Project Assignment

ISEN 601 – Location Logistics of Industrial Facilities

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Introduction

Sanjay Gupta founded SportStuff.com in 2004 with a mission of supplying parents with more affordable sports equipment for their children. Parents complained about having to discard expensive skates, skis, jackets, and shoes because children outgrew them rapidly. Sanjay’s initial plan was for the company to purchase used equipment and jackets from families and any surplus equipment from manufacturers and retailers and sell these over the Internet. The idea was well received in the marketplace, demand grew rapidly, and by the end of 2004, the company had sales of $0.8 million. By this time, a variety of new and used products were being sold, and the company received significant venture capital support.

In June 2004, Sanjay leased part of a warehouse on the outskirts of St. Louis to manage the large amount of product being sold. Suppliers sent their product to the warehouse. Customer orders were packed and shipped by UPS from there. As demand grew, SportStuff.com leased more space within the warehouse. By 2007, SportStuff.com leased the entire warehouse and orders were being shipped to customers all over the United States. Management divided the United States into six customer zones for planning purposes. Sanjay estimated that the next three years would see a growth rate of about 80% per year, after which demand would level off.

In December 2008, Sanjay Gupta and his management team were busy evaluating the performance at SportStuff.com over the previous year. Demand had grown by 80%. This growth, however, was a mixed blessing. The venture capitalists supporting the company were very pleased with the growth in sales and the resulting increase in revenue. Sanjay and his team, however, could clearly see that costs would grow faster than revenues if demand continued to grow and the supply chain network was not redesigned. They decided to analyze the performance of the current network to see how it could be redesigned to best cope with the rapid growth anticipated over the next three years.

The scope of this project to redesign the current network to cope with the significantly increased growth after three years.

Problem Formulation

Indices

I - Customer Zones, I∈{1, …, 6}

J - Warehouses J∈{1, …, 10}

K – Small Warehouses K∈{1, …, 5}

L – Large Warehouses L∈{6, ..., 10}

|  |  |
| --- | --- |
| Index [I] | Customer Zone |
| 1 | Northwest |
| 2 | Southwest |
| 3 | Upper Midwest |
| 4 | Lower Midwest |
| 5 | Northeast |
| 6 | Southeast |

|  |  |
| --- | --- |
| Index [J] | Warehouse |
| 1 | Seattle Small Warehouse |
| 2 | Denver Small Warehouse |
| 3 | St. Louis Small Warehouse |
| 4 | Atlanta Small Warehouse |
| 5 | Philadelphia Small Warehouse |
| 6 | Seattle Large Warehouse |
| 7 | Denver Large Warehouse |
| 8 | St. Louis Large Warehouse |
| 9 | Atlanta Large Warehouse |
| 10 | Philadelphia Large Warehouse |

|  |  |
| --- | --- |
| Index [K] | Small warehouse |
| 1 | Seattle Small Warehouse |
| 2 | Denver Small Warehouse |
| 3 | St. Louis Small Warehouse |
| 4 | Atlanta Small Warehouse |
| 5 | Philadelphia Small Warehouse |

|  |  |
| --- | --- |
| Index [L] | Large Warehouse |
| 6 | Seattle Large Warehouse |
| 7 | Denver Large Warehouse |
| 8 | St. Louis Large Warehouse |
| 9 | Atlanta Large Warehouse |
| 10 | Philadelphia Large Warehouse |

Parameters

– Cost of transporting a unit from warehouse j to customer I, i∈I, j∈J

– Demand of the customer zone I, i∈I

Fixed Cost of warehouse j, j∈J

Variables

, j∈J

Number of units transported from warehouse j to customer I, i∈I, j∈J

Objective Function

Minimize Total Annual Cost:

Constraints

(1)

(2)

(3)

(4)

Constraint (1) stipulates that the total number of units, from all warehouses, which are transported to the customer in zone i, is at least equal to the demand at zone i.

Constraint (2) states that the number of units shipped from the Small Warehouse k, is at most the maximum capacity of the Small Warehouse k, i.e. 2000000 units.

According to constraint (3), the number of units shipped from the Large Warehouse l, is at most the maximum capacity of the Large Warehouse l, i.e. 4000000 units.

Constraint (4) is the non-negativity constraint which ensures that the number of units transported is always zero or positive.

Solution

The demands at the different zones, after 3 years are shown in the table below. These values were arrived at by considering an 80% growth every year for 3 years.

|  |  |
| --- | --- |
| Zone | Demand in 2010 |
| Northwest | 1866240 |
| Southwest | 1166400 |
| Upper Midwest | 933120 |
| Lower Midwest | 1283040 |
| Northeast | 2041200 |
| Southeast | 1020600 |

The transportation costs incurred by the company to pay UPS for each unit is shown in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Zone\Warehouse Location | Seattle | Denver | St. Louis | Atlanta | Philadelphia |
| Northwest | $0.50 | $0.63 | $0.88 | $1.00 | $1.13 |
| Southwest | $0.63 | $0.63 | $0.88 | $1.00 | $1.25 |
| Upper Midwest | $0.88 | $0.63 | $0.63 | $0.75 | $0.75 |
| Lower Midwest | $1.00 | $0.75 | $0.63 | $0.63 | $0.88 |
| Northeast | $1.25 | $1.00 | $0.75 | $0.75 | $0.63 |
| Southeast | $1.38 | $1.13 | $0.88 | $0.63 | $1.00 |

The problem was solved in AMPL using the BARON Solver.

Question 1

What is the cost SportStuff.com incurs if all warehouses leased are in St. Louis?

The cost incurred would be $11,385,700. This would also require 3 Large Warehouses to be leased in St. Louis.

Refer to the appendix 1 for the formulation used to model the problem, the data for the problem and the solution obtained from the BARON Solver.

Question 2

What supply chain network configuration do you recommend for SportStuff.com? Why?

The optimal supply chain network has a Small Warehouse located in St. Louis and a Large Warehouse located in Denver and Atlanta. The optimal total cost incurred by having such a supply chain network is $10,896,200.

Refer to the appendix 2 for the formulation used to model the problem, the data for the problem and the solution obtained from the BARON Solver.

Question 3

How would your recommendation change if transportation costs were twice the current values?

If the transportation costs were doubled, then the optimal supply chain network changes. Now, the network has a Small Warehouse located in Philadelphia and a Large Warehouse located in Seattle and Atlanta. The optimal total cost incurred is $15,922,100.

Refer to the appendix 3 for the formulation used to model the problem, the data for the problem and the solution obtained from the BARON Solver.

Appendix 1

Model File

set I:=1..6;

set J:=1..2;

set IJ= {I,J};

param c{IJ};

param mu{I};

param f{J};

var X{J}integer;

var Y{IJ} >=0;

minimize total\_cost:

sum{j in J}X[j]\*f[j] + sum{(i,j) in IJ}Y[i,j]\*(c[i,j]+0.2) + sum{j in J}sqrt(sum{i in I}Y[i,j])\*600;

s.t.

constraint1{i in I}:sum{j in J}Y[i,j]>=mu[i];

constraint2:sum{i in I}Y[i,1]<=2000000\*X[1];

constraint3:sum{i in I}Y[i,2]<=4000000\*X[2];

#NonNeg{(i,j) in IJ}:Y[i,j]>=0;

Data File

param c: 1 2:=

1 0.88 0.88

2 0.88 0.88

3 0.63 0.63

4 0.63 0.63

5 0.75 0.75

6 0.88 0.88;

param mu:=

1 1866240

2 1166400

3 933120

4 1283040

5 2041200

6 1020600;

param f:=

1 300000

2 500000;

Command File

solve;

option omit\_zero\_cols 1;

option omit\_zero\_rows 1;

display total\_cost, X,Y;

Output File

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

NEOS Server Version 5.0

Job# : 6431799

Password : PNpTEjmv

User : None

Solver : go:BARON:AMPL

Start : 2018-12-06 14:55:27

End : 2018-12-06 14:55:38

Host : NEOS HTCondor Pool

Disclaimer:

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File exists

You are using the solver baron.

Checking ampl.mod for baron\_options...

Checking ampl.com for baron\_options...

Executing AMPL.

processing data.

processing commands.

Executing on prod-exec-5.neos-server.org

14 variables:

2 integer variables

12 nonlinear variables

8 constraints, all linear; 26 nonzeros

8 inequality constraints

1 nonlinear objective; 14 nonzeros.

BARON 18.5.8 (2018.05.08): threads=4

BARON 18.5.8 (2018.05.08): 1 iterations, optimal within tolerances.

Objective 11385738.68

total\_cost = 11385700

X [\*] :=

2 3

;

Y :=

1 2 1866240

2 2 1166400

3 2 933120

4 2 1283040

5 2 2041200

6 2 1020600

;

Appendix 2

Model File

set I:=1..6;

set J:=1..10;

set K:=1..5;

set L:=6..10;

set IJ= {I,J};

param c{IJ};

param mu{I};

param f{J};

var X{J}binary;

var Y{IJ} >=0;

minimize total\_cost:

sum{j in J}X[j]\*f[j] + sum{(i,j) in IJ}Y[i,j]\*(c[i,j]+0.2) + sum{j in J}sqrt(sum{i in I}Y[i,j])\*600;

s.t.

constraint1{i in I}:sum{j in J}Y[i,j]>=mu[i];

constraint2{k in K}:sum{i in I}Y[i,k]<=2000000\*X[k];

constraint3{l in L}:sum{i in I}Y[i,l]<=4000000\*X[l];

#NonNeg{(i,j) in IJ}:Y[i,j]>=0;

Data File

param c: 1 2 3 4 5 6 7 8 9 10:=

1 0.50 0.63 0.88 1.00 1.13 0.50 0.63 0.88 1.00 1.13

2 0.63 0.63 0.88 1.00 1.25 0.63 0.63 0.88 1.00 1.25

3 0.88 0.63 0.63 0.75 0.75 0.88 0.63 0.63 0.75 0.75

4 1.00 0.75 0.63 0.63 0.88 1.00 0.75 0.63 0.63 0.88

5 1.25 1.00 0.75 0.75 0.63 1.25 1.00 0.75 0.75 0.63

6 1.38 1.13 0.88 0.63 1.00 1.38 1.13 0.88 0.63 1.00;

param mu:=

1 1866240

2 1166400

3 933120

4 1283040

5 2041200

6 1020600;

param f:=

1 300000

2 250000

3 220000

4 220000

5 240000

6 500000

7 420000

8 375000

9 375000

10 405000;

Output File

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NEOS Server Version 5.0

Job# : 6431801

Password : mEtHeFoh

User : None

Solver : go:BARON:AMPL

Start : 2018-12-06 14:56:25

End : 2018-12-06 14:57:05

Host : NEOS HTCondor Pool

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File exists

You are using the solver baron.

Checking ampl.mod for baron\_options...

Checking ampl.com for baron\_options...

Executing AMPL.

processing data.

processing commands.

Executing on prod-exec-5.neos-server.org

70 variables:

10 binary variables

60 nonlinear variables

16 constraints, all linear; 130 nonzeros

16 inequality constraints

1 nonlinear objective; 70 nonzeros.

BARON 18.5.8 (2018.05.08): threads=4

BARON 18.5.8 (2018.05.08): 18805 iterations, optimal within tolerances.

Objective 10896239.8

total\_cost = 10896200

X [\*] :=

3 1

7 1

9 1

;

Y :=

1 7 1866240

2 7 1166400

3 7 933120

4 7 34240

4 9 1248800

5 3 310600

5 9 1730600

6 9 1020600

;

Appendix 3

Model File

set I:=1..6;

set J:=1..10;

set K:=1..5;

set L:=6..10;

set IJ= {I,J};

param c{IJ};

param mu{I};

param f{J};

var X{J}binary;

var Y{IJ} >=0;

minimize total\_cost:

sum{j in J}X[j]\*f[j] + sum{(i,j) in IJ}Y[i,j]\*(c[i,j]+0.2) + sum{j in J}sqrt(sum{i in I}Y[i,j])\*600;

s.t.

constraint1{i in I}:sum{j in J}Y[i,j]>=mu[i];

constraint2{k in K}:sum{i in I}Y[i,k]<=2000000\*X[k];

constraint3{l in L}:sum{i in I}Y[i,l]<=4000000\*X[l];

#NonNeg{(i,j) in IJ}:Y[i,j]>=0;

Data File

param c: 1 2 3 4 5 6 7 8 9 10:=

1 1.00 1.25 1.75 2.00 2.25 1.00 1.25 1.75 2.00 2.25

2 1.25 1.25 1.75 2.00 2.50 1.25 1.25 1.75 2.00 2.50

3 1.75 1.25 1.25 1.50 1.50 1.75 1.25 1.25 1.50 1.50

4 2.00 1.50 1.25 1.25 1.75 2.00 1.50 1.25 1.25 1.75

5 2.50 2.00 1.50 1.50 1.25 2.50 2.00 1.50 1.50 1.25

6 2.75 2.25 1.75 1.25 2.00 2.75 2.25 1.75 1.25 2.00;

param mu:=

1 1866240

2 1166400

3 933120

4 1283040

5 2041200

6 1020600;

param f:=

1 300000

2 250000

3 220000

4 220000

5 240000

6 500000

7 420000

8 375000

9 375000

10 405000;

Output File

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NEOS Server Version 5.0

Job# : 6431693

Password : jCscDXOf

User : None

Solver : go:BARON:AMPL

Start : 2018-12-06 13:47:21

End : 2018-12-06 13:47:31

Host : NEOS HTCondor Pool

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File exists

You are using the solver baron.

Checking ampl.mod for baron\_options...

Checking ampl.com for baron\_options...

Executing AMPL.

processing data.

processing commands.

Executing on prod-exec-5.neos-server.org

70 variables:

10 binary variables

60 nonlinear variables

16 constraints, all linear; 130 nonzeros

16 inequality constraints

1 nonlinear objective; 70 nonzeros.

BARON 18.5.8 (2018.05.08): threads=4

BARON 18.5.8 (2018.05.08): 33 iterations, optimal within tolerances.

Objective 15922094.99

total\_cost = 15922100

X [\*] :=

5 1

6 1

9 1

;

Y :=

1 6 1866240

2 6 1166400

3 9 933120

4 9 1283040

5 5 2e+06

5 9 41200

6 9 1020600

;