Z_f(model):
    value = sum(model.Z[i,'A'] for i in model.Ore)
    return model.A_comb_min['Zinc']*model.U['A']<=value
model.Metal_in_alloy_limit_A_Z_f = Constraint(rule=Metal_in_alloy_rule_A_Z_f)
def Metal_in_alloy_rule_A_Z_t(model):
    value = sum(model.Z[i,'A'] for i in model.Ore)
    return value<=model.A_comb_max['Zinc']*model.U['A']
model.Metal_in_alloy_limit_A_Z_t = Constraint(rule=Metal_in_alloy_rule_A_Z_t)
```

[ ]:
```
def Metal_in_alloy_rule_A_C_f(model):
    value = sum(model.C[i,'A'] for i in model.Ore)
    return model.A_comb_min['Copper']*model.U['A']<=value
model.Metal_in_alloy_limit_A_C_f = Constraint(rule=Metal_in_alloy_rule_A_C_f)
def Metal_in_alloy_rule_A_C_t(model):
    value = sum(model.C[i,'A'] for i in model.Ore)
    return value<=model.A_comb_max['Copper']*model.U['A']
model.Metal_in_alloy_limit_A_C_t = Constraint(rule=Metal_in_alloy_rule_A_C_t)
```

[ ]:
```
def Metal_in_alloy_rule_A_A_f(model):
    value = sum(model.A[i,'A'] for i in model.Ore)
    return model.A_comb_min['Aluminum']*model.U['A']<=value
model.Metal_in_alloy_limit_A_A_f = Constraint(rule=Metal_in_alloy_rule_A_A_f)
def Metal_in_alloy_rule_A_A_t(model):
    value = sum(model.A[i,'A'] for i in model.Ore)
    return value<=model.A_comb_max['Aluminum']*model.U['A']
model.Metal_in_alloy_limit_A_A_t = Constraint(rule=Metal_in_alloy_rule_A_A_t)
```

[ ]:
```
def Metal_in_alloy_rule_A_F_f(model):
    value = sum(model.F[i,'A'] for i in model.Ore)
    return model.A_comb_min['Iron']*model.U['A']<=value
model.Metal_in_alloy_limit_A_F_f = Constraint(rule=Metal_in_alloy_rule_A_F_f)
def Metal_in_alloy_rule_A_F_t(model):
    value = sum(model.F[i,'A'] for i in model.Ore)
    return value<=model.A_comb_max['Iron']*model.U['A']
model.Metal_in_alloy_limit_A_F_t = Constraint(rule=Metal_in_alloy_rule_A_F_t)
```

[ ]:
```
def Metal_in_alloy_rule_B_Z_f(model):
    value = sum(model.Z[i,'B'] for i in model.Ore)
    return model.B_comb_min['Zinc']*model.U['B']<=value
model.Metal_in_alloy_limit_B_Z_f = Constraint(rule=Metal_in_alloy_rule_B_Z_f)
def Metal_in_alloy_rule_B_Z_t(model):
    value = sum(model.Z[i,'B'] for i in model.Ore)
    return value<=model.B_comb_max['Zinc']*model.U['B']
model.Metal_in_alloy_limit_B_Z_t = Constraint(rule=Metal_in_alloy_rule_B_Z_t)
```

[ ]:
```
def Metal_in_alloy_rule_B_C_f(model):
    value = sum(model.C[i,'B'] for i in model.Ore)
```

```
    return model.B_comb_min['Copper']*model.U['B']<=value
model.Metal_in_alloy_limit_B_C_f = Constraint(rule=Metal_in_alloy_rule_B_C_f)
def Metal_in_alloy_rule_B_C_t(model):
    value = sum(model.C[i,'B'] for i in model.Ore)
    return value<=model.B_comb_max['Copper']*model.U['B']
model.Metal_in_alloy_limit_B_C_t = Constraint(rule=Metal_in_alloy_rule_B_C_t)
```

[ ]:
```
def Metal_in_alloy_rule_B_A_f(model):
    value = sum(model.A[i,'B'] for i in model.Ore)
    return model.B_comb_min['Aluminum']*model.U['B']<=value
model.Metal_in_alloy_limit_B_A_f = Constraint(rule=Metal_in_alloy_rule_B_A_f)
def Metal_in_alloy_rule_B_A_t(model):
    value = sum(model.A[i,'B'] for i in model.Ore)
    return value<=model.B_comb_max['Aluminum']*model.U['B']
model.Metal_in_alloy_limit_B_A_t = Constraint(rule=Metal_in_alloy_rule_B_A_t)
```

[ ]:
```
def Metal_in_alloy_rule_B_F_f(model):
    value = sum(model.F[i,'B'] for i in model.Ore)
    return model.B_comb_min['Iron']*model.U['B']<=value
model.Metal_in_alloy_limit_B_F_f = Constraint(rule=Metal_in_alloy_rule_B_F_f)
def Metal_in_alloy_rule_B_F_t(model):
    value = sum(model.F[i,'B'] for i in model.Ore)
    return value<=model.B_comb_max['Iron']*model.U['B']
model.Metal_in_alloy_limit_B_F_t = Constraint(rule=Metal_in_alloy_rule_B_F_t)
```

Rule for amount of exported alloy from main Factory, it should be less than(or equal to):

[ ]:
```
def Export_from_main_fac_rule(model,i):
    return model.U[i] >= sum(model.t[i,'Main',k] for k in model.Depots)
model.Export_from_main_fac_limit = Constraint(model.
 ↪Alloys,rule=Export_from_main_fac_rule)
```

Rule of Limits of buying from factories:

[ ]:
```
def buy_from_fac_rule_f(model,i):
    value = sum(sum(model.t[j,i,k] for k in model.Depots)\
                                                for j in model.Alloys)
    return model.min_buy_fac[i]*model.h[i]<=value
model.buy_from_fac_limit_f= Constraint([1,2],rule=buy_from_fac_rule_f)
def buy_from_fac_rule_t(model,i):
    value = sum(sum(model.t[j,i,k] for k in model.Depots)\
                                                for j in model.Alloys)
    return value<=model.max_buy_fac[i]*model.h[i]
model.buy_from_fac_limit_t= Constraint([1,2],rule=buy_from_fac_rule_t)
```

Rule of limit for Alloys in one container from Factory to Depot:

[ ]:
```
def container_rule(model,i,j):
    return sum(model.t[a,i,j] for a in model.Alloys) <= model.B[i,j]*model.
 ↪container_cap
model.container_limit = Constraint(model.Factories, model.Depots,␣
 ↪rule=container_rule)
```

Rule of limit for transporting from fac to depots No1.:

[ ]:
```
def transportation_rule_t(model,i,j):
    return model.B[i,j]<= model.Container_Max_to_be_sent_depot[i,j]*model.h[i]
model.transportation_limit_t = Constraint(model.Factories,model.Depots, rule=␣
 ↪transportation_rule_t)
def transportation_rule_f(model,i,j):
    return model.Container_min_to_be_sent_depot[i,j]*model.h[i]<=model.B[i,j]
model.transportation_limit_f = Constraint(model.Factories,model.Depots, rule=␣
 ↪transportation_rule_f)
```

Rule of limit for transporting from fac to depots No2.:

[ ]:
```
def transportation_rule2(model,j):
    return inequality(model.depots_min_to_receive[j],sum(model.B[i,j] for i in␣
 ↪model.Factories),\
                      model.depots_Max_to_receive[j])
model.transportation_limit2 = Constraint(model.Depots,rule=␣
 ↪transportation_rule2)
```

Rule of limit for transporting from depots to markets:

[ ]:
```
def transp_from_dep_to_marker_rule(model,i,k):
    return sum(model.t[i,j,k] for j in model.Factories) >= sum(model.g[i,k,l]␣
 ↪for l in model.Markets)
model.transp_from_dep_to_marker_limit = Constraint(model.Alloys,model.Depots,\
                                                   rule=␣
 ↪transp_from_dep_to_marker_rule)
```

Rule of limits for Alloys in containers transporting from depots to markets:

[ ]:
```
def container_rule2(model,i,j):
    return sum(model.g[l,i,j] for l in model.Alloys) <= model.G[i,j]*model.
 ↪container_cap
model.container_limit2 = Constraint(model.Depots, model.Markets,␣
 ↪rule=container_rule2)
```

Limit for containers to be sent to markets:

[ ]:
```
def market_sell_rule_f(model,i,j):
    return model.Container_min_to_be_sent_market[i,j]*model.l[i,j]<=model.G[i,j]
model.market_sell_limit_f = Constraint(model.Depots,model.Markets, rule=␣
 ↪market_sell_rule_f)
```

```
def market_sell_rule_t(model,i,j):
    return model.G[i,j]<=model.Container_min_to_be_sent_market[i,j]*model.l[i,j]
model.market_sell_limit_t = Constraint(model.Depots,model.Markets, rule=␣
 ↪market_sell_rule_t)
```

Here we have maximum market demands rule:

[ ]:
```
def max_market_demand_rule(model,k,i):
    return sum(model.g[i,j,k] for j in model.Depots) <= model.
 ↪Max_market_demand[k,i]
model.max_market_demand_limit = Constraint(model.Markets, model.Alloys, rule=␣
 ↪max_market_demand_rule)
```

The `Objective` component is used to define the revenue objective. This component uses a rule function to construct the objective expression:

sense = *maximize* means we want to maximize the revenue.

[ ]:
```
def revenue_rule(model):
    return sum(sum(model.Market_price[m,j]*sum(model.g[j,k,m] for k in model.
 ↪Depots) for j in model.Alloys) for m in model.Markets)-\
           sum(model.Extracted_ore[i]*model.Ore_cost[i] for i in model.Ore)-\
           sum(sum(model.price_of_alloy_fac[u,j]*sum(model.t[j,u,k] for k in␣
 ↪model.Depots) for j in model.Alloys) for u in model.Factories)-\
           sum(model.h[u]*model.contract_cost[u] for u in model.Factories)-\
           sum(sum(model.Container_cost_to_be_sent_depot[i,j]*model.B[i,j] for␣
 ↪j in model.Depots) for i in model.Factories)-\
           sum(sum(model.G[i,j]*model.Container_cost_to_be_sent_market[i,j] for␣
 ↪j in model.Markets) for i in model.Depots)
```

[ ]:
```
model.revenue = Objective(rule=revenue_rule, sense=maximize)
```

here is added constraints and adjusted revenue for `part B`:

[ ]:
```
def discount_rule_1(model,u):
    return sum(sum(model.t[j,u,k] for j in model.Alloys) for k in model.
 ↪Depots)+epsilon <= model.d[u]*model.discount_margin[u] +\

 ↪  model.discount_margin[u]

def discount_rule_2(model,u):
    return sum(sum(model.t[j,u,k] for j in model.Alloys) for k in model.Depots)␣
 ↪>= model.discount_margin[u]*model.d[u]

def discount_rule_3(model,u,j):
    return sum(model.t[j,u,k] for k in model.Depots) >= model.R[j,u]

def discount_rule_4(model,u):
    return sum(model.R[j,u] for j in model.Alloys) <= model.d[u]*M
```

```
def revenue_rule_discount_added(model):
    return sum(sum(model.Market_price[m,j]*sum(model.g[j,k,m] for k in model.
 ↪Depots) for j in model.Alloys) for m in model.Markets)-\
           sum(model.Extracted_ore[i]*model.Ore_cost[i] for i in model.Ore)-\
           sum(sum(model.price_of_alloy_fac[u,j]*sum(model.t[j,u,k] for k in␣
 ↪model.Depots) for j in model.Alloys) for u in model.Factories)-\
           sum(model.h[u]*model.contract_cost[u] for u in model.Factories)-\
           sum(sum(model.Container_cost_to_be_sent_depot[i,j]*model.B[i,j] for␣
 ↪j in model.Depots) for i in model.Factories)-\
           sum(sum(model.G[i,j]*model.Container_cost_to_be_sent_market[i,j] for␣
 ↪j in model.Markets) for i in model.Depots)+\
           sum(sum(discount_percentage*model.R[j,u]*model.
 ↪price_of_alloy_fac[u,j] for u in [1,2]) for j in model.Alloys)

def apply_discount_rule():
    model.discount_limit_1 = Constraint([1,2],rule=discount_rule_1)
    model.discount_limit_2 = Constraint([1,2],rule=discount_rule_2)
    model.discount_limit_3 = Constraint([1,2],model.Alloys,rule=discount_rule_3)
    model.discount_limit_4 = Constraint([1,2],rule=discount_rule_4)
    model.revenue = Objective(rule=revenue_rule_discount_added, sense=maximize)
```

1.3 model data

since we have made an abstract model, we can add the data after creating model, to see the data we are feeding the model

execute command below or have a look at params.dat:

[6]:
```
!cat params.dat
```

```
set Alloys:=
       A
       B;

param: Factories:         min_buy_fac  discount_margin  max_buy_fac
contract_cost:=
       1                  2000         2500             5000            120
       2                  2500         3000             6000            90
       Main               0            .                .               0   ;

param: Depots:         depots_min_to_receive  depots_Max_to_receive :=
       Tehran          20                     65
       Isfahan         30                     70   ;

param container_cap:= 100;

set Markets:=
```

```
       Mashhad
       Kerman
       Ahvaz
       Tabriz  ;

param: Metals:       A_comb_min   A_comb_max    B_comb_min   B_comb_max :=
       Iron          0            0.25          0.45         0.70
       Aluminum      0.55         1             0            0.70
       Zinc          0            0.8           0            1
       Copper        0            1             0.35         1  ;

param: Ore:                  Max_ore      Ore_cost :=
       1                     560          45
       2                     1000         65
       3                     1440          70  ;

param Ore_combination:
                        Iron    Aluminum    Zinc    Copper :=
       1                .05     .35         .25     .30
       2                .20     .30         .15     .25
       3                .05     .25         .65     .05 ;


param Container_min_to_be_sent_depot:
                       Tehran        Isfahan :=
       Main            5             5
       1               10            10
       2               5             5      ;


param Container_Max_to_be_sent_depot:
                       Tehran        Isfahan :=
       Main            20            20
       1               30            30
       2               25            15      ;

param Container_cost_to_be_sent_depot:
                       Tehran        Isfahan :=
       Main            200            230
       1               180            210
       2               240            220      ;



param Container_min_to_be_sent_market:
                       Mashhad      Kerman    Ahvaz   Tabriz :=
       Tehran          3            6         10      5
       Isfahan         4            5         5       10  ;
```

```
param Container_Max_to_be_sent_market:
                    Mashhad      Kerman    Ahvaz   Tabriz :=
       Tehran       7            12        18      15
       Isfahan      6            14        20      20  ;

param Container_cost_to_be_sent_market:
                    Mashhad      Kerman    Ahvaz   Tabriz :=
       Tehran       110          85        120     100
       Isfahan      100          100       110     90  ;



param Max_market_demand:
                    A      B :=
       Mashhad      600    400
       Kerman       800    1200
       Ahvaz        1500   1500
       Tabriz       1400   1100   ;

param Market_price:
                    A      B :=
       Mashhad      520    700
       Kerman       540    690
       Ahvaz        490    730
       Tabriz       500    710   ;


param price_of_alloy_fac:
                    A      B :=
       1            375    520
       2            390    540
       Main         0      0      ;
```

1.4 Solution

To get the result of a problem,you can execute the command below:

make sure to replace `-problem-number` with correct number, use porblem-dict.

results are also saved in `results.yaml`

[2]:
```
!python model_runner.py -problem-number
```

this is problem-dictionary

```
{     '-a':' ',     '-b':' ',     '-c':' ',     '-d':' ',     '-e':' ',
'-f':' ',     '-g':' ',     '-h':' ',     '-i':' ' {
```

for example you can execute the code below to see results of problem :

1.4.1 Problem A

[7]:
```
!python model_runner.py -a
```

```
results for problem: -a

Problem:
- Name: unknown
  Lower bound: 1593740.3030303
  Upper bound: 1593740.3030303
  Number of objectives: 1
  Number of constraints: 97
  Number of variables: 82
  Number of nonzeros: 304
  Sense: maximize
Solver:
- Status: ok
  Termination condition: optimal
  Statistics:
    Branch and bound:
      Number of bounded subproblems: 39
      Number of created subproblems: 39
  Error rc: 0
  Time: 0.010610103607177734
Solution:
- number of solutions: 0
  number of solutions displayed: 0

Model OR1

  Variables:
    Z : Size=6, Index=Ore*Alloys
        Key      : Lower : Value            : Upper : Fixed : Stale : Domain
        (1, 'A') :     0 :            140.0 :  None : False : False :
NonNegativeReals
        (1, 'B') :     0 :              0.0 :  None : False : False :
NonNegativeReals
        (2, 'A') :     0 :            150.0 :  None : False : False :
NonNegativeReals
        (2, 'B') :     0 :              0.0 :  None : False : False :
NonNegativeReals
        (3, 'A') :     0 :  225.69696969697 :  None : False : False :
NonNegativeReals
        (3, 'B') :     0 : 133.333333333333 :  None : False : False :
NonNegativeReals
    F : Size=6, Index=Ore*Alloys
```

```
        Key      : Lower : Value : Upper : Fixed : Stale : Domain
        (1, 'A') :     0 :   0.0 :  None : False : False : NonNegativeReals
        (1, 'B') :     0 :  28.0 :  None : False : False : NonNegativeReals
        (2, 'A') :     0 :   0.0 :  None : False : False : NonNegativeReals
        (2, 'B') :     0 : 200.0 :  None : False : False : NonNegativeReals
        (3, 'A') :     0 :   0.0 :  None : False : False : NonNegativeReals
        (3, 'B') :     0 :  72.0 :  None : False : False : NonNegativeReals
    A : Size=6, Index=Ore*Alloys
        Key      : Lower : Value : Upper : Fixed : Stale : Domain
        (1, 'A') :     0 : 196.0 :  None : False : False : NonNegativeReals
        (1, 'B') :     0 :   0.0 :  None : False : False : NonNegativeReals
        (2, 'A') :     0 : 300.0 :  None : False : False : NonNegativeReals
        (2, 'B') :     0 :   0.0 :  None : False : False : NonNegativeReals
        (3, 'A') :     0 : 360.0 :  None : False : False : NonNegativeReals
        (3, 'B') :     0 :   0.0 :  None : False : False : NonNegativeReals
    C : Size=6, Index=Ore*Alloys
        Key      : Lower : Value            : Upper : Fixed : Stale : Domain
        (1, 'A') :     0 :              0.0 :  None : False : False :
NonNegativeReals
        (1, 'B') :     0 :            168.0 :  None : False : False :
NonNegativeReals
        (2, 'A') :     0 : 184.666666666667 :  None : False : False :
NonNegativeReals
        (2, 'B') :     0 : 65.3333333333333 :  None : False : False :
NonNegativeReals
        (3, 'A') :     0 :              0.0 :  None : False : False :
NonNegativeReals
        (3, 'B') :     0 :              0.0 :  None : False : False :
NonNegativeReals
    U : Size=2, Index=Alloys
        Key : Lower : Value            : Upper : Fixed : Stale : Domain
          A :     0 : 1556.36363636364 :  None : False : False :
NonNegativeReals
          B :     0 : 666.666666666667 :  None : False : False :
NonNegativeReals
    t : Size=12, Index=Alloys*Factories*Depots
        Key                      : Lower : Value            : Upper : Fixed :
Stale : Domain
             ('A', 1, 'Isfahan') :     0 :              0.0 :  None : False :
False : NonNegativeReals
              ('A', 1, 'Tehran') :     0 :              0.0 :  None : False :
False : NonNegativeReals
             ('A', 2, 'Isfahan') :     0 :              0.0 :  None : False :
False : NonNegativeReals
              ('A', 2, 'Tehran') :     0 :              0.0 :  None : False :
False : NonNegativeReals
        ('A', 'Main', 'Isfahan') :     0 : 1256.36363636364 :  None : False :
False : NonNegativeReals
```

```
         ('A', 'Main', 'Tehran') :     0 :            300.0 :  None : False :
False : NonNegativeReals
             ('B', 1, 'Isfahan') :     0 : 676.969696969697 :  None : False :
False : NonNegativeReals
              ('B', 1, 'Tehran') :     0 :          1900.0 :  None : False :
False : NonNegativeReals
             ('B', 2, 'Isfahan') :     0 :             0.0 :  None : False :
False : NonNegativeReals
              ('B', 2, 'Tehran') :     0 :             0.0 :  None : False :
False : NonNegativeReals
         ('B', 'Main', 'Isfahan') :     0 : 466.666666666667 :  None : False :
False : NonNegativeReals
          ('B', 'Main', 'Tehran') :     0 :            200.0 :  None : False :
False : NonNegativeReals
    Extracted_ore : Size=3, Index=Ore
        Key : Lower : Value  : Upper : Fixed : Stale : Domain
          1 :     0 :  560.0 :  None : False : False : NonNegativeReals
          2 :     0 : 1000.0 :  None : False : False : NonNegativeReals
          3 :     0 : 1440.0 :  None : False : False : NonNegativeReals
    h : Size=3, Index=Factories
        Key  : Lower : Value : Upper : Fixed : Stale : Domain
           1 :     0 :   1.0 :     1 : False : False : Binary
           2 :     0 :   0.0 :     1 : False : False : Binary
        Main :     0 :   1.0 :     1 : False : False : Binary
    B : Size=6, Index=Factories*Depots
        Key                  : Lower : Value : Upper : Fixed : Stale : Domain
             (1, 'Isfahan') :     0 :  12.0 :  None : False : False :
NonNegativeIntegers
              (1, 'Tehran') :     0 :  19.0 :  None : False : False :
NonNegativeIntegers
             (2, 'Isfahan') :     0 :   0.0 :  None : False : False :
NonNegativeIntegers
              (2, 'Tehran') :     0 :   0.0 :  None : False : False :
NonNegativeIntegers
         ('Main', 'Isfahan') :     0 :  18.0 :  None : False : False :
NonNegativeIntegers
          ('Main', 'Tehran') :     0 :   5.0 :  None : False : False :
NonNegativeIntegers
    g : Size=16, Index=Alloys*Depots*Markets
        Key                          : Lower : Value            : Upper : Fixed :
Stale : Domain
           ('A', 'Isfahan', 'Ahvaz') :     0 :              0.0 :  None : False :
False : NonNegativeReals
          ('A', 'Isfahan', 'Kerman') :     0 :            500.0 :  None : False :
False : NonNegativeReals
         ('A', 'Isfahan', 'Mashhad') :     0 : 356.363636363636 :  None : False :
False : NonNegativeReals
          ('A', 'Isfahan', 'Tabriz') :     0 :            400.0 :  None : False :
```

```
False : NonNegativeReals
          ('A', 'Tehran', 'Ahvaz') :     0 :              0.0 :  None : False :
False : NonNegativeReals
         ('A', 'Tehran', 'Kerman') :     0 :            300.0 :  None : False :
False : NonNegativeReals
        ('A', 'Tehran', 'Mashhad') :     0 :              0.0 :  None : False :
False : NonNegativeReals
         ('A', 'Tehran', 'Tabriz') :     0 :              0.0 :  None : False :
False : NonNegativeReals
         ('B', 'Isfahan', 'Ahvaz') :     0 :            500.0 :  None : False :
False : NonNegativeReals
        ('B', 'Isfahan', 'Kerman') :     0 :              0.0 :  None : False :
False : NonNegativeReals
       ('B', 'Isfahan', 'Mashhad') :     0 : 43.6363636363637 :  None : False :
False : NonNegativeReals
        ('B', 'Isfahan', 'Tabriz') :     0 :            600.0 :  None : False :
False : NonNegativeReals
          ('B', 'Tehran', 'Ahvaz') :     0 :           1000.0 :  None : False :
False : NonNegativeReals
         ('B', 'Tehran', 'Kerman') :     0 :            300.0 :  None : False :
False : NonNegativeReals
        ('B', 'Tehran', 'Mashhad') :     0 :            300.0 :  None : False :
False : NonNegativeReals
         ('B', 'Tehran', 'Tabriz') :     0 :            500.0 :  None : False :
False : NonNegativeReals
    G : Size=8, Index=Depots*Markets
        Key                    : Lower : Value : Upper : Fixed : Stale : Domain
          ('Isfahan', 'Ahvaz') :     0 :   5.0 :  None : False : False :
NonNegativeIntegers
         ('Isfahan', 'Kerman') :     0 :   5.0 :  None : False : False :
NonNegativeIntegers
        ('Isfahan', 'Mashhad') :     0 :   4.0 :  None : False : False :
NonNegativeIntegers
         ('Isfahan', 'Tabriz') :     0 :  10.0 :  None : False : False :
NonNegativeIntegers
          ('Tehran', 'Ahvaz') :     0 :  10.0 :  None : False : False :
NonNegativeIntegers
         ('Tehran', 'Kerman') :     0 :   6.0 :  None : False : False :
NonNegativeIntegers
        ('Tehran', 'Mashhad') :     0 :   3.0 :  None : False : False :
NonNegativeIntegers
         ('Tehran', 'Tabriz') :     0 :   5.0 :  None : False : False :
NonNegativeIntegers
    l : Size=8, Index=Depots*Markets
        Key                    : Lower : Value : Upper : Fixed : Stale : Domain
          ('Isfahan', 'Ahvaz') :     0 :   1.0 :     1 : False : False : Binary
         ('Isfahan', 'Kerman') :     0 :   1.0 :     1 : False : False : Binary
        ('Isfahan', 'Mashhad') :     0 :   1.0 :     1 : False : False : Binary
```

```
     ('Isfahan', 'Tabriz') :     0 :   1.0 :     1 : False : False : Binary
       ('Tehran', 'Ahvaz') :     0 :   1.0 :     1 : False : False : Binary
      ('Tehran', 'Kerman') :     0 :   1.0 :     1 : False : False : Binary
     ('Tehran', 'Mashhad') :     0 :   1.0 :     1 : False : False : Binary
      ('Tehran', 'Tabriz') :     0 :   1.0 :     1 : False : False : Binary
  d : Size=2, Index={1, 2}
      Key : Lower : Value : Upper : Fixed : Stale : Domain
        1 :     0 :  None :     1 : False :  True : Binary
        2 :     0 :  None :     1 : False :  True : Binary
  R : Size=4, Index=Alloys*{1, 2}
      Key      : Lower : Value : Upper : Fixed : Stale : Domain
      ('A', 1) :     0 :     0 :  None : False :  True : NonNegativeReals
      ('A', 2) :     0 :     0 :  None : False :  True : NonNegativeReals
      ('B', 1) :     0 :     0 :  None : False :  True : NonNegativeReals
      ('B', 2) :     0 :     0 :  None : False :  True : NonNegativeReals

Objectives:
  revenue : Size=1, Index=None, Active=True
      Key  : Active : Value
      None :   True : 1593740.3030303027

Constraints:
  Max_extracted_ore_limit : Size=3
      Key : Lower : Body   : Upper
        1 :  None :  560.0 :   560
        2 :  None : 1000.0 :  1000
        3 :  None : 1440.0 :  1440
  Alloy_sum_limit : Size=2
      Key : Lower : Body                    : Upper
        A :  None : 2.9558577807620168e-12 :   0.0
        B :  None :  6.821210263296962e-13 :   0.0
  Metal_sum_limit_Z : Size=3
      Key : Lower : Body              : Upper
        1 :  None :               0.0 :   0.0
        2 :  None :               0.0 :   0.0
        3 :  None : -576.969696969697 :   0.0
  Metal_sum_limit_F : Size=3
      Key : Lower : Body : Upper
        1 :  None :  0.0 :   0.0
        2 :  None :  0.0 :   0.0
        3 :  None :  0.0 :   0.0
  Metal_sum_limit_C : Size=3
      Key : Lower : Body                  : Upper
        1 :  None :                   0.0 :   0.0
        2 :  None : 2.984279490192421e-13 :   0.0
        3 :  None :                 -72.0 :   0.0
  Metal_sum_limit_A : Size=3
      Key : Lower : Body : Upper
```

```
      1 :  None :  0.0 :   0.0
      2 :  None :  0.0 :   0.0
      3 :  None :  0.0 :   0.0
Metal_in_alloy_limit_A_Z_f : Size=1
    Key  : Lower : Body             : Upper
    None :  None : -515.69696969697 :   0.0
Metal_in_alloy_limit_A_Z_t : Size=1
    Key  : Lower : Body              : Upper
    None :  None : -729.393939393942 :   0.0
Metal_in_alloy_limit_A_C_f : Size=1
    Key  : Lower : Body              : Upper
    None :  None : -184.666666666667 :   0.0
Metal_in_alloy_limit_A_C_t : Size=1
    Key  : Lower : Body               : Upper
    None :  None : -1371.696969696973 :   0.0
Metal_in_alloy_limit_A_A_f : Size=1
    Key  : Lower : Body                     : Upper
    None :  None : 2.0463630789890885e-12 :   0.0
Metal_in_alloy_limit_A_A_t : Size=1
    Key  : Lower : Body               : Upper
    None :  None : -700.3636363636399 :   0.0
Metal_in_alloy_limit_A_F_f : Size=1
    Key  : Lower : Body : Upper
    None :  None :  0.0 :   0.0
Metal_in_alloy_limit_A_F_t : Size=1
    Key  : Lower : Body             : Upper
    None :  None : -389.09090909091 :   0.0
Metal_in_alloy_limit_B_Z_f : Size=1
    Key  : Lower : Body              : Upper
    None :  None : -133.333333333333 :   0.0
Metal_in_alloy_limit_B_Z_t : Size=1
    Key  : Lower : Body               : Upper
    None :  None : -533.3333333333339 :   0.0
Metal_in_alloy_limit_B_C_f : Size=1
    Key  : Lower : Body                     : Upper
    None :  None : 1.1368683772161603e-13 :   0.0
Metal_in_alloy_limit_B_C_t : Size=1
    Key  : Lower : Body                : Upper
    None :  None : -433.33333333333366 :   0.0
Metal_in_alloy_limit_B_A_f : Size=1
    Key  : Lower : Body : Upper
    None :  None :  0.0 :   0.0
Metal_in_alloy_limit_B_A_t : Size=1
    Key  : Lower : Body                : Upper
    None :  None : -466.66666666666686 :   0.0
Metal_in_alloy_limit_B_F_f : Size=1
    Key  : Lower : Body                     : Upper
    None :  None : 1.7053025658242404e-13 :   0.0
```

```
Metal_in_alloy_limit_B_F_t : Size=1
    Key  : Lower : Body                 : Upper
    None :  None : -166.66666666666686 :   0.0
Export_from_main_fac_limit : Size=2
    Key : Lower : Body                   : Upper
      A :  None :                    0.0 :   0.0
      B :  None : 5.684341886080802e-14 :   0.0
buy_from_fac_limit_f : Size=2
    Key : Lower : Body              : Upper
      1 :  None : -576.969696969697 :   0.0
      2 :  None :               0.0 :   0.0
buy_from_fac_limit_t : Size=2
    Key : Lower : Body               : Upper
      1 :  None : -2423.030303030303 :   0.0
      2 :  None :                0.0 :   0.0
container_limit : Size=6
    Key                 : Lower : Body               : Upper
         (1, 'Isfahan') :  None :  -523.030303030303 :   0.0
          (1, 'Tehran') :  None :                0.0 :   0.0
         (2, 'Isfahan') :  None :                0.0 :   0.0
          (2, 'Tehran') :  None :                0.0 :   0.0
    ('Main', 'Isfahan') :  None : -76.96969696969308 :   0.0
     ('Main', 'Tehran') :  None :                0.0 :   0.0
transportation_limit_t : Size=6
    Key                 : Lower : Body  : Upper
         (1, 'Isfahan') :  None : -18.0 :   0.0
          (1, 'Tehran') :  None : -11.0 :   0.0
         (2, 'Isfahan') :  None :   0.0 :   0.0
          (2, 'Tehran') :  None :   0.0 :   0.0
    ('Main', 'Isfahan') :  None :  -2.0 :   0.0
     ('Main', 'Tehran') :  None : -15.0 :   0.0
transportation_limit_f : Size=6
    Key                 : Lower : Body  : Upper
         (1, 'Isfahan') :  None :  -2.0 :   0.0
          (1, 'Tehran') :  None :  -9.0 :   0.0
         (2, 'Isfahan') :  None :   0.0 :   0.0
          (2, 'Tehran') :  None :   0.0 :   0.0
    ('Main', 'Isfahan') :  None : -13.0 :   0.0
     ('Main', 'Tehran') :  None :   0.0 :   0.0
transportation_limit2 : Size=2
    Key     : Lower : Body : Upper
    Isfahan :  30.0 : 30.0 :  70.0
     Tehran :  20.0 : 24.0 :  65.0
transp_from_dep_to_market_limit : Size=4
    Key              : Lower : Body                    : Upper
    ('A', 'Isfahan') :  None :  -3.865352482534945e-12 :   0.0
     ('A', 'Tehran') :  None :                     0.0 :   0.0
    ('B', 'Isfahan') :  None : -2.2737367544323206e-13 :   0.0
```

```
     ('B', 'Tehran') :  None :                    0.0 :   0.0
container_limit2 : Size=8
    Key                    : Lower : Body                   : Upper
      ('Isfahan', 'Ahvaz') :  None :                    0.0 :   0.0
     ('Isfahan', 'Kerman') :  None :                    0.0 :   0.0
    ('Isfahan', 'Mashhad') :  None : -3.268496584496461e-13 :   0.0
     ('Isfahan', 'Tabriz') :  None :                    0.0 :   0.0
       ('Tehran', 'Ahvaz') :  None :                    0.0 :   0.0
      ('Tehran', 'Kerman') :  None :                    0.0 :   0.0
     ('Tehran', 'Mashhad') :  None :                    0.0 :   0.0
      ('Tehran', 'Tabriz') :  None :                    0.0 :   0.0
market_sell_limit_f : Size=8
    Key                    : Lower : Body : Upper
      ('Isfahan', 'Ahvaz') :  None :  0.0 :   0.0
     ('Isfahan', 'Kerman') :  None :  0.0 :   0.0
    ('Isfahan', 'Mashhad') :  None :  0.0 :   0.0
     ('Isfahan', 'Tabriz') :  None :  0.0 :   0.0
       ('Tehran', 'Ahvaz') :  None :  0.0 :   0.0
      ('Tehran', 'Kerman') :  None :  0.0 :   0.0
     ('Tehran', 'Mashhad') :  None :  0.0 :   0.0
      ('Tehran', 'Tabriz') :  None :  0.0 :   0.0
market_sell_limit_t : Size=8
    Key                    : Lower : Body : Upper
      ('Isfahan', 'Ahvaz') :  None :  0.0 :   0.0
     ('Isfahan', 'Kerman') :  None :  0.0 :   0.0
    ('Isfahan', 'Mashhad') :  None :  0.0 :   0.0
     ('Isfahan', 'Tabriz') :  None :  0.0 :   0.0
       ('Tehran', 'Ahvaz') :  None :  0.0 :   0.0
      ('Tehran', 'Kerman') :  None :  0.0 :   0.0
     ('Tehran', 'Mashhad') :  None :  0.0 :   0.0
      ('Tehran', 'Tabriz') :  None :  0.0 :   0.0
max_market_demand_limit : Size=8
    Key              : Lower : Body              : Upper
      ('Ahvaz', 'A') :  None :               0.0 : 1500.0
      ('Ahvaz', 'B') :  None :            1500.0 : 1500.0
     ('Kerman', 'A') :  None :             800.0 :  800.0
     ('Kerman', 'B') :  None :             300.0 : 1200.0
    ('Mashhad', 'A') :  None :  356.363636363636 :  600.0
    ('Mashhad', 'B') :  None : 343.6363636363637 :  400.0
     ('Tabriz', 'A') :  None :             400.0 : 1400.0
     ('Tabriz', 'B') :  None :            1100.0 : 1100.0
results saved in results.yaml
```

1.4.2 Problem B

[8]:
```
!python model_runner.py -b
```

```
results for problem: -b
```

```
WARNING: Implicitly replacing the Component attribute revenue (type=<class
'pyomo.core.base.objective.ScalarObjective'>) on block OR1 with a new
Component (type=<class 'pyomo.core.base.objective.ScalarObjective'>). This is
usually indicative of a modelling error. To avoid this warning, use
block.del_component() and block.add_component().

Problem:
- Name: unknown
  Lower bound: 1593740.3030303
  Upper bound: 1593740.3030303
  Number of objectives: 1
  Number of constraints: 97
  Number of variables: 82
  Number of nonzeros: 304
  Sense: maximize
Solver:
- Status: ok
  Termination condition: optimal
  Statistics:
    Branch and bound:
      Number of bounded subproblems: 39
      Number of created subproblems: 39
  Error rc: 0
  Time: 0.009909868240356445
Solution:
- number of solutions: 0
  number of solutions displayed: 0

Model OR1

  Variables:
    Z : Size=6, Index=Ore*Alloys
        Key      : Lower : Value            : Upper : Fixed : Stale : Domain
        (1, 'A') :     0 :            140.0 :  None : False : False :
NonNegativeReals
        (1, 'B') :     0 :              0.0 :  None : False : False :
NonNegativeReals
        (2, 'A') :     0 :            150.0 :  None : False : False :
NonNegativeReals
        (2, 'B') :     0 :              0.0 :  None : False : False :
NonNegativeReals
        (3, 'A') :     0 :  225.69696969697 :  None : False : False :
NonNegativeReals
        (3, 'B') :     0 : 133.333333333333 :  None : False : False :
NonNegativeReals
    F : Size=6, Index=Ore*Alloys
        Key      : Lower : Value : Upper : Fixed : Stale : Domain
        (1, 'A') :     0 :   0.0 :  None : False : False : NonNegativeReals
```

```
        (1, 'B') :     0 :  28.0 :  None : False : False : NonNegativeReals
        (2, 'A') :     0 :   0.0 :  None : False : False : NonNegativeReals
        (2, 'B') :     0 : 200.0 :  None : False : False : NonNegativeReals
        (3, 'A') :     0 :   0.0 :  None : False : False : NonNegativeReals
        (3, 'B') :     0 :  72.0 :  None : False : False : NonNegativeReals
    A : Size=6, Index=Ore*Alloys
        Key      : Lower : Value : Upper : Fixed : Stale : Domain
        (1, 'A') :     0 : 196.0 :  None : False : False : NonNegativeReals
        (1, 'B') :     0 :   0.0 :  None : False : False : NonNegativeReals
        (2, 'A') :     0 : 300.0 :  None : False : False : NonNegativeReals
        (2, 'B') :     0 :   0.0 :  None : False : False : NonNegativeReals
        (3, 'A') :     0 : 360.0 :  None : False : False : NonNegativeReals
        (3, 'B') :     0 :   0.0 :  None : False : False : NonNegativeReals
    C : Size=6, Index=Ore*Alloys
        Key      : Lower : Value            : Upper : Fixed : Stale : Domain
        (1, 'A') :     0 :              0.0 :  None : False : False :
NonNegativeReals
        (1, 'B') :     0 :            168.0 :  None : False : False :
NonNegativeReals
        (2, 'A') :     0 : 184.666666666667 :  None : False : False :
NonNegativeReals
        (2, 'B') :     0 : 65.3333333333333 :  None : False : False :
NonNegativeReals
        (3, 'A') :     0 :              0.0 :  None : False : False :
NonNegativeReals
        (3, 'B') :     0 :              0.0 :  None : False : False :
NonNegativeReals
    U : Size=2, Index=Alloys
        Key : Lower : Value            : Upper : Fixed : Stale : Domain
          A :     0 : 1556.36363636364 :  None : False : False :
NonNegativeReals
          B :     0 : 666.666666666667 :  None : False : False :
NonNegativeReals
    t : Size=12, Index=Alloys*Factories*Depots
        Key                      : Lower : Value            : Upper : Fixed :
Stale : Domain
             ('A', 1, 'Isfahan') :     0 :              0.0 :  None : False :
False : NonNegativeReals
              ('A', 1, 'Tehran') :     0 :              0.0 :  None : False :
False : NonNegativeReals
             ('A', 2, 'Isfahan') :     0 :              0.0 :  None : False :
False : NonNegativeReals
              ('A', 2, 'Tehran') :     0 :              0.0 :  None : False :
False : NonNegativeReals
        ('A', 'Main', 'Isfahan') :     0 : 1256.36363636364 :  None : False :
False : NonNegativeReals
         ('A', 'Main', 'Tehran') :     0 :            300.0 :  None : False :
False : NonNegativeReals
```

```
            ('B', 1, 'Isfahan') :     0 : 676.969696969697 :  None : False :
False : NonNegativeReals
             ('B', 1, 'Tehran') :     0 :           1900.0 :  None : False :
False : NonNegativeReals
            ('B', 2, 'Isfahan') :     0 :              0.0 :  None : False :
False : NonNegativeReals
             ('B', 2, 'Tehran') :     0 :              0.0 :  None : False :
False : NonNegativeReals
        ('B', 'Main', 'Isfahan') :     0 : 466.666666666667 :  None : False :
False : NonNegativeReals
         ('B', 'Main', 'Tehran') :     0 :            200.0 :  None : False :
False : NonNegativeReals
    Extracted_ore : Size=3, Index=Ore
        Key : Lower : Value  : Upper : Fixed : Stale : Domain
          1 :     0 :  560.0 :  None : False : False : NonNegativeReals
          2 :     0 : 1000.0 :  None : False : False : NonNegativeReals
          3 :     0 : 1440.0 :  None : False : False : NonNegativeReals
    h : Size=3, Index=Factories
        Key  : Lower : Value : Upper : Fixed : Stale : Domain
           1 :     0 :   1.0 :     1 : False : False : Binary
           2 :     0 :   0.0 :     1 : False : False : Binary
        Main :     0 :   1.0 :     1 : False : False : Binary
    B : Size=6, Index=Factories*Depots
        Key                 : Lower : Value : Upper : Fixed : Stale : Domain
            (1, 'Isfahan') :     0 :  12.0 :  None : False : False :
NonNegativeIntegers
             (1, 'Tehran') :     0 :  19.0 :  None : False : False :
NonNegativeIntegers
            (2, 'Isfahan') :     0 :   0.0 :  None : False : False :
NonNegativeIntegers
             (2, 'Tehran') :     0 :   0.0 :  None : False : False :
NonNegativeIntegers
        ('Main', 'Isfahan') :     0 :  18.0 :  None : False : False :
NonNegativeIntegers
         ('Main', 'Tehran') :     0 :   5.0 :  None : False : False :
NonNegativeIntegers
    g : Size=16, Index=Alloys*Depots*Markets
        Key                         : Lower : Value            : Upper : Fixed :
Stale : Domain
          ('A', 'Isfahan', 'Ahvaz') :     0 :              0.0 :  None : False :
False : NonNegativeReals
         ('A', 'Isfahan', 'Kerman') :     0 :            500.0 :  None : False :
False : NonNegativeReals
        ('A', 'Isfahan', 'Mashhad') :     0 : 356.363636363636 :  None : False :
False : NonNegativeReals
         ('A', 'Isfahan', 'Tabriz') :     0 :            400.0 :  None : False :
False : NonNegativeReals
           ('A', 'Tehran', 'Ahvaz') :     0 :              0.0 :  None : False :
```

```
False : NonNegativeReals
          ('A', 'Tehran', 'Kerman') :     0 :            300.0 :  None : False :
False : NonNegativeReals
         ('A', 'Tehran', 'Mashhad') :     0 :              0.0 :  None : False :
False : NonNegativeReals
          ('A', 'Tabriz', 'Tehran') :     0 :              0.0 :  None : False :
False : NonNegativeReals
          ('B', 'Isfahan', 'Ahvaz') :     0 :            500.0 :  None : False :
False : NonNegativeReals
         ('B', 'Isfahan', 'Kerman') :     0 :              0.0 :  None : False :
False : NonNegativeReals
        ('B', 'Isfahan', 'Mashhad') :     0 : 43.6363636363637 :  None : False :
False : NonNegativeReals
         ('B', 'Isfahan', 'Tabriz') :     0 :            600.0 :  None : False :
False : NonNegativeReals
           ('B', 'Tehran', 'Ahvaz') :     0 :           1000.0 :  None : False :
False : NonNegativeReals
          ('B', 'Tehran', 'Kerman') :     0 :            300.0 :  None : False :
False : NonNegativeReals
         ('B', 'Tehran', 'Mashhad') :     0 :            300.0 :  None : False :
False : NonNegativeReals
          ('B', 'Tehran', 'Tabriz') :     0 :            500.0 :  None : False :
False : NonNegativeReals
    G : Size=8, Index=Depots*Markets
        Key                     : Lower : Value : Upper : Fixed : Stale : Domain
          ('Isfahan', 'Ahvaz') :     0 :   5.0 :  None : False : False :
NonNegativeIntegers
         ('Isfahan', 'Kerman') :     0 :   5.0 :  None : False : False :
NonNegativeIntegers
        ('Isfahan', 'Mashhad') :     0 :   4.0 :  None : False : False :
NonNegativeIntegers
         ('Isfahan', 'Tabriz') :     0 :  10.0 :  None : False : False :
NonNegativeIntegers
           ('Tehran', 'Ahvaz') :     0 :  10.0 :  None : False : False :
NonNegativeIntegers
          ('Tehran', 'Kerman') :     0 :   6.0 :  None : False : False :
NonNegativeIntegers
         ('Tehran', 'Mashhad') :     0 :   3.0 :  None : False : False :
NonNegativeIntegers
          ('Tehran', 'Tabriz') :     0 :   5.0 :  None : False : False :
NonNegativeIntegers
    l : Size=8, Index=Depots*Markets
        Key                     : Lower : Value : Upper : Fixed : Stale : Domain
          ('Isfahan', 'Ahvaz') :     0 :   1.0 :     1 : False : False : Binary
         ('Isfahan', 'Kerman') :     0 :   1.0 :     1 : False : False : Binary
        ('Isfahan', 'Mashhad') :     0 :   1.0 :     1 : False : False : Binary
         ('Isfahan', 'Tabriz') :     0 :   1.0 :     1 : False : False : Binary
           ('Tehran', 'Ahvaz') :     0 :   1.0 :     1 : False : False : Binary
```

```
      ('Tehran', 'Kerman') :     0 :   1.0 :     1 : False : False : Binary
     ('Tehran', 'Mashhad') :     0 :   1.0 :     1 : False : False : Binary
      ('Tehran', 'Tabriz') :     0 :   1.0 :     1 : False : False : Binary
  d : Size=2, Index={1, 2}
      Key : Lower : Value : Upper : Fixed : Stale : Domain
        1 :     0 :  None :     1 : False :  True : Binary
        2 :     0 :  None :     1 : False :  True : Binary
  R : Size=4, Index=Alloys*{1, 2}
      Key      : Lower : Value : Upper : Fixed : Stale : Domain
      ('A', 1) :     0 :     0 :  None : False :  True : NonNegativeReals
      ('A', 2) :     0 :     0 :  None : False :  True : NonNegativeReals
      ('B', 1) :     0 :     0 :  None : False :  True : NonNegativeReals
      ('B', 2) :     0 :     0 :  None : False :  True : NonNegativeReals

Objectives:
  revenue : Size=1, Index=None, Active=True
      Key  : Active : Value
      None :   True : 1593740.3030303027

Constraints:
  Max_extracted_ore_limit : Size=3
      Key : Lower : Body   : Upper
        1 :  None :  560.0 :   560
        2 :  None : 1000.0 :  1000
        3 :  None : 1440.0 :  1440
  Alloy_sum_limit : Size=2
      Key : Lower : Body                    : Upper
        A :  None : 2.9558577807620168e-12 :   0.0
        B :  None :  6.821210263296962e-13 :   0.0
  Metal_sum_limit_Z : Size=3
      Key : Lower : Body              : Upper
        1 :  None :               0.0 :   0.0
        2 :  None :               0.0 :   0.0
        3 :  None : -576.969696969697 :   0.0
  Metal_sum_limit_F : Size=3
      Key : Lower : Body : Upper
        1 :  None :  0.0 :   0.0
        2 :  None :  0.0 :   0.0
        3 :  None :  0.0 :   0.0
  Metal_sum_limit_C : Size=3
      Key : Lower : Body                  : Upper
        1 :  None :                   0.0 :   0.0
        2 :  None : 2.984279490192421e-13 :   0.0
        3 :  None :                 -72.0 :   0.0
  Metal_sum_limit_A : Size=3
      Key : Lower : Body : Upper
        1 :  None :  0.0 :   0.0
        2 :  None :  0.0 :   0.0
```

```
      3 :  None :  0.0 :   0.0
Metal_in_alloy_limit_A_Z_f : Size=1
    Key  : Lower : Body             : Upper
    None :  None : -515.69696969697 :   0.0
Metal_in_alloy_limit_A_Z_t : Size=1
    Key  : Lower : Body              : Upper
    None :  None : -729.393939393942 :   0.0
Metal_in_alloy_limit_A_C_f : Size=1
    Key  : Lower : Body              : Upper
    None :  None : -184.666666666667 :   0.0
Metal_in_alloy_limit_A_C_t : Size=1
    Key  : Lower : Body               : Upper
    None :  None : -1371.696969696973 :   0.0
Metal_in_alloy_limit_A_A_f : Size=1
    Key  : Lower : Body                    : Upper
    None :  None : 2.0463630789890885e-12 :   0.0
Metal_in_alloy_limit_A_A_t : Size=1
    Key  : Lower : Body               : Upper
    None :  None : -700.3636363636399 :   0.0
Metal_in_alloy_limit_A_F_f : Size=1
    Key  : Lower : Body : Upper
    None :  None :  0.0 :   0.0
Metal_in_alloy_limit_A_F_t : Size=1
    Key  : Lower : Body             : Upper
    None :  None : -389.09090909091 :   0.0
Metal_in_alloy_limit_B_Z_f : Size=1
    Key  : Lower : Body              : Upper
    None :  None : -133.333333333333 :   0.0
Metal_in_alloy_limit_B_Z_t : Size=1
    Key  : Lower : Body               : Upper
    None :  None : -533.3333333333339 :   0.0
Metal_in_alloy_limit_B_C_f : Size=1
    Key  : Lower : Body                    : Upper
    None :  None : 1.1368683772161603e-13 :   0.0
Metal_in_alloy_limit_B_C_t : Size=1
    Key  : Lower : Body                : Upper
    None :  None : -433.33333333333366 :   0.0
Metal_in_alloy_limit_B_A_f : Size=1
    Key  : Lower : Body : Upper
    None :  None :  0.0 :   0.0
Metal_in_alloy_limit_B_A_t : Size=1
    Key  : Lower : Body                : Upper
    None :  None : -466.66666666666686 :   0.0
Metal_in_alloy_limit_B_F_f : Size=1
    Key  : Lower : Body                    : Upper
    None :  None : 1.7053025658242404e-13 :   0.0
Metal_in_alloy_limit_B_F_t : Size=1
    Key  : Lower : Body                : Upper
```

```
    None :  None : -166.66666666666686 :   0.0
Export_from_main_fac_limit : Size=2
    Key : Lower : Body                  : Upper
      A :  None :                   0.0 :   0.0
      B :  None : 5.684341886080802e-14 :   0.0
buy_from_fac_limit_f : Size=2
    Key : Lower : Body              : Upper
      1 :  None : -576.969696969697 :   0.0
      2 :  None :               0.0 :   0.0
buy_from_fac_limit_t : Size=2
    Key : Lower : Body               : Upper
      1 :  None : -2423.030303030303 :   0.0
      2 :  None :                0.0 :   0.0
container_limit : Size=6
    Key                 : Lower : Body                : Upper
         (1, 'Isfahan') :  None :  -523.030303030303 :   0.0
          (1, 'Tehran') :  None :                0.0 :   0.0
         (2, 'Isfahan') :  None :                0.0 :   0.0
          (2, 'Tehran') :  None :                0.0 :   0.0
    ('Main', 'Isfahan') :  None : -76.96969696969308 :   0.0
     ('Main', 'Tehran') :  None :                0.0 :   0.0
transportation_limit_t : Size=6
    Key                 : Lower : Body  : Upper
         (1, 'Isfahan') :  None : -18.0 :   0.0
          (1, 'Tehran') :  None : -11.0 :   0.0
         (2, 'Isfahan') :  None :   0.0 :   0.0
          (2, 'Tehran') :  None :   0.0 :   0.0
    ('Main', 'Isfahan') :  None :  -2.0 :   0.0
     ('Main', 'Tehran') :  None : -15.0 :   0.0
transportation_limit_f : Size=6
    Key                 : Lower : Body  : Upper
         (1, 'Isfahan') :  None :  -2.0 :   0.0
          (1, 'Tehran') :  None :  -9.0 :   0.0
         (2, 'Isfahan') :  None :   0.0 :   0.0
          (2, 'Tehran') :  None :   0.0 :   0.0
    ('Main', 'Isfahan') :  None : -13.0 :   0.0
     ('Main', 'Tehran') :  None :   0.0 :   0.0
transportation_limit2 : Size=2
    Key     : Lower : Body : Upper
    Isfahan :  30.0 : 30.0 :  70.0
     Tehran :  20.0 : 24.0 :  65.0
transp_from_dep_to_market_limit : Size=4
    Key              : Lower : Body                     : Upper
    ('A', 'Isfahan') :  None :  -3.865352482534945e-12 :   0.0
     ('A', 'Tehran') :  None :                     0.0 :   0.0
    ('B', 'Isfahan') :  None : -2.2737367544323206e-13 :   0.0
     ('B', 'Tehran') :  None :                     0.0 :   0.0
container_limit2 : Size=8
```

```
        Key                    : Lower : Body                    : Upper
          ('Isfahan', 'Ahvaz') :  None :                     0.0 :   0.0
         ('Isfahan', 'Kerman') :  None :                     0.0 :   0.0
        ('Isfahan', 'Mashhad') :  None : -3.268496584496461e-13 :   0.0
         ('Isfahan', 'Tabriz') :  None :                     0.0 :   0.0
           ('Tehran', 'Ahvaz') :  None :                     0.0 :   0.0
          ('Tehran', 'Kerman') :  None :                     0.0 :   0.0
         ('Tehran', 'Mashhad') :  None :                     0.0 :   0.0
          ('Tehran', 'Tabriz') :  None :                     0.0 :   0.0
    market_sell_limit_f : Size=8
        Key                    : Lower : Body : Upper
          ('Isfahan', 'Ahvaz') :  None :  0.0 :   0.0
         ('Isfahan', 'Kerman') :  None :  0.0 :   0.0
        ('Isfahan', 'Mashhad') :  None :  0.0 :   0.0
         ('Isfahan', 'Tabriz') :  None :  0.0 :   0.0
           ('Tehran', 'Ahvaz') :  None :  0.0 :   0.0
          ('Tehran', 'Kerman') :  None :  0.0 :   0.0
         ('Tehran', 'Mashhad') :  None :  0.0 :   0.0
          ('Tehran', 'Tabriz') :  None :  0.0 :   0.0
    market_sell_limit_t : Size=8
        Key                    : Lower : Body : Upper
          ('Isfahan', 'Ahvaz') :  None :  0.0 :   0.0
         ('Isfahan', 'Kerman') :  None :  0.0 :   0.0
        ('Isfahan', 'Mashhad') :  None :  0.0 :   0.0
         ('Isfahan', 'Tabriz') :  None :  0.0 :   0.0
           ('Tehran', 'Ahvaz') :  None :  0.0 :   0.0
          ('Tehran', 'Kerman') :  None :  0.0 :   0.0
         ('Tehran', 'Mashhad') :  None :  0.0 :   0.0
          ('Tehran', 'Tabriz') :  None :  0.0 :   0.0
    max_market_demand_limit : Size=8
        Key                : Lower : Body              : Upper
          ('Ahvaz', 'A') :  None :               0.0 : 1500.0
          ('Ahvaz', 'B') :  None :            1500.0 : 1500.0
         ('Kerman', 'A') :  None :             800.0 :  800.0
         ('Kerman', 'B') :  None :             300.0 : 1200.0
        ('Mashhad', 'A') :  None :  356.363636363636 :  600.0
        ('Mashhad', 'B') :  None : 343.6363636363637 :  400.0
         ('Tabriz', 'A') :  None :             400.0 : 1400.0
         ('Tabriz', 'B') :  None :            1100.0 : 1100.0
results saved in results.yaml
```

you can see result file using code below:

[1]:
```
!cat results.yaml
```

```
# ==========================================================
# = Solver Results                                         =
# ==========================================================
# ----------------------------------------------------------
```

```
#   Problem Information
# ------------------------------------------------------------
Problem:
- Name: x1
  Lower bound: 1439591.6161616163
  Upper bound: 1439600.1414141413
  Number of objectives: 1
  Number of constraints: 97
  Number of variables: 82
  Number of binary variables: 11
  Number of integer variables: 25
  Number of continuous variables: 57
  Number of nonzeros: 304
  Sense: maximize
# ------------------------------------------------------------
#   Solver Information
# ------------------------------------------------------------
Solver:
- Status: ok
  Return code: 0
  Message: Model was solved to optimality (subject to tolerances), and an
optimal solution is available.
  Termination condition: optimal
  Termination message: Model was solved to optimality (subject to tolerances),
and an optimal solution is available.
  Wall time: 0.008729934692382812
  Error rc: 0
  Time: 0.11020445823669434
# ------------------------------------------------------------
#   Solution Information
# ------------------------------------------------------------
Solution:
- number of solutions: 0
  number of solutions displayed: 0
```

1.5 Sensitivity Analysis

here we produce sensitivity analysis, be aware that, here we should eliminate binaries and integers to make sensitivity analysis, because glpk does not work with MIP(Mixed Integer Problem) problems, we will use this file later on.

[2]:
```
!glpsol -m model.lp --lp --ranges sensit.sen
```

```
GLPSOL--GLPK LP/MIP Solver 5.0
Parameter(s) specified in the command line:
 -m model.lp --lp --ranges sensit.sen
Reading problem data from 'model.lp'…
107 rows, 88 columns, 342 non-zeros
```

```
808 lines were read
GLPK Simplex Optimizer 5.0
107 rows, 88 columns, 342 non-zeros
Preprocessing…
99 rows, 88 columns, 324 non-zeros
Scaling…
 A: min|aij| =  5.000e-02  max|aij| =  1.000e+09  ratio =  2.000e+10
GM: min|aij| =  1.160e-01  max|aij| =  8.621e+00  ratio =  7.433e+01
EQ: min|aij| =  1.350e-02  max|aij| =  1.000e+00  ratio =  7.408e+01
Constructing initial basis…
Size of triangular part is 99
      0: obj =  -0.000000000e+00 inf =   1.586e+03 (2)
     10: obj =  -2.613400000e+05 inf =   0.000e+00 (0)
*   108: obj =   1.660813370e+06 inf =   6.698e-11 (0)
OPTIMAL LP SOLUTION FOUND
Time used:   0.0 secs
Memory used: 0.2 Mb (197469 bytes)
Write sensitivity analysis report to 'sensit.sen'…
```

1.5.1 Sensit file

to see sensit.sen, we run code below:

[9]:
```
!cat sensit.sen
```

```
GLPK 5.0  - SENSITIVITY ANALYSIS REPORT
Page   1

Problem:
Objective:  revenue = 1660813.37 (MAXimum)

   No. Row name     St      Activity         Slack   Lower bound       Activity
Obj coef  Obj value at Limiting
                                          Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------ ------------ -------------  -------------
------------ ------------ ------------
     1 c_u_Max_extracted_ore_limit(1)_
                    NU     560.00000        .               -Inf      471.42857
-209.57253   1.64225e+06 c_u_max_market_demand_limit(Mashhad_B)_
                                       209.57253     560.00000      628.57143
+Inf   1.67518e+06 g(B_Isfahan_Mashhad)

     2 c_u_Max_extracted_ore_limit(2)_
                    NU    1000.00000        .               -Inf      896.66667
-325.65010   1.62716e+06 c_u_max_market_demand_limit(Mashhad_B)_
                                       325.65010    1000.00000     1077.74879
+Inf   1.68613e+06 c_u_discount_limit_4(1)_
```

```
     3 c_u_Max_extracted_ore_limit(3)_
                    NU    1440.00000        .               -Inf     1316.00000
-127.51434     1.645e+06 c_u_max_market_demand_limit(Mashhad_B)_
                                         127.51434    1440.00000     1536.00000
+Inf   1.67305e+06 g(B_Isfahan_Mashhad)

     4 c_u_Alloy_sum_limit(A)_
                    NU        .             .               -Inf     -576.96970
.        1.66081e+06 c_u_Metal_sum_limit_Z(3)_
                                           .             .          225.69697
+Inf   1.66081e+06 Z(3_A)

     5 c_u_Alloy_sum_limit(B)_
                    NU        .             .               -Inf     -533.33333
.        1.66081e+06 c_u_Metal_in_alloy_limit_B_Z_t_
                                           .             .          133.33333
+Inf   1.66081e+06 c_u_Metal_in_alloy_limit_B_Z_f_

     6 c_u_Metal_sum_limit_Z(1)_
                    NU        .             .               -Inf     -140.00000
.        1.66081e+06 Z(1_A)
                                           .             .          225.69697
+Inf   1.66081e+06 Z(3_A)

     7 c_u_Metal_sum_limit_Z(2)_
                    NU        .             .               -Inf     -150.00000
.        1.66081e+06 Z(2_A)
                                           .             .          225.69697
+Inf   1.66081e+06 Z(3_A)

     8 c_u_Metal_sum_limit_Z(3)_
                    BS    -576.96970     576.96970          -Inf     -648.96970
.        1.66081e+06 C(3_A)
                                           .             .          -436.96970
.        1.66081e+06 c_u_Metal_sum_limit_Z(1)_

     9 c_u_Metal_sum_limit_F(1)_
                    NU        .             .               -Inf      -28.00000
-1097.37778   1.63009e+06 F(1_B)
                                      1097.37778         .            21.42857
+Inf   1.68433e+06 C(2_A)

    10 c_u_Metal_sum_limit_F(2)_
                    NU        .             .               -Inf     -139.63636
-1097.37778   1.50758e+06 t(B_Main_Isfahan)
                                      1097.37778         .            21.42857
+Inf   1.68433e+06 C(2_A)
```

Problem:
Objective: revenue = 1660813.37 (MAXimum)

No.	Row name	St	Activity	Slack	Lower bound	Activity	Obj coef	Obj value at Limiting
				Marginal	Upper bound	range	range	break point variable
11	c_u_Metal_sum_limit_F(3)_	NU	.	.	-Inf	-72.00000	-1097.37778	1.5818e+06 F(3_B)
				1097.37778	.	21.42857	+Inf	1.68433e+06 C(2_A)
12	c_u_Metal_sum_limit_C(1)_	NU	.	.	-Inf	-168.00000	.	1.66081e+06 C(1_A)
				.	.	225.69697	+Inf	1.66081e+06 Z(3_A)
13	c_u_Metal_sum_limit_C(2)_	NU	.	.	-Inf	-16.66667	.	1.66081e+06 C(2_A)
				.	.	225.69697	+Inf	1.66081e+06 Z(3_A)
14	c_u_Metal_sum_limit_C(3)_	BS	-72.00000	72.00000	-Inf	-72.00000	-Inf	+Inf
				.	.	153.69697	.	1.66081e+06 C(3_A)
15	c_u_Metal_sum_limit_A(1)_	NU	.	.	-Inf	-31.00000	-570.58182	1.64313e+06 c_u_max_market_demand_limit(Mashhad_B)_
				570.58182	.	24.00000	+Inf	1.67451e+06 g(B_Isfahan_Mashhad)
16	c_u_Metal_sum_limit_A(2)_	NU	.	.	-Inf	-31.00000	-570.58182	1.64313e+06 c_u_max_market_demand_limit(Mashhad_B)_
				570.58182	.	24.00000	+Inf	1.67451e+06 g(B_Isfahan_Mashhad)

```
    17 c_u_Metal_sum_limit_A(3)_
                     NU        .             .               -Inf      -31.00000
-570.58182   1.64313e+06 c_u_max_market_demand_limit(Mashhad_B)_
                                         570.58182        .            24.00000
+Inf   1.67451e+06 g(B_Isfahan_Mashhad)

    18 c_u_Metal_in_alloy_limit_A_Z_f_
                     BS    -515.69697     515.69697          -Inf     -683.69697
.        1.66081e+06 c_u_Metal_sum_limit_C(1)_
                                           .             .          -443.69697
.        1.66081e+06 C(3_A)

    19 c_u_Metal_in_alloy_limit_A_Z_t_
                     BS    -729.39394     729.39394          -Inf     -801.39394
.        1.66081e+06 C(3_A)
                                           .             .          -561.39394
.        1.66081e+06 c_u_Metal_sum_limit_C(1)_

    20 c_u_Metal_in_alloy_limit_A_C_f_
                     BS    -184.66667     184.66667          -Inf     -256.66667
.        1.66081e+06 C(3_A)
                                           .             .           -16.66667
.        1.66081e+06 c_u_Metal_sum_limit_C(1)_

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)

   No. Row name     St      Activity         Slack   Lower bound       Activity
Obj coef  Obj value at Limiting
                                        Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------- ------------- -------------  -------------
------------- ------------- ------------
    21 c_u_Metal_in_alloy_limit_A_C_t_
                     BS   -1371.69697    1371.69697          -Inf    -1539.69697
.        1.66081e+06 c_u_Metal_sum_limit_C(1)_
                                           .             .         -1299.69697
.        1.66081e+06 C(3_A)

    22 c_u_Metal_in_alloy_limit_A_A_f_
                     NU        .             .               -Inf      -31.00000
-570.58182   1.64313e+06 c_u_max_market_demand_limit(Mashhad_B)_
                                         570.58182        .            24.00000
+Inf   1.67451e+06 g(B_Isfahan_Mashhad)
```

```
    23 c_u_Metal_in_alloy_limit_A_A_t_
                    BS    -700.36364     700.36364          -Inf     -700.36364
-Inf          +Inf
                                              .             .          -644.00000
313.82000   1.44103e+06 c_u_Metal_in_alloy_limit_A_A_f_

    24 c_u_Metal_in_alloy_limit_A_F_f_
                    BS        .              .               -Inf      -28.00000
-1097.37778   1.66081e+06 F(1_A)
                                              .             .              .
+Inf   1.66081e+06

    25 c_u_Metal_in_alloy_limit_A_F_t_
                    BS    -389.09091     389.09091          -Inf     -389.09091
-Inf          +Inf
                                              .             .          -361.09091
1097.37778   1.23383e+06 F(1_A)

    26 c_u_Metal_in_alloy_limit_B_Z_f_
                    BS    -133.33333     133.33333          -Inf     -666.66667
.        1.66081e+06 c_u_Alloy_sum_limit(B)_
                                              .             .          -116.66667
.        1.66081e+06 c_u_Metal_in_alloy_limit_B_C_f_

    27 c_u_Metal_in_alloy_limit_B_Z_t_
                    BS    -533.33333     533.33333          -Inf     -550.00000
.        1.66081e+06 c_u_Metal_in_alloy_limit_B_C_f_
                                              .             .            43.63636
.        1.66081e+06 c_u_Alloy_sum_limit(B)_

    28 c_u_Metal_in_alloy_limit_B_C_f_
                    NU        .              .               -Inf      -16.66667
.        1.66081e+06 C(2_A)
                                              .             .          225.69697
+Inf   1.66081e+06 Z(3_A)

    29 c_u_Metal_in_alloy_limit_B_C_t_
                    BS    -433.33333     433.33333          -Inf     -433.33333
-Inf          +Inf
                                              .             .          -416.66667
.        1.66081e+06 c_u_Metal_in_alloy_limit_B_C_f_

    30 c_u_Metal_in_alloy_limit_B_A_f_
                    BS        .              .               -Inf      -31.00000
-570.58182   1.66081e+06 A(1_B)
                                              .             .              .
+Inf   1.66081e+06
```

Problem:
Objective: revenue = 1660813.37 (MAXimum)

```
   No. Row name     St      Activity         Slack   Lower bound       Activity
Obj coef  Obj value at Limiting
                                          Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------- ------------- -------------  -------------
------------- ------------- ------------
    31 c_u_Metal_in_alloy_limit_B_A_t_
                    BS    -466.66667     466.66667          -Inf     -466.66667
-Inf          +Inf
                                             .             .          -435.66667
570.58182   1.39454e+06 A(1_B)

    32 c_u_Metal_in_alloy_limit_B_F_f_
                    NU        .              .               -Inf      -92.30769
-1097.37778   1.55952e+06 c_u_Metal_in_alloy_limit_B_Z_f_
                                       1097.37778        .            21.42857
+Inf   1.68433e+06 C(2_A)

    33 c_u_Metal_in_alloy_limit_B_F_t_
                    BS    -166.66667     166.66667          -Inf     -166.66667
-Inf          +Inf
                                             .             .           -23.07692
705.45714   1.54324e+06 c_u_Metal_in_alloy_limit_B_F_f_

    34 c_u_Export_from_main_fac_limit(A)_
                    NU        .              .               -Inf      -56.36364
-313.82000   1.64313e+06 c_u_max_market_demand_limit(Mashhad_B)_
                                        313.82000        .            43.63636
+Inf   1.67451e+06 g(B_Isfahan_Mashhad)

    35 c_u_Export_from_main_fac_limit(B)_
                    NU        .              .               -Inf     -310.30303
-493.82000   1.50758e+06 t(B_Main_Isfahan)
                                        493.82000        .            76.96345
+Inf   1.69882e+06 c_u_discount_limit_4(1)_

    36 c_u_buy_from_fac_limit_f(1)_
                    BS   -1517.97980    1517.97980          -Inf    -1517.97980
-.42000   1.66145e+06 c_u_container_limit(2_Isfahan)_
                                             .             .         -1414.54545
.06000   1.66072e+06 c_u_transportation_limit_t(1_Tehran)_
```

```
    37 c_u_buy_from_fac_limit_f(2)_
                     BS        .             .               -Inf         .
-.26400   1.66081e+06 t(B_2_Tehran)
                                             .             .              .
.03600   1.66081e+06 c_u_transportation_limit_t(2_Isfahan)_

    38 c_u_buy_from_fac_limit_t(1)_
                     BS     -70.50505      70.50505          -Inf     -329.09091
-.02400   1.66082e+06 c_u_transportation_limit_t(1_Tehran)_
                                             .             .           -70.50505
.16800    1.6608e+06 c_u_container_limit(2_Isfahan)_

    39 c_u_buy_from_fac_limit_t(2)_
                     BS        .             .               -Inf         .
-.01500   1.66081e+06 c_u_transportation_limit_t(2_Isfahan)_
                                             .             .              .
.11000   1.66081e+06 t(B_2_Tehran)

    40 c_u_container_limit(1_Tehran)_
                     NU        .             .               -Inf     -310.30303
-1.82000   1.66025e+06 t(B_Main_Isfahan)
                                          1.82000          .            84.60606
+Inf   1.66097e+06 c_u_buy_from_fac_limit_t(1)_

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)

   No. Row name     St      Activity         Slack   Lower bound       Activity
Obj coef  Obj value at Limiting
                                        Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------- ------------- -------------  -------------
------------- ------------- ------------
    41 c_u_container_limit(1_Isfahan)_
                     BS    -600.00000     600.00000          -Inf    -1223.03030
-2.12000   1.66209e+06 r_l_transportation_limit2(Isfahan)_
                                             .             .           -600.00000
.14000   1.66073e+06 c_u_container_limit(2_Isfahan)_

    42 c_u_container_limit(2_Tehran)_
                     NU        .             .               -Inf         .
-2.40000   1.66081e+06 c_u_transportation_limit_t(2_Tehran)_
                                          2.40000          .              .
+Inf   1.66081e+06 B(2_Tehran)
```

```
    43 c_u_container_limit(2_Isfahan)_
                      NU        .             .              -Inf         .
-.14000   1.66081e+06 c_u_buy_from_fac_limit_f(2)_
                                             .14000        .             .
+Inf   1.66081e+06 c_u_buy_from_fac_limit_t(2)_

    44 c_u_container_limit(Main_Tehran)_
                      NU        .             .              -Inf    -1188.48485
-2.00000   1.65844e+06 c_u_transportation_limit_t(Main_Tehran)_
                                           2.00000        .          311.51515
+Inf   1.66144e+06 c_u_transportation_limit_f(Main_Tehran)_

    45 c_u_container_limit(Main_Isfahan)_
                      NU        .             .              -Inf      -84.60606
-.18000    1.6608e+06 c_u_buy_from_fac_limit_t(1)_
                                             .18000        .          623.03030
+Inf   1.66093e+06 c_u_transportation_limit_f(Main_Tehran)_

    46 c_u_transportation_limit_t(1_Tehran)_
                      NU        .             .              -Inf       -3.10303
-2.00000   1.66081e+06 t(B_Main_Isfahan)
                                           2.00000        .             .84606
+Inf   1.66082e+06 c_u_buy_from_fac_limit_t(1)_

    47 c_u_transportation_limit_t(1_Isfahan)_
                      NU        .             .              -Inf       -6.23030
-2.00000    1.6608e+06 c_u_transportation_limit_f(Main_Tehran)_
                                           2.00000        .             .84606
+Inf   1.66082e+06 c_u_buy_from_fac_limit_t(1)_

    48 c_u_transportation_limit_t(2_Tehran)_
                      BS        .             .              -Inf         .
-3.60000   1.66081e+06 c_u_transportation_limit_t(2_Isfahan)_
                                             .             .             .
16.50000   1.66081e+06 t(B_2_Tehran)

    49 c_u_transportation_limit_t(2_Isfahan)_
                      NU        .             .              -Inf         .
-6.00000   1.66081e+06 c_u_transportation_limit_f(2_Isfahan)_
                                           6.00000        .             .
+Inf   1.66081e+06 c_u_buy_from_fac_limit_t(2)_

    50 c_u_transportation_limit_t(Main_Tehran)_
                      BS     -11.88485      11.88485          -Inf      -15.00000
-4.00000   1.66086e+06 c_u_transportation_limit_t(1_Isfahan)_
                                             .             .          -6.00000
.        1.66081e+06 h(Main)
```

Problem:
Objective: revenue = 1660813.37 (MAXimum)

No.	Row name	St	Activity	Slack	Lower bound	Activity	Obj coef	Obj value at	Limiting
				Marginal	Upper bound	range	range	break point	variable
51	c_u_transportation_limit_t(Main_Isfahan)_	BS	-5.88485	5.88485	-Inf	-7.43636	-4.00000	1.66084e+06	c_u_transportation_limit_t(1_Tehran)_
				.	.	6.00000	.	1.66081e+06	h(Main)
52	c_u_transportation_limit_f(1_Tehran)_	BS	-10.58990	10.58990	-Inf	-12.66667	-6.00000	1.66088e+06	c_u_transportation_limit_t(1_Isfahan)_
				.	.	-8.52121	3.00000	1.66078e+06	c_u_transportation_limit_t(1_Tehran)_
53	c_u_transportation_limit_f(1_Isfahan)_	BS	-10.58990	10.58990	-Inf	-11.62424	-6.00000	1.66088e+06	c_u_transportation_limit_t(1_Tehran)_
				.	.	-6.43636	3.00000	1.66078e+06	c_u_transportation_limit_t(1_Isfahan)_
54	c_u_transportation_limit_f(2_Tehran)_	BS	.	.	-Inf	.	-33.00000	1.66081e+06	t(B_2_Tehran)
				.	.	.	18.00000	1.66081e+06	c_u_transportation_limit_t(2_Isfahan)_
55	c_u_transportation_limit_f(2_Isfahan)_	BS	.	.	-Inf	.	-21.00000	1.66081e+06	c_u_container_limit(2_Isfahan)_
				.	.	.	18.00000	1.66081e+06	c_u_transportation_limit_t(2_Isfahan)_
56	c_u_transportation_limit_f(Main_Tehran)_	BS	-3.11515	3.11515	-Inf	-4.58636	.	1.66081e+06	h(Main)
				.	.	2.00000	4.00000	1.6608e+06	c_u_transportation_limit_t(1_Isfahan)_

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    57 c_u_transportation_limit_f(Main_Isfahan)_
                     BS      -9.11515       9.11515          -Inf      -10.58636
.        1.66081e+06 h(Main)
                                               .             .           -7.56364
4.00000   1.66078e+06 c_u_transportation_limit_t(1_Tehran)_

    58 r_l_transportation_limit2(Tehran)_
                     BS      24.00000      -4.00000      20.00000       23.56364
-18318.00000   1.22118e+06 l(Tehran_Tabriz)
                                               .              +Inf       27.10303
182.00000   1.66518e+06 c_u_container_limit(1_Tehran)_

    59 r_u_transportation_limit2(Tehran)_
                     BS      24.00000      41.00000          -Inf       23.56364
-18318.00000   1.22118e+06 l(Tehran_Tabriz)
                                               .           65.00000       27.10303
182.00000   1.66518e+06 c_u_container_limit(1_Tehran)_

    60 r_l_transportation_limit2(Isfahan)_
                     NL      30.00000        .           30.00000       29.15394
-Inf   1.66099e+06 c_u_buy_from_fac_limit_t(1)_
                                         -212.00000          +Inf       36.23030
212.00000   1.65949e+06 c_u_transportation_limit_f(Main_Tehran)_

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)

   No. Row name     St      Activity         Slack   Lower bound       Activity
Obj coef  Obj value at Limiting
                                          Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------- ------------- -------------  -------------
------------- ------------- ------------
    61 r_u_transportation_limit2(Isfahan)_
                     BS      30.00000      40.00000          -Inf       30.00000
-Inf          -Inf
                                               .           70.00000       36.23030
212.00000   1.66717e+06 r_l_transportation_limit2(Isfahan)_

    62 c_u_transp_from_dep_to_market_limit(A_Tehran)_
                     NU        .             .               -Inf      -56.36364
-315.82000   1.64301e+06 c_u_max_market_demand_limit(Mashhad_B)_
                                          315.82000        .           43.63636
+Inf   1.67459e+06 g(B_Isfahan_Mashhad)
```

```
    63 c_u_transp_from_dep_to_market_limit(A_Isfahan)_
                    NU        .             .               -Inf      -56.36364
-314.00000   1.64312e+06 c_u_max_market_demand_limit(Mashhad_B)_
                                         314.00000        .           43.63636
+Inf   1.67452e+06 g(B_Isfahan_Mashhad)

    64 c_u_transp_from_dep_to_market_limit(B_Tehran)_
                    NU        .             .               -Inf     -310.30303
-495.82000   1.50696e+06 t(B_Main_Isfahan)
                                         495.82000        .           76.96345
+Inf   1.69897e+06 c_u_discount_limit_4(1)_

    65 c_u_transp_from_dep_to_market_limit(B_Isfahan)_
                    NU        .             .               -Inf      -70.50505
-494.00000   1.62598e+06 c_u_buy_from_fac_limit_t(1)_
                                         494.00000        .           76.96345
+Inf   1.69883e+06 c_u_discount_limit_4(1)_

    66 c_u_container_limit2(Tehran_Mashhad)_
                    NU        .             .               -Inf      -76.96345
-204.18000    1.6451e+06 c_u_discount_limit_4(1)_
                                         204.18000        .           56.36364
+Inf   1.67232e+06 c_u_max_market_demand_limit(Mashhad_B)_

    67 c_u_container_limit2(Tehran_Kerman)_
                    NU        .             .               -Inf      -76.96345
-194.18000   1.64587e+06 c_u_discount_limit_4(1)_
                                         194.18000        .           310.30303
+Inf   1.72107e+06 t(B_Main_Isfahan)

    68 c_u_container_limit2(Tehran_Ahvaz)_
                    NU        .             .               -Inf      -76.96345
-234.18000   1.64279e+06 c_u_discount_limit_4(1)_
                                         234.18000        .             .
+Inf   1.66081e+06 c_u_max_market_demand_limit(Ahvaz_B)_

    69 c_u_container_limit2(Tehran_Tabriz)_
                    NU        .             .               -Inf      -43.63636
-184.18000   1.65278e+06 g(B_Isfahan_Mashhad)
                                         184.18000        .           56.36364
+Inf   1.67119e+06 c_u_max_market_demand_limit(Mashhad_B)_

    70 c_u_container_limit2(Isfahan_Mashhad)_
                    NU        .             .               -Inf      -43.63636
-206.00000   1.65182e+06 g(B_Isfahan_Mashhad)
                                         206.00000        .           56.36364
+Inf   1.67242e+06 c_u_max_market_demand_limit(Mashhad_B)_
```

Problem:
Objective: revenue = 1660813.37 (MAXimum)

No.	Row name	St	Activity	Slack	Lower bound	Activity	Obj coef	Obj value at	Limiting
				Marginal	Upper bound	range	range	break point	variable
71	c_u_container_limit2(Isfahan_Kerman)_	NU	.	.	-Inf	-76.96345	-196.00000	1.64573e+06	c_u_discount_limit_4(1)_
				196.00000	.	70.50505	+Inf	1.67463e+06	c_u_buy_from_fac_limit_t(1)_
72	c_u_container_limit2(Isfahan_Ahvaz)_	NU	.	.	-Inf	-76.96345	-236.00000	1.64265e+06	c_u_discount_limit_4(1)_
				236.00000	.	.	+Inf	1.66081e+06	c_u_max_market_demand_limit(Ahvaz_B)_
73	c_u_container_limit2(Isfahan_Tabriz)_	NU	.	.	-Inf	-43.63636	-186.00000	1.6527e+06	g(B_Isfahan_Mashhad)
				186.00000	.	56.36364	+Inf	1.6713e+06	c_u_max_market_demand_limit(Mashhad_B)_
74	c_u_market_sell_limit_f(Tehran_Mashhad)_	BS	.	.	-Inf	.	-Inf	1.66081e+06	
				.	.	.76963	20308.00000	1.66081e+06	c_u_market_sell_limit_t(Tehran_Mashhad)_
75	c_u_market_sell_limit_f(Tehran_Kerman)_	BS	.	.	-Inf	.	-Inf	1.66081e+06	
				.	.	.76963	19333.00000	1.66081e+06	c_u_market_sell_limit_t(Tehran_Kerman)_
76	c_u_market_sell_limit_f(Tehran_Ahvaz)_	BS	.	.	-Inf	.	-Inf	1.66081e+06	
				.	.	.76963	23298.00000	1.66081e+06	c_u_market_sell_limit_t(Tehran_Ahvaz)_

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    77 c_u_market_sell_limit_f(Tehran_Tabriz)_
                     BS        .             .               -Inf         .
-Inf   1.66081e+06
                                             .             .              .43636
18318.00000   1.66081e+06 c_u_market_sell_limit_t(Tehran_Tabriz)_

    78 c_u_market_sell_limit_f(Isfahan_Mashhad)_
                     BS        .             .               -Inf         .
-Inf   1.66081e+06
                                             .             .              .43636
20500.00000   1.66081e+06 c_u_market_sell_limit_t(Isfahan_Mashhad)_

    79 c_u_market_sell_limit_f(Isfahan_Kerman)_
                     BS        .             .               -Inf         .
-Inf   1.66081e+06
                                             .             .              .76963
19500.00000   1.66081e+06 c_u_market_sell_limit_t(Isfahan_Kerman)_

    80 c_u_market_sell_limit_f(Isfahan_Ahvaz)_
                     BS        .             .               -Inf         .
-Inf   1.66081e+06
                                             .             .              .76963
23490.00000   1.66081e+06 c_u_market_sell_limit_t(Isfahan_Ahvaz)_

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)

   No. Row name     St      Activity         Slack   Lower bound       Activity
Obj coef  Obj value at Limiting
                                        Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------- ------------ -------------  -------------
------------- ------------- ------------
    81 c_u_market_sell_limit_f(Isfahan_Tabriz)_
                     BS        .             .               -Inf         .
-Inf   1.66081e+06
                                             .             .              .43636
18510.00000   1.66081e+06 c_u_market_sell_limit_t(Isfahan_Tabriz)_

    82 c_u_market_sell_limit_t(Tehran_Mashhad)_
                     NU        .             .               -Inf         .
-20308.00000   1.66081e+06 c_u_market_sell_limit_f(Tehran_Mashhad)_
                                      20308.00000        .              .56364
+Inf   1.67226e+06 c_u_max_market_demand_limit(Mashhad_B)_
```

```
    83 c_u_market_sell_limit_t(Tehran_Kerman)_
                     NU        .             .               -Inf         .
-19333.00000   1.66081e+06 c_u_market_sell_limit_f(Tehran_Kerman)_
                                       19333.00000        .             3.10303
+Inf    1.7208e+06 t(B_Main_Isfahan)

    84 c_u_market_sell_limit_t(Tehran_Ahvaz)_
                     NU        .             .               -Inf         .
-23298.00000   1.66081e+06 c_u_market_sell_limit_f(Tehran_Ahvaz)_
                                       23298.00000        .             .
+Inf   1.66081e+06 c_u_max_market_demand_limit(Ahvaz_B)_

    85 c_u_market_sell_limit_t(Tehran_Tabriz)_
                     NU        .             .               -Inf         .
-18318.00000   1.66081e+06 c_u_market_sell_limit_f(Tehran_Tabriz)_
                                       18318.00000        .             .56364
+Inf   1.67114e+06 c_u_max_market_demand_limit(Mashhad_B)_

    86 c_u_market_sell_limit_t(Isfahan_Mashhad)_
                     NU        .             .               -Inf         .
-20500.00000   1.66081e+06 c_u_market_sell_limit_f(Isfahan_Mashhad)_
                                       20500.00000        .             .56364
+Inf   1.67237e+06 c_u_max_market_demand_limit(Mashhad_B)_

    87 c_u_market_sell_limit_t(Isfahan_Kerman)_
                     NU        .             .               -Inf         .
-19500.00000   1.66081e+06 c_u_market_sell_limit_f(Isfahan_Kerman)_
                                       19500.00000        .             .70505
+Inf   1.67456e+06 c_u_buy_from_fac_limit_t(1)_

    88 c_u_market_sell_limit_t(Isfahan_Ahvaz)_
                     NU        .             .               -Inf         .
-23490.00000   1.66081e+06 c_u_market_sell_limit_f(Isfahan_Ahvaz)_
                                       23490.00000        .             .
+Inf   1.66081e+06 c_u_max_market_demand_limit(Ahvaz_B)_

    89 c_u_market_sell_limit_t(Isfahan_Tabriz)_
                     NU        .             .               -Inf         .
-18510.00000   1.66081e+06 c_u_market_sell_limit_f(Isfahan_Tabriz)_
                                       18510.00000        .             .56364
+Inf   1.67125e+06 c_u_max_market_demand_limit(Mashhad_B)_

    90 c_u_max_market_demand_limit(Mashhad_A)_
                     BS     356.36364     243.63636          -Inf      300.00000
-30.00000   1.65012e+06 c_u_max_market_demand_limit(Tabriz_B)_
                                       .          600.00000      400.00000
30.00000    1.6715e+06 c_u_max_market_demand_limit(Kerman_A)_
```

Problem:
Objective: revenue = 1660813.37 (MAXimum)

No.	Row name	St	Activity	Slack / Marginal	Lower bound / Upper bound	Activity	Obj coef	Obj value at Limiting range	Limiting variable
91	c_u_max_market_demand_limit(Mashhad_B)_	BS	343.63636	56.36364	-Inf	300.00000	-30.00000	1.6505e+06	c_u_max_market_demand_limit(Kerman_A)_
				.	400.00000	700.00000	30.00000	1.67112e+06	c_u_max_market_demand_limit(Tabriz_B)_
92	c_u_max_market_demand_limit(Kerman_A)_	NU	800.00000	.	-Inf	756.36364	-30.00000	1.6595e+06	g(B_Isfahan_Mashhad)
				30.00000	800.00000	856.36364	+Inf	1.6625e+06	c_u_max_market_demand_limit(Mashhad_B)_
93	c_u_max_market_demand_limit(Kerman_B)_	BS	300.00000	900.00000	-Inf	223.03655	-193.33000	1.60281e+06	l(Tehran_Kerman)
				.	1200.00000	343.63636	30.00000	1.66981e+06	c_u_max_market_demand_limit(Kerman_A)_
94	c_u_max_market_demand_limit(Ahvaz_A)_	BS	.	1500.00000	-Inf	.	-Inf	1.66081e+06	
				.	1500.00000	56.36364	60.00000	1.66081e+06	g(A_Isfahan_Ahvaz)
95	c_u_max_market_demand_limit(Ahvaz_B)_	BS	1500.00000	.	-Inf	1443.63636	-60.00000	1.57081e+06	g(A_Isfahan_Ahvaz)
				.	1500.00000	1500.00000	+Inf	+Inf	
96	c_u_max_market_demand_limit(Tabriz_A)_	BS	400.00000	1000.00000	-Inf	356.36364	-183.18000	1.58754e+06	l(Tehran_Tabriz)
				.	1400.00000	456.36364	30.00000	1.67281e+06	c_u_max_market_demand_limit(Tabriz_B)_

```
    97 c_u_max_market_demand_limit(Tabriz_B)_
                     NU    1100.00000        .               -Inf     1043.63636
-30.00000   1.65912e+06 c_u_max_market_demand_limit(Mashhad_B)_
                                          30.00000    1100.00000     1143.63636
+Inf   1.66212e+06 g(B_Isfahan_Mashhad)

    98 c_u_discount_limit_1(1)_
                     NU    2500.00000        .               -Inf       76.96970
.        1.66081e+06 d(1)
                                           .         2500.00000     2576.96325
+Inf   1.66081e+06 c_u_discount_limit_4(1)_

    99 c_u_discount_limit_1(2)_
                     BS        .         3000.00000          -Inf         .
-Inf   1.66081e+06
                                           .         3000.00000         .
19.14006   1.66081e+06 c_u_discount_limit_2(2)_

   100 c_u_discount_limit_2(1)_
                     BS   -2500.00000    2500.00000          -Inf    -2500.00000
-Inf          +Inf
                                           .             .          -76.96970
.        1.66081e+06 c_u_discount_limit_1(1)_

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)

   No. Row name     St      Activity         Slack   Lower bound       Activity
Obj coef  Obj value at Limiting
                                          Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------- ------------- -------------  -------------
------------- ------------- ------------
   101 c_u_discount_limit_2(2)_
                     NU        .             .               -Inf         .
-19.14006   1.66081e+06 c_u_buy_from_fac_limit_f(2)_
                                          19.14006        .              .
+Inf   1.66081e+06 c_u_buy_from_fac_limit_t(2)_

   102 c_u_discount_limit_3(1_A)_
                     NU        .             .               -Inf         .
-18.75000   1.66081e+06 R(A_1)
                                          18.75000        .         3.07853e+07
+Inf   5.78885e+08 c_u_discount_limit_4(1)_
```

```
   103 c_u_discount_limit_3(1_B)_
                     NU        .             .              -Inf    -2576.96970
-26.00000   1.59381e+06 R(B_1)
                                          26.00000        .         3.07853e+07
+Inf   8.02079e+08 c_u_discount_limit_4(1)_

   104 c_u_discount_limit_3(2_A)_
                     NU        .             .              -Inf         .
-19.49994   1.66081e+06 R(A_2)
                                          19.49994        .              .
+Inf   1.66081e+06 c_u_buy_from_fac_limit_f(2)_

   105 c_u_discount_limit_3(2_B)_
                     NU        .             .              -Inf         .
-26.99994   1.66081e+06 R(B_2)
                                          26.99994        .              .
+Inf   1.66081e+06 c_u_buy_from_fac_limit_f(2)_

   106 c_u_discount_limit_4(1)_
                     BS  -3.07853e+07   3.07853e+07          -Inf   -9.99997e+08
.        1.66081e+06 c_u_discount_limit_1(1)_
                                             .             .       -3.07853e+07
.00005   1.65934e+06 c_u_discount_limit_4(2)_

   107 c_u_discount_limit_4(2)_
                     NU        .             .              -Inf         .
-.00006   1.66081e+06 c_u_buy_from_fac_limit_f(2)_
                                           .00006        .              .
+Inf   1.66081e+06 c_u_buy_from_fac_limit_t(2)_

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)

   No. Column name  St      Activity      Obj coef   Lower bound       Activity
Obj coef  Obj value at Limiting
                                          Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------- ------------- -------------  -------------
------------- ------------- ------------
     1 g(A_Tehran_Mashhad)
                     NL        .          520.00000        .           -43.63636
-Inf   1.66081e+06 g(B_Isfahan_Mashhad)
                                             .              +Inf      300.00000
520.00000   1.66081e+06 g(B_Tehran_Mashhad)
```

```
     2 g(A_Tehran_Kerman)
                       BS     300.00000     540.00000        .           256.36364
510.00000   1.65181e+06 c_u_max_market_demand_limit(Kerman_A)_
                                               .               +Inf       600.00000
540.00000   1.66081e+06 g(B_Isfahan_Kerman)

     3 g(A_Tehran_Ahvaz)
                       NL        .           490.00000        .              .
-Inf   1.66081e+06 c_u_max_market_demand_limit(Ahvaz_B)_
                                            -60.00000          +Inf        56.36364
550.00000   1.65743e+06 c_u_max_market_demand_limit(Mashhad_B)_

     4 g(A_Tehran_Tabriz)
                       NL        .           500.00000        .           -155.15152
-Inf   1.66081e+06 t(B_Main_Isfahan)
                                               .               +Inf       400.00000
500.00000   1.66081e+06 g(A_Isfahan_Tabriz)

     5 g(A_Isfahan_Mashhad)
                       BS     356.36364     520.00000        .            56.36364
520.00000   1.66081e+06 g(A_Tehran_Mashhad)
                                               .               +Inf       400.00000
550.00000    1.6715e+06 c_u_max_market_demand_limit(Kerman_A)_

     6 g(A_Isfahan_Kerman)
                       BS     500.00000     540.00000        .           200.00000
540.00000   1.66081e+06 g(B_Isfahan_Kerman)
                                               .               +Inf       500.00000
+Inf          +Inf

     7 g(A_Isfahan_Ahvaz)
                       NL        .           490.00000        .              .
-Inf   1.66081e+06 c_u_max_market_demand_limit(Ahvaz_B)_
                                            -60.00000          +Inf        56.36364
550.00000   1.65743e+06 c_u_max_market_demand_limit(Mashhad_B)_

     8 g(A_Isfahan_Tabriz)
                       BS     400.00000     500.00000        .           -100.00000
500.00000   1.66081e+06 g(A_Tehran_Tabriz)
                                               .               +Inf       456.36364
530.00000   1.67281e+06 c_u_max_market_demand_limit(Tabriz_B)_

     9 g(B_Tehran_Mashhad)
                       BS     300.00000     700.00000        .            -56.36364
700.00000   1.66081e+06 g(A_Tehran_Mashhad)
                                               .               +Inf       300.00000
+Inf          +Inf
```

```
    10 g(B_Tehran_Kerman)
                   BS     300.00000     690.00000             .          -200.00000
690.00000   1.66081e+06 g(B_Isfahan_Kerman)
                                             .               +Inf      343.63636
720.00000   1.66981e+06 c_u_max_market_demand_limit(Kerman_A)_

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)

   No. Column name  St      Activity      Obj coef   Lower bound       Activity
Obj coef  Obj value at Limiting
                                          Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------ ------------- -------------  -------------
------------- ------------- ------------
    11 g(B_Tehran_Ahvaz)
                   BS    1000.00000     730.00000             .           943.63636
670.00000   1.60081e+06 g(A_Tehran_Ahvaz)
                                             .               +Inf     1000.00000
+Inf          +Inf

    12 g(B_Tehran_Tabriz)
                   BS     500.00000     710.00000             .           100.00000
710.00000   1.66081e+06 g(A_Tehran_Tabriz)
                                             .               +Inf      500.00000
+Inf          +Inf

    13 g(B_Isfahan_Mashhad)
                   BS      43.63636     700.00000             .          -111.51515
670.00000    1.6595e+06 c_u_max_market_demand_limit(Kerman_A)_
                                             .               +Inf      343.63636
700.00000   1.66081e+06 g(A_Tehran_Mashhad)

    14 g(B_Isfahan_Kerman)
                   NL        .          690.00000             .          -155.15152
-Inf   1.66081e+06 t(B_Main_Isfahan)
                                             .               +Inf      300.00000
690.00000   1.66081e+06 g(B_Tehran_Kerman)

    15 g(B_Isfahan_Ahvaz)
                   BS     500.00000     730.00000             .           443.63636
670.00000   1.63081e+06 g(A_Isfahan_Ahvaz)
                                             .               +Inf      500.00000
+Inf          +Inf
```

```
    16 g(B_Isfahan_Tabriz)
                   BS     600.00000     710.00000        .           543.63636
680.00000   1.64281e+06 c_u_max_market_demand_limit(Tabriz_B)_
                                           .              +Inf     1000.00000
710.00000   1.66081e+06 g(A_Tehran_Tabriz)

    17 Extracted_ore(1)
                   BS     560.00000     -45.00000        .           471.42857
-254.57253   1.54345e+06 c_u_Max_extracted_ore_limit(1)_
                                           .              +Inf      560.00000
+Inf          +Inf

    18 Extracted_ore(2)
                   BS    1000.00000     -65.00000        .           896.66667
-390.65010   1.33516e+06 c_u_Max_extracted_ore_limit(2)_
                                           .              +Inf     1000.00000
+Inf          +Inf

    19 Extracted_ore(3)
                   BS    1440.00000     -70.00000        .          1316.00000
-197.51434   1.47719e+06 c_u_Max_extracted_ore_limit(3)_
                                           .              +Inf     1440.00000
+Inf          +Inf

    20 t(A_1_Tehran)
                   NL        .         -375.00000        .             .
-Inf   1.66081e+06 R(A_1)
                                         -42.25000          +Inf       43.63636
-332.75000   1.65897e+06 g(B_Isfahan_Mashhad)

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)

   No. Column name  St      Activity      Obj coef   Lower bound       Activity
Obj coef  Obj value at Limiting
                                         Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------ ------------- -------------  -------------
------------ ------------ ------------
    21 t(A_1_Isfahan)
                   NL        .         -375.00000        .             .
-Inf   1.66081e+06 R(A_1)
                                         -42.25000          +Inf       43.63636
-332.75000   1.65897e+06 g(B_Isfahan_Mashhad)
```

```
    22 t(A_2_Tehran)
                      NL        .          -390.00000        .             .
-Inf   1.66081e+06 R(A_2)
                                            -37.94000          +Inf         .
-352.06000   1.66081e+06 c_u_buy_from_fac_limit_t(2)_

    23 t(A_2_Isfahan)
                      NL        .          -390.00000        .             .
-Inf   1.66081e+06 R(A_2)
                                            -37.50000          +Inf         .
-352.50000   1.66081e+06 t(B_2_Isfahan)

    24 t(B_1_Tehran)
                      BS    1588.48485     -520.00000        .          1433.33333
-520.04000   1.66075e+06 c_u_transportation_limit_t(1_Tehran)_
                                                .               +Inf     1900.00000
-519.96000   1.66088e+06 c_u_transportation_limit_t(1_Isfahan)_

    25 t(B_1_Isfahan)
                      BS     988.48485     -520.00000        .           676.96970
-520.04000   1.66077e+06 c_u_transportation_limit_t(1_Isfahan)_
                                                .               +Inf     1143.63636
-519.96000   1.66085e+06 c_u_transportation_limit_t(1_Tehran)_

    26 t(B_2_Tehran)
                      NL        .          -540.00000        .             .
-Inf   1.66081e+06 B(2_Tehran)
                                              -.44000          +Inf         .
-539.56000   1.66081e+06 c_u_buy_from_fac_limit_t(2)_

    27 t(B_2_Isfahan)
                      BS        .          -540.00000        .             .
-540.44000   1.66081e+06 t(B_2_Tehran)
                                                .               +Inf         .
-520.86000   1.66081e+06 c_u_discount_limit_4(2)_

    28 h(1)           BS        .52949     -120.00000        .             .52949
-960.00000   1.66037e+06 c_u_container_limit(2_Isfahan)_
                                                .            1.00000         .58121
.        1.66088e+06 c_u_transportation_limit_t(1_Tehran)_

    29 h(2)           BS        .           -90.00000        .             .
-750.00000   1.66081e+06 t(B_2_Tehran)
                                                .            1.00000         .
.        1.66081e+06 c_u_transportation_limit_t(2_Isfahan)_

    30 B(1_Tehran)  BS      15.88485     -180.00000        .            14.33333
```

```
-184.00000   1.66075e+06 c_u_transportation_limit_t(1_Tehran)_
                                          .               +Inf       19.00000
-176.00000   1.66088e+06 c_u_transportation_limit_t(1_Isfahan)_

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)

   No. Column name  St      Activity      Obj coef   Lower bound       Activity
Obj coef  Obj value at Limiting
                                          Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------ ------------ -------------  -------------
------------ ------------- ------------
    31 B(1_Isfahan) BS      15.88485    -210.00000        .            12.76970
-214.00000   1.66075e+06 c_u_transportation_limit_t(1_Isfahan)_
                                          .               +Inf       17.43636
-206.00000   1.66088e+06 c_u_transportation_limit_t(1_Tehran)_

    32 B(2_Tehran)  BS        .         -240.00000        .              .
-Inf   1.66081e+06
                                          .               +Inf          .
-196.00000   1.66081e+06 t(B_2_Tehran)

    33 B(2_Isfahan) BS        .         -220.00000        .              .
-264.00000   1.66081e+06 t(B_2_Tehran)
                                          .               +Inf          .
-206.00000   1.66081e+06 c_u_container_limit(2_Isfahan)_

    34 B(Main_Tehran)
                    BS       8.11515    -200.00000        .             5.00000
-204.00000   1.66078e+06 c_u_transportation_limit_t(1_Isfahan)_
                                          .               +Inf        9.66667
-196.00000   1.66085e+06 c_u_transportation_limit_t(1_Tehran)_

    35 B(Main_Isfahan)
                    BS      14.11515    -230.00000        .            12.56364
-234.00000   1.66076e+06 c_u_transportation_limit_t(1_Tehran)_
                                          .               +Inf       17.23030
-226.00000   1.66087e+06 c_u_transportation_limit_t(1_Isfahan)_

    36 G(Tehran_Mashhad)
                    BS       3.00000    -110.00000        .             2.23037
-20418.00000   1.59989e+06 l(Tehran_Mashhad)
                                          .               +Inf        3.00000
+Inf          +Inf
```

```
    37 G(Tehran_Kerman)
                     BS       6.00000     -85.00000        .             5.23037
-19418.00000   1.54482e+06 l(Tehran_Kerman)
                                          .               +Inf        6.00000
+Inf          +Inf

    38 G(Tehran_Ahvaz)
                     BS      10.00000    -120.00000        .             9.23037
-23418.00000   1.42783e+06 l(Tehran_Ahvaz)
                                          .               +Inf       10.00000
+Inf          +Inf

    39 G(Tehran_Tabriz)
                     BS       5.00000    -100.00000        .             4.56364
-18418.00000   1.56922e+06 l(Tehran_Tabriz)
                                          .               +Inf        5.00000
+Inf          +Inf

    40 G(Isfahan_Mashhad)
                     BS       4.00000    -100.00000        .             3.56364
-20600.00000   1.57881e+06 l(Isfahan_Mashhad)
                                          .               +Inf        4.00000
+Inf          +Inf

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)

   No. Column name  St      Activity      Obj coef   Lower bound       Activity
Obj coef  Obj value at Limiting
                                         Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------- ------------- -------------  -------------
------------- ------------- ------------
    41 G(Isfahan_Kerman)
                     BS       5.00000    -100.00000        .             4.23037
-19600.00000   1.56331e+06 l(Isfahan_Kerman)
                                          .               +Inf        5.00000
+Inf          +Inf

    42 G(Isfahan_Ahvaz)
                     BS       5.00000    -110.00000        .             4.23037
-23600.00000   1.54336e+06 l(Isfahan_Ahvaz)
                                          .               +Inf        5.00000
+Inf          +Inf
```

```
    43 G(Isfahan_Tabriz)
                     BS      10.00000     -90.00000        .             9.56364
-18600.00000   1.47571e+06 l(Isfahan_Tabriz)
                                          .              +Inf       10.00000
+Inf          +Inf

    44 R(A_1)        BS        .           18.75000        .               -Inf
.        1.66081e+06 c_u_discount_limit_3(1_A)_
                                          .              +Inf       43.63636
61.00000   1.66081e+06 t(A_1_Tehran)

    45 R(A_2)        BS        .           19.50000        .               .
.00006   1.66081e+06 c_u_discount_limit_3(2_A)_
                                          .              +Inf         .
57.00000   1.66081e+06 t(A_2_Isfahan)

    46 R(B_1)        BS    2576.96970      26.00000        .          2576.96970
6.86000   1.61149e+06 c_u_discount_limit_4(2)_
                                          .              +Inf     2647.11111
251.42714   2.24173e+06 c_u_Max_extracted_ore_limit(3)_

    47 R(B_2)        BS        .           27.00000        .               .
.00014   1.66081e+06 c_u_discount_limit_3(2_B)_
                                          .              +Inf         .
46.14000   1.66081e+06 c_u_discount_limit_4(2)_

    48 U(A)          BS    1556.36364        .             .          1500.00000
-280.53156    1.2242e+06 c_u_Max_extracted_ore_limit(3)_
                                          .              +Inf     1556.36364
+Inf          +Inf

    49 Z(1_A)        BS     140.00000        .             .          -436.96970
.        1.66081e+06 c_u_Metal_sum_limit_Z(1)_
                                          .              +Inf      140.00000
+Inf          +Inf

    50 Z(2_A)        BS     150.00000        .             .            16.66667
.        1.66081e+06 Z(2_B)
                                          .              +Inf      150.00000
+Inf          +Inf

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)
```

```
   No. Column name  St      Activity      Obj coef   Lower bound       Activity
Obj coef  Obj value at Limiting
                                                    Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------ ------------ -------------  -------------
------------- ------------- ------------
    51 Z(3_A)       BS     225.69697        .             .           153.69697
.        1.66081e+06 C(3_A)
                                                    .              +Inf      365.69697
.        1.66081e+06 c_u_Metal_sum_limit_Z(1)_

    52 C(1_A)       BS     168.00000        .             .           -65.33333
.        1.66081e+06 C(1_B)
                                                    .              +Inf      168.00000
+Inf          +Inf

    53 C(2_A)       BS      16.66667        .             .          -168.00000
.        1.66081e+06 c_u_Metal_sum_limit_C(2)_
                                                    .              +Inf      184.66667
.        1.66081e+06 C(1_B)

    54 C(3_A)       NL        .             .             .          -184.66667
-Inf   1.66081e+06 c_u_Metal_in_alloy_limit_A_C_f_
                                                    .              +Inf       72.00000
.        1.66081e+06 c_u_Metal_sum_limit_C(3)_

    55 A(1_A)       BS     196.00000        .             .           165.00000
-570.58182   1.54898e+06 A(1_B)
                                                    .              +Inf      196.00000
+Inf          +Inf

    56 A(2_A)       BS     300.00000        .             .           269.00000
-570.58182   1.48964e+06 A(2_B)
                                                    .              +Inf      300.00000
+Inf          +Inf

    57 A(3_A)       BS     360.00000        .             .           329.00000
-510.05737   1.47719e+06 c_u_Max_extracted_ore_limit(3)_
                                                    .              +Inf      360.00000
+Inf          +Inf

    58 F(1_A)       NL        .             .             .              .
-Inf   1.66081e+06 c_u_Metal_in_alloy_limit_A_F_f_
                                          -1097.37778          +Inf       28.00000
1097.37778   1.63009e+06 F(1_B)

    59 F(2_A)       NL        .             .             .              .
-Inf   1.66081e+06 c_u_Metal_in_alloy_limit_A_F_f_
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                                      -1097.37778          +Inf       126.95455
1097.37778    1.5215e+06 Z(3_A)

    60 F(3_A)       NL        .             .             .              .
-Inf   1.66081e+06 c_u_Metal_in_alloy_limit_A_F_f_
                                      -1097.37778          +Inf        72.00000
1097.37778    1.5818e+06 F(3_B)

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)

   No. Column name  St      Activity      Obj coef   Lower bound       Activity
Obj coef  Obj value at Limiting
                                          Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------ ------------- -------------  -------------
------------ ------------ ------------
    61 U(B)         BS     666.66667        .             .           604.44444
-493.82000    1.3316e+06 F(1_A)
                                          .              +Inf       666.66667
+Inf          +Inf

    62 Z(1_B)       NL        .             .             .          -225.69697
-Inf   1.66081e+06 Z(3_A)
                                          .              +Inf       133.33333
.        1.66081e+06 Z(3_B)

    63 Z(2_B)       NL        .             .             .          -225.69697
-Inf   1.66081e+06 Z(3_A)
                                          .              +Inf       133.33333
.        1.66081e+06 Z(3_B)

    64 Z(3_B)       BS     133.33333        .             .            -6.66667
.        1.66081e+06 Z(1_B)
                                          .              +Inf       666.66667
.        1.66081e+06 c_u_Alloy_sum_limit(B)_

    65 C(1_B)       NL        .             .             .          -16.66667
-Inf   1.66081e+06 C(2_A)
                                          .              +Inf       168.00000
.        1.66081e+06 C(1_A)

    66 C(2_B)       BS     233.33333        .             .           65.33333
.        1.66081e+06 C(1_B)
                                          .              +Inf       250.00000
```

```
.        1.66081e+06 c_u_Metal_in_alloy_limit_B_C_f_

    67 C(3_B)       NL        .             .             .           -16.66667
-Inf   1.66081e+06 C(2_A)
                                          .               +Inf       72.00000
.        1.66081e+06 c_u_Metal_sum_limit_C(3)_

    68 A(1_B)       NL        .             .             .             .
-Inf   1.66081e+06 c_u_Metal_in_alloy_limit_B_A_f_
                                       -570.58182         +Inf       31.00000
570.58182   1.64313e+06 c_u_max_market_demand_limit(Mashhad_B)_

    69 A(2_B)       NL        .             .             .             .
-Inf   1.66081e+06 c_u_Metal_in_alloy_limit_B_A_f_
                                       -570.58182         +Inf       31.00000
570.58182   1.64313e+06 c_u_max_market_demand_limit(Mashhad_B)_

    70 A(3_B)       NL        .             .             .             .
-Inf   1.66081e+06 c_u_Metal_in_alloy_limit_B_A_f_
                                       -570.58182         +Inf       31.00000
570.58182   1.64313e+06 c_u_max_market_demand_limit(Mashhad_B)_

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)

   No. Column name  St      Activity      Obj coef   Lower bound       Activity
Obj coef  Obj value at Limiting
                                          Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------- ------------- -------------  -------------
------------- ------------- ------------
    71 F(1_B)       BS      28.00000        .             .           -98.95455
-1097.37778   1.63009e+06 F(1_A)
                                          .               +Inf       28.00000
+Inf          +Inf

    72 F(2_B)       BS     200.00000        .             .            73.04545
-1097.37778   1.44134e+06 F(2_A)
                                          .               +Inf      200.00000
+Inf          +Inf

    73 F(3_B)       BS      72.00000        .             .           -54.95455
-1097.37778    1.5818e+06 F(3_A)
                                          .               +Inf       72.00000
+Inf          +Inf
```

```
    74 t(A_Main_Tehran)
                       BS     300.00000        .             .           256.36364
-30.00000   1.65181e+06 c_u_max_market_demand_limit(Kerman_A)_
                                                .               +Inf      600.00000
.        1.66081e+06 g(A_Tehran_Mashhad)

    75 t(A_Main_Isfahan)
                       BS    1256.36364        .             .           956.36364
.        1.66081e+06 g(A_Tehran_Mashhad)
                                                .               +Inf     1300.00000
30.00000    1.6985e+06 c_u_max_market_demand_limit(Kerman_A)_

    76 t(B_Main_Tehran)
                       BS     511.51515        .             .           211.51515
.        1.66081e+06 g(A_Tehran_Mashhad)
                                                .               +Inf      666.66667
.04000   1.66083e+06 c_u_transportation_limit_t(1_Tehran)_

    77 t(B_Main_Isfahan)
                       BS     155.15152        .             .          -639.09091
-.04000   1.66081e+06 c_u_transportation_limit_t(1_Tehran)_
                                                .               +Inf      455.15152
.        1.66081e+06 g(A_Tehran_Mashhad)

    78 h(Main)         NU       1.00000        .             .              .70576
.        1.66081e+06 c_u_transportation_limit_t(Main_Isfahan)_
                                                .           1.00000        1.62303
+Inf   1.66081e+06 c_u_transportation_limit_f(Main_Tehran)_

    79 l(Tehran_Mashhad)
                       NU       1.00000        .             .              .74346
-60924.00000   1.64518e+06 c_u_discount_limit_4(1)_
                                         60924.00000       1.00000        1.18788
+Inf   1.67226e+06 c_u_max_market_demand_limit(Mashhad_B)_

    80 l(Tehran_Kerman)
                       NU       1.00000        .             .              .87173
-115998.00000   1.64593e+06 c_u_discount_limit_4(1)_
                                        115998.00000       1.00000        1.51717
+Inf    1.7208e+06 t(B_Main_Isfahan)

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Problem:
Objective:  revenue = 1660813.37 (MAXimum)
```

```
   No. Column name  St      Activity      Obj coef   Lower bound       Activity
Obj coef  Obj value at Limiting
                                         Marginal   Upper bound          range
range   break point variable
------ ------------ -- ------------- ------------- -------------  -------------
------------- ------------- ------------
    81 l(Tehran_Ahvaz)
                     NU       1.00000         .             .             .92304
-232980.00000   1.64288e+06 c_u_discount_limit_4(1)_
                                      232980.00000       1.00000        1.00000
+Inf   1.66081e+06 c_u_max_market_demand_limit(Ahvaz_B)_

    82 l(Tehran_Tabriz)
                     NU       1.00000         .             .             .91273
-91590.00000   1.65282e+06 g(B_Isfahan_Mashhad)
                                       91590.00000       1.00000        1.11273
+Inf   1.67114e+06 c_u_max_market_demand_limit(Mashhad_B)_

    83 l(Isfahan_Mashhad)
                     NU       1.00000         .             .             .89091
-82000.00000   1.65187e+06 g(B_Isfahan_Mashhad)
                                       82000.00000       1.00000        1.14091
+Inf   1.67237e+06 c_u_max_market_demand_limit(Mashhad_B)_

    84 l(Isfahan_Kerman)
                     NU       1.00000         .             .             .84607
-97500.00000   1.64581e+06 c_u_discount_limit_4(1)_
                                       97500.00000       1.00000        1.14101
+Inf   1.67456e+06 c_u_buy_from_fac_limit_t(1)_

    85 l(Isfahan_Ahvaz)
                     NU       1.00000         .             .             .84607
-117450.00000   1.64273e+06 c_u_discount_limit_4(1)_
                                      117450.00000       1.00000        1.00000
+Inf   1.66081e+06 c_u_max_market_demand_limit(Ahvaz_B)_

    86 l(Isfahan_Tabriz)
                     NU       1.00000         .             .             .95636
-185100.00000   1.65274e+06 g(B_Isfahan_Mashhad)
                                      185100.00000       1.00000        1.05636
+Inf   1.67125e+06 c_u_max_market_demand_limit(Mashhad_B)_

    87 d(1)          BS        .03079         .             .             .03079
-47849.99991   1.65934e+06 c_u_discount_limit_4(2)_
                                              .          1.00000        1.03079
.        1.66081e+06 c_u_discount_limit_1(1)_

    88 d(2)          BS             .         .             .             .
```

```
-1.94999e+10   1.66081e+06 c_u_discount_limit_3(2_A)_
                                                .            1.00000          .
57419.99989   1.66081e+06 c_u_discount_limit_4(2)_

End of report
```

1.5.2 Analysis G

From among the coefficients of the objective function, select one coefficient arbitrarily and, likewise, from among the values of the right-hand side constraints, consider one value arbitrarily. Then examine the effect of each of these changes on the value of the objective function by plotting a graph.

For right-hand side, we chose Max_ore of Factory 2 and for constraint coefficient we chose price_of_alloy_fac for Alloy B in Factory 2, the result are as shown:

[ ]:
```
!python model_runner.py -g
```

the result will be a html output in your browser, because the code takes long to generate output page, some images of output are shown below.