SPORTS-STUFF.COM

# LOGISTICS & SUPPLY CHAIN MANAGEMENT

A case study on SportsStuff from a supply chain perspective

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**CASE STUDY
FLOW**

**SPORT STUFF**

# STRATEGIC POSITIONING

**COMPETITORS**

SportStuff's competition includes other **online sports equipment retailers** like Amazon, eBay, etc.

**UNIQUE SELLING POINT**

SportStuff.com provides affordable sports equipment's to parents for their children by resale of discarded equipment.

**CUSTOMER DEMOGRAPHICS**

Mainly targeted at the **price-sensitive** customer segment which accounts to over 60% of the US sports market.

# SPORT-STUFF'S JOURNEY TILL NOW

**2004**
FOUNDING YEAR

Achieved Sales of $0.8 Million by the end of the year

**HUMBLE BEGINNINGS**

The company witnessed decent demand and growth in the initial few years and leased some space in a single warehouse in St. Louis

**2006-7**

The senior management noticed that the demand is growing but the costs are growing faster.

**2008**

If the supply chain model is not re designed immediately the company would face a huge loss.

**FEW KEY THINGS TO NOTICE**

Investors were happy. But Why ?

Senior management knew what was coming

Unsustainable business which was bound to fail without proper redesigning of the Logistics Model shows the **importance of Logistics and Supply Chain Management as a subject**

# SCM PERFORMANCE MEASURES

SCM performance measures are important to judge the performance of the supply chain system.

There are two categories:

•Qualitative Measures: Customer Satisfaction and Product quality.

•Quantitative Measures: Order-to-delivery lead time, flexibility, resource utilization, delivery performance.

# QUANTITATIVE MEASURES

**Non-Financial Measures:**

A. **Cycle Time**: The company must reduce the supply chain lead time and order-to-delivery lead time to be an effective supply chain.

B. **Customer Service Level**:

   i) *Order Fill Rate*:

   ii) *Stockout Rate*

   iii) *Backorder Level*
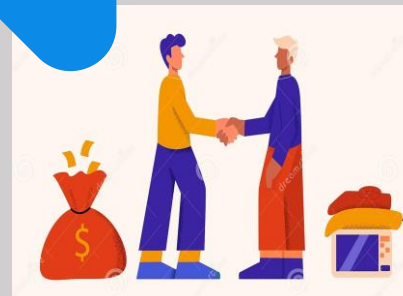
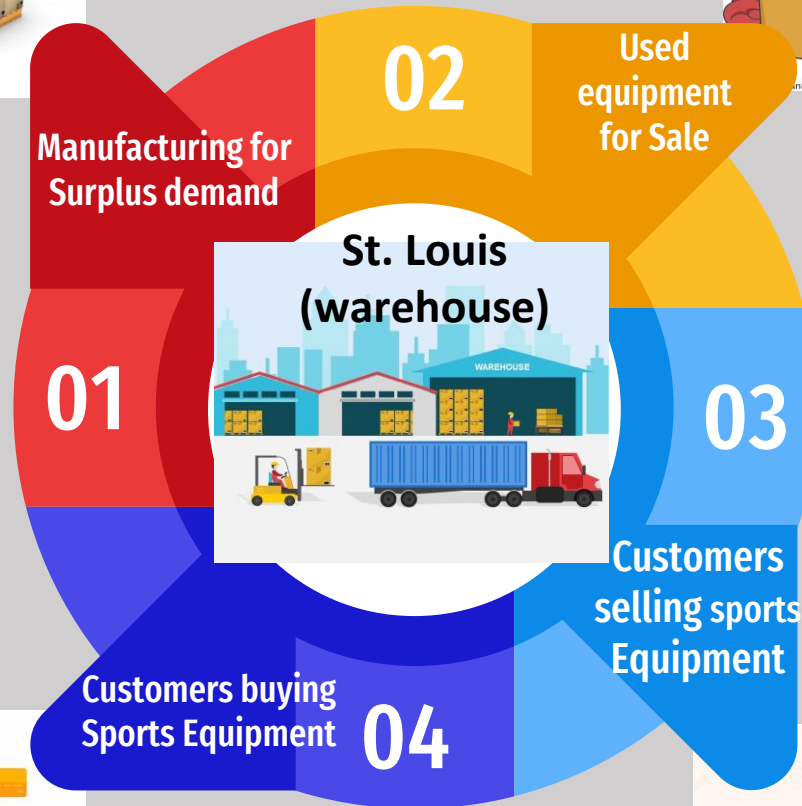   iv) *Probability of one-time delivery*.

In order to maximize the customer service level, it is important to maximize order fill rate, minimize stockout rate, and minimize backorder levels.

**Financial Performance:**

The financial performance of a supply chain is assessed by considering the following items

1. Cost of raw materials.
2. Revenue from goods sold.
3. Inventory holding costs.
4. Transportation costs.

# CURRENT LOGISTICS MODEL OF SPORTSTUFF.COM



**Manufacturing for Surplus demand**
**01**

**02**
**Used equipment for Sale**

**St. Louis (warehouse)**

**03**
**Customers selling sports Equipment**

**Customers buying Sports Equipment**
**04**

## CHANGE IN LOGISTICS MODEL

- During the initial year sof sportstuff.com the **network distribution model** of the company follows the "**Distribution storage with carriage model**" with the only distribution warehouse in the outskirts of St. Louis.

## CHANGE IN BUSINESS MODEL

- Initially the founder had plans to purchase used equipment and jackets from families and any surplus equipment from manufacturers and retailers and sell these over the Internet, which later on enhanced and led to the direct purchasing of the products from sellers and thus transformed the company into a **full fledged professional E-commerce** company.

# THE PROBLEM STATEMENT AND THE GIVEN DATA

## Table 5-15  Regional Demand at SportStuff.com for 2007

| Zone | Demand in 2007 | Zone | Demand in 2007 |
|------|---------------|------|---------------|
| Northwest | 320,000 | Lower Midwest | 220,000 |
| Southwest | 200,000 | Northeast | 350,000 |
| Upper Midwest | 160,000 | Southeast | 175,000 |

## Table 5-16  Fixed and Variable Costs of Potential Warehouses

| Location | Small Warehouse Fixed Cost ($/year) | Small Warehouse Variable Cost ($/Unit Flow) | Large Warehouse Fixed Cost ($/year) | Large Warehouse Variable Cost ($/Unit Flow) |
|----------|---------|---------|---------|---------|
| Seattle | 300,000 | 0.20 | 500,000 | 0.20 |
| Denver | 250,000 | 0.20 | 420,000 | 0.20 |
| St. Louis | 220,000 | 0.20 | 375,000 | 0.20 |
| Atlanta | 220,000 | 0.20 | 375,000 | 0.20 |
| Philadelphia | 240,000 | 0.20 | 400,000 | 0.20 |

## Table 5-17  UPS Charges per Shipment (Four Units)

| | Northwest | Southwest | Upper Midwest | Lower Midwest | Northeast | Southeast |
|------|-----------|-----------|---------------|---------------|-----------|-----------|
| Seattle | $2.00 | $2.50 | $3.50 | $4.00 | $5.00 | $5.50 |
| Denver | $2.50 | $2.50 | $2.50 | $3.00 | $4.00 | $4.50 |
| St. Louis | $3.50 | $3.50 | $2.50 | $2.50 | $3.00 | $3.50 |
| Atlanta | $4.00 | $4.00 | $3.00 | $2.50 | $3.00 | $2.50 |
| Philadelphia | $4.50 | $5.00 | $3.00 | $3.50 | $2.50 | $4.00 |

## QUESTIONS TO ANSWER

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

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

- Any other recommendations?

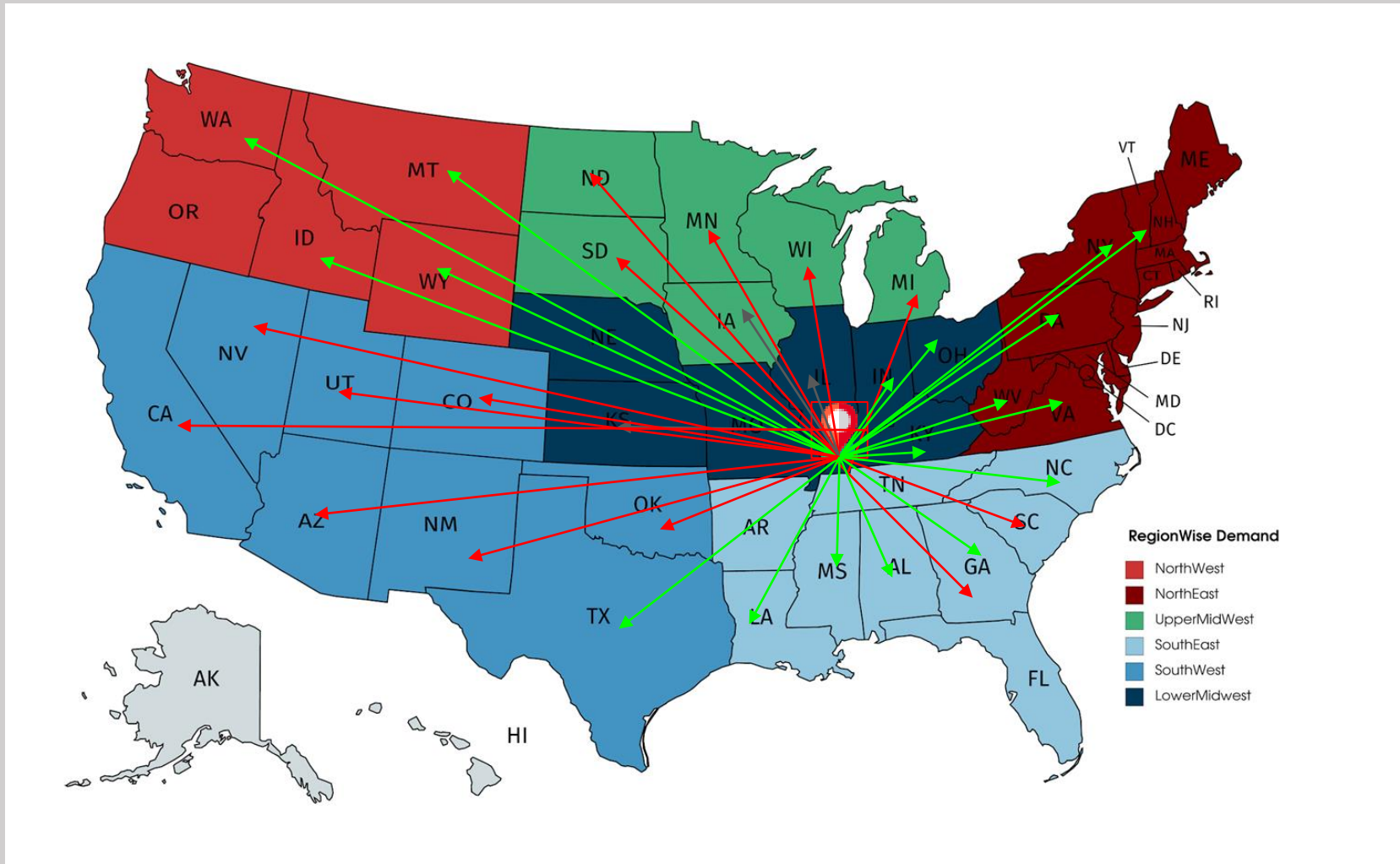# OUR SOLUTION METHODOLOGY



LINEAR
PROGRAMMING
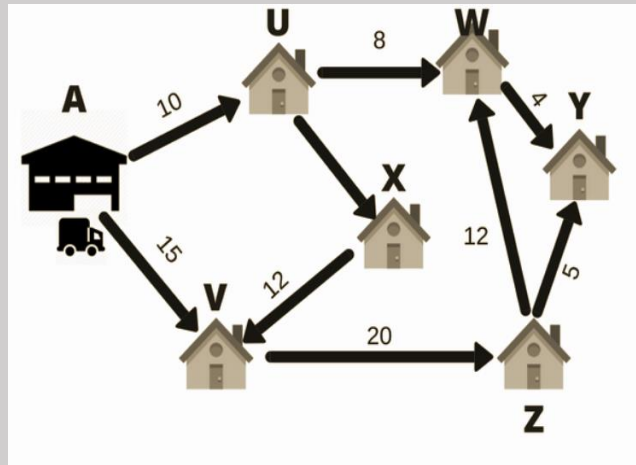


GREEDY
ALGORITHM
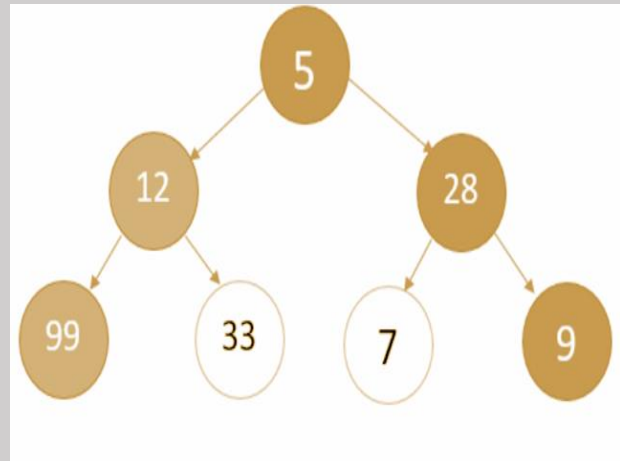
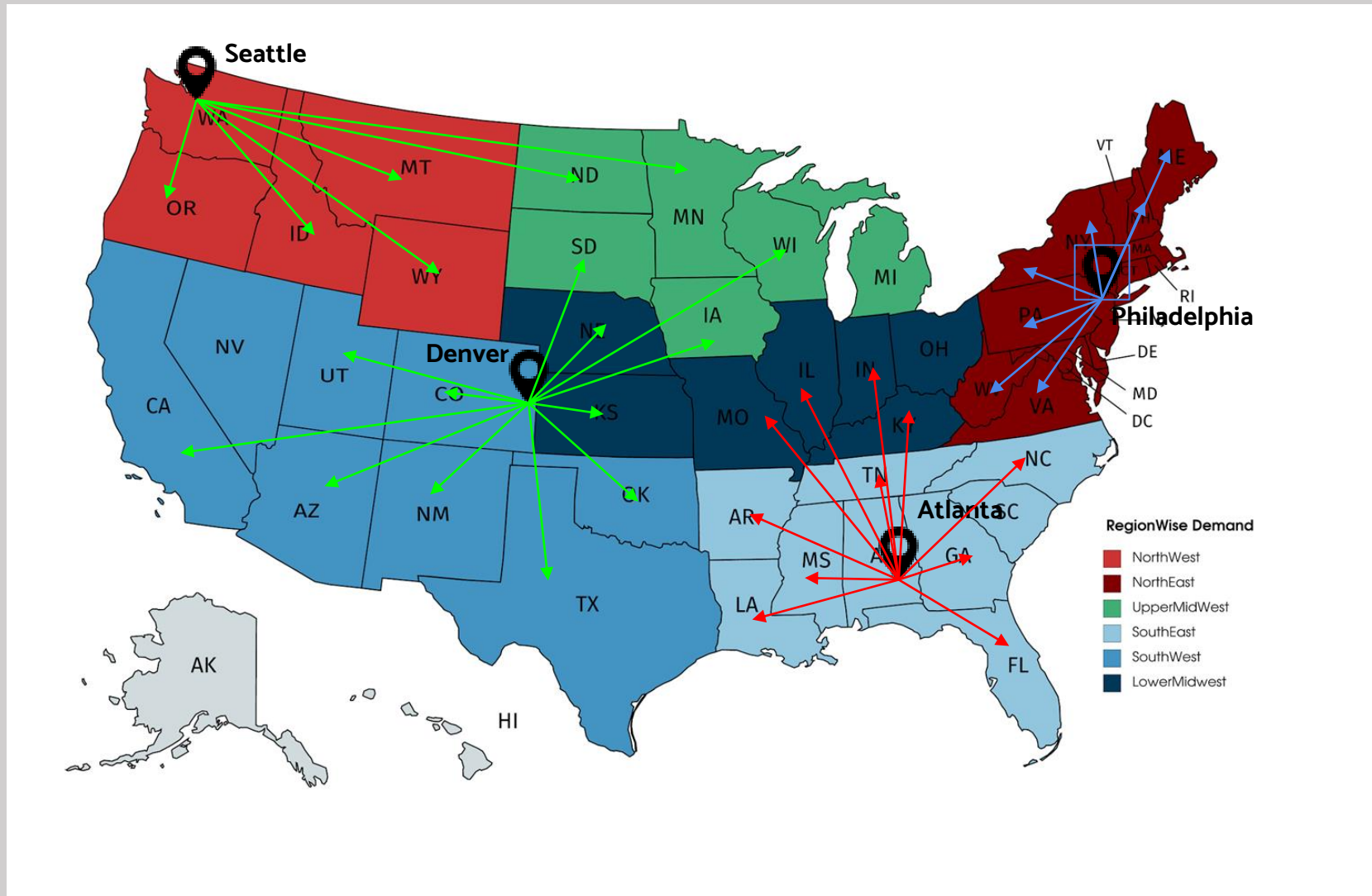We provide two unique approaches to solve this case, the first is a typical linear programming formulation that we have solved in excel and the other is an approach using Greedy Algorithm based formulation which we found to be fascinating.

# Redesigning the Supply Chain

# Redesigning the Supply Chain

# QUESTION 1
What is the cost SportStuff.com incurs if all warehouses leased are in St. Louis?

# THE PROBLEM STATEMENT AND THE GIVEN DATA

**Table 5-15** Regional Demand at SportStuff.com for 2007

| Zone | Demand in 2007 | Zone | Demand in 2007 |
|------|----------------|------|----------------|
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| Upper Midwest | 160,000 | Southeast | 175,000 |

**Table 5-16** Fixed and Variable Costs of Potential Warehouses

| Location | Small Warehouse | | Large Warehouse | |
|----------|-----------------|---------------------------|-----------------|---------------------------|
| | Fixed Cost ($/year) | Variable Cost ($/Unit Flow) | Fixed Cost ($/year) | Variable Cost ($/Unit Flow) |
| Seattle | 300,000 | 0.20 | 500,000 | 0.20 |
| Denver | 250,000 | 0.20 | 420,000 | 0.20 |
| St. Louis | 220,000 | 0.20 | 375,000 | 0.20 |
| Atlanta | 220,000 | 0.20 | 375,000 | 0.20 |
| Philadelphia | 240,000 | 0.20 | 400,000 | 0.20 |

**Table 5-17** UPS Charges per Shipment (Four Units)

| | Northwest | Southwest | Upper Midwest | Lower Midwest | Northeast | Southeast |
|-----|-----------|-----------|---------------|---------------|-----------|-----------|
| Seattle | $2.00 | $2.50 | $3.50 | $4.00 | $5.00 | $5.50 |
| Denver | $2.50 | $2.50 | $2.50 | $3.00 | $4.00 | $4.50 |
| St. Louis | $3.50 | $3.50 | $2.50 | $2.50 | $3.00 | $3.50 |
| Atlanta | $4.00 | $4.00 | $3.00 | $2.50 | $3.00 | $2.50 |
| Philadelphia | $4.50 | $5.00 | $3.00 | $3.50 | $2.50 | $4.00 |

## QUESTIONS TO ANSWER

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

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

- Any other recommendations?

# Total Costs Calculation

Shipping Cost = (Demand/4)*($3)
Shipment Charges = Demand*(Shipping Cost/4)

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | Zone | Demand in 2007 | Shipping cost | Shipping cost from St. L | Shipment charges |
| 2 | Northwest | 320,000 | 240,000 | 3.5 | 280,000 |
| 3 | Southwest | 200,000 | 150,000 | 3.5 | 175,000 |
| 4 | Upper Midwest | 160,000 | 120,000 | 2.5 | 100,000 |
| 5 | Lower Midwest | 220,000 | 165,000 | 2.5 | 137,500 |
| 6 | Northeast | 350,000 | 262,500 | 3.0 | 262,500 |
| 7 | Southeast | 175,000 | 131,250 | 3.5 | 153,125 |
| 8 | Total Demand | 1,425,000 | 1,068,750 | | 1,108,125 |

Calculating the total cost by summing up all the costs as shown below:

**Lease Cost = Fixed Cost + (Variable Cost x Total Demand)**

$$= 220,000 + (1,425,000 \times 0.20)$$
$$= \$505,000$$

**Shipping cost** = 1425000*3/4
**Shipping Charges = $1,108,125**

# Total Costs Calculation

Shipping Cost = (Demand/4)*($3)
Shipment Charges = Demand*(Shipping Cost/4)

Total Cost = Lease Cost + Inventory Holding Cost - Shipping Cost + Shipping Charges
      = $505000 + $710125 - $1068750 + $1108125
      = $1254500

Therefore, the company will incur the cost of $1,254,500 if all warehouses leased are in location St. Louis in 2007.

# Total Demand Calculation(2008)

| | A | B | C | D |
|---|---|---|---|---|
| 1 | Zone | Demand in 2007 | Increased Demand | New Demand |
| 2 | Northwest | 320,000 | 256,000 | 576,000 |
| 3 | Southwest | 200,000 | 160,000 | 360,000 |
| 4 | Upper Midwest | 160,000 | 128,000 | 288,000 |
| 5 | Lower Midwest | 220,000 | 176,000 | 396,000 |
| 6 | Northeast | 350,000 | 280,000 | 630,000 |
| 7 | Southeast | 175,000 | 140,000 | 315,000 |
| 8 | Total Demand | 1,425,000 | | 2,565,000 |

We consider a large Warehouse in St.Louis Considering a Demand of 2565000 unit

Lease Cost= Fixed Cost + ( Variable Cost x Total Demand)
$\qquad$ = 375,000 + (2,565,000 x 0.2)
$\qquad$ = $888,000

Holding Cost = $ 475,000 Y + 0.165F
`
$\qquad$ = $898,225

# Total Costs Calculation (2008)

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | Zone | Demand in 2007 | Increased Demand | New Demand | Shipping cost | Shipping cost from St. L | Shipment charges |
| 2 | Northwest | 320,000 | 256,000 | 576,000 | 432,000 | 3.5 | 504,000 |
| 3 | Southwest | 200,000 | 160,000 | 360,000 | 270,000 | 3.5 | 315,000 |
| 4 | Upper Midwest | 160,000 | 128,000 | 288,000 | 216,000 | 2.5 | 180,000 |
| 5 | Lower Midwest | 220,000 | 176,000 | 396,000 | 297,000 | 2.5 | 247,500 |
| 6 | Northeast | 350,000 | 280,000 | 630,000 | 472,500 | 3.0 | 472,500 |
| 7 | Southeast | 175,000 | 140,000 | 315,000 | 236,250 | 3.5 | 275,625 |
| 8 | Total Demand | 1,425,000 | | 2,565,000 | 1,923,750 | | 1,994,625 |

Total Cost = Lease Cost + Inventory Holding Cost - Shipping Cost + Shipping Charges

= 888,000 + 898,225 - 1923750 + 1994625

= \$1,857,100

Therefore,

Optimal Solution = \$ 1,857,100

`

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Calculating Total Cost for year 2009 by estimating an increase of 80% in the demand as shown below:

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| | A | B | C | D |
|---|---|---|---|---|
| 1 | Zone | Demand in 2008 | Increased Demand | New Demand |
| 2 | Northwest | 576,000 | 460,800 | 1,036,800 |
| 3 | Southwest | 360,000 | 288,000 | 648,000 |
| 4 | Upper Midwest | 288,000 | 230,400 | 518,400 |
| 5 | Lower Midwest | 396,000 | 316,800 | 712,800 |
| 6 | Northeast | 630,000 | 504,000 | 1,134,000 |
| 7 | Southeast | 315,000 | 252,000 | 567,000 |
| 8 | Total Demand | 1,425,000 | | 4,617,000 |

We consider a large and small Warehouse in St.Louis Considering a Demand

of 4,617,000
Lease Cost = Fixed Cost + (Variable Cost x Total Demand)
            =$1,5118,400

# Total Costs Calculation (2009)

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | Zone | Demand in 2008 | Increased Demand | New Demand | Shipping cost | Shipping cost from St. L | Shipment charges |
| 2 | Northwest | 576,000 | 460,800 | 1,036,800 | 777,600 | 3.5 | 907,200 |
| 3 | Southwest | 360,000 | 288,000 | 648,000 | 486,000 | 3.5 | 567,000 |
| 4 | Upper Midwest | 288,000 | 230,400 | 518,400 | 388,800 | 2.5 | 324,000 |
| 5 | Lower Midwest | 396,000 | 316,800 | 712,800 | 534,600 | 2.5 | 445,500 |
| 6 | Northeast | 630,000 | 504,000 | 1,134,000 | 850,500 | 3.0 | 850,500 |
| 7 | Southeast | 315,000 | 252,000 | 567,000 | 425,250 | 3.5 | 496,125 |
| 8 | Total Demand | 1,425,000 | | 4,617,000 | 3,462,750 | | 3,590,325 |

Calculating the holding cost for single linear inventory shown below:

Holding Cost = ($475,000Y + 0.165F) x 2

$\qquad$ = $ 2,473,610

Total Cost = Lease Cost + Inventory Holding Cost - Shipping Cost + Shipping Cost

$\qquad$ =$4,119,585

# Total Demand Calculation (2010)

| | A | B | C | D |
|---|---|---|---|---|
| 1 | Zone | Demand in 2009 | Increased Demand | New Demand |
| 2 | Northwest | 1,036,800 | 829,440 | 1,866,240 |
| 3 | Southwest | 648,000 | 518,400 | 1,166,400 |
| 4 | Upper Midwest | 518,400 | 414,720 | 933,120 |
| 5 | Lower Midwest | 712,800 | 570,240 | 1,283,040 |
| 6 | Northeast | 1,134,000 | 907,200 | 2,041,200 |
| 7 | Southeast | 567,000 | 453,600 | 1,020,600 |
| 8 | Total Demand | 4,617,000 | | 8,310,600 |

We consider a 2 large and small Warehouse in St.Louis Considering a Demand of 8,310,600

Lease Cost= Fixed Cost + ( Variable Cost x Total Demand)

= 2 x 375,000 + 220,000 + (8,310,600 x 0.2)

= $2,632,120

Holding Cost = $ 5,538,747

# Total Costs Calculation (2010)

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | Zone | Demand in 2009 | Increased Demand | New Demand | Shipping cost | Shipping cost from St. L | Shipment charges |
| 2 | Northwest | 1,036,800 | 829,440 | 1,866,240 | 1,399,680 | 3.5 | 1,632,960 |
| 3 | Southwest | 648,000 | 518,400 | 1,166,400 | 874,800 | 3.5 | 1,020,600 |
| 4 | Upper Midwest | 518,400 | 414,720 | 933,120 | 699,840 | 2.5 | 583,200 |
| 5 | Lower Midwest | 712,800 | 570,240 | 1,283,040 | 962,280 | 2.5 | 801,900 |
| 6 | Northeast | 1,134,000 | 907,200 | 2,041,200 | 1,530,900 | 3.0 | 1,530,900 |
| 7 | Southeast | 567,000 | 453,600 | 1,020,600 | 765,450 | 3.5 | 893,025 |
| 8 | Total Demand | 4,617,000 | | 8,310,600 | 6,232,950 | | 6,462,585 |

Total Cost = Lease Cost + Inventory Holding Cost - Shipping Cost + Shipping Charges
 = $ 8,400,502

Therefore ,
 the optimal solution for 2010 calls for one small and two  large warehouse will incur
 the cost of $ 8,400,502
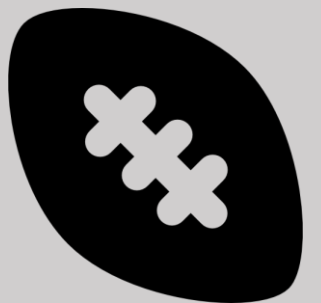
# PROBLEMS WITH CURRENT SUPPLY CHAIN MODEL

-565,000
(Storage capacity-Demand)

Total Cost =$1,857,100

-2,617,000
(Storage capacity-Demand)

Total Cost =$4,119,610

**2008**

**2007**

**2009**

575,000
(Storage capacity-Demand)

Total Cost =$1,254,500

**2010**

-6,310,600
(Storage capacity-Demand)

Total Cost =$8,400,502
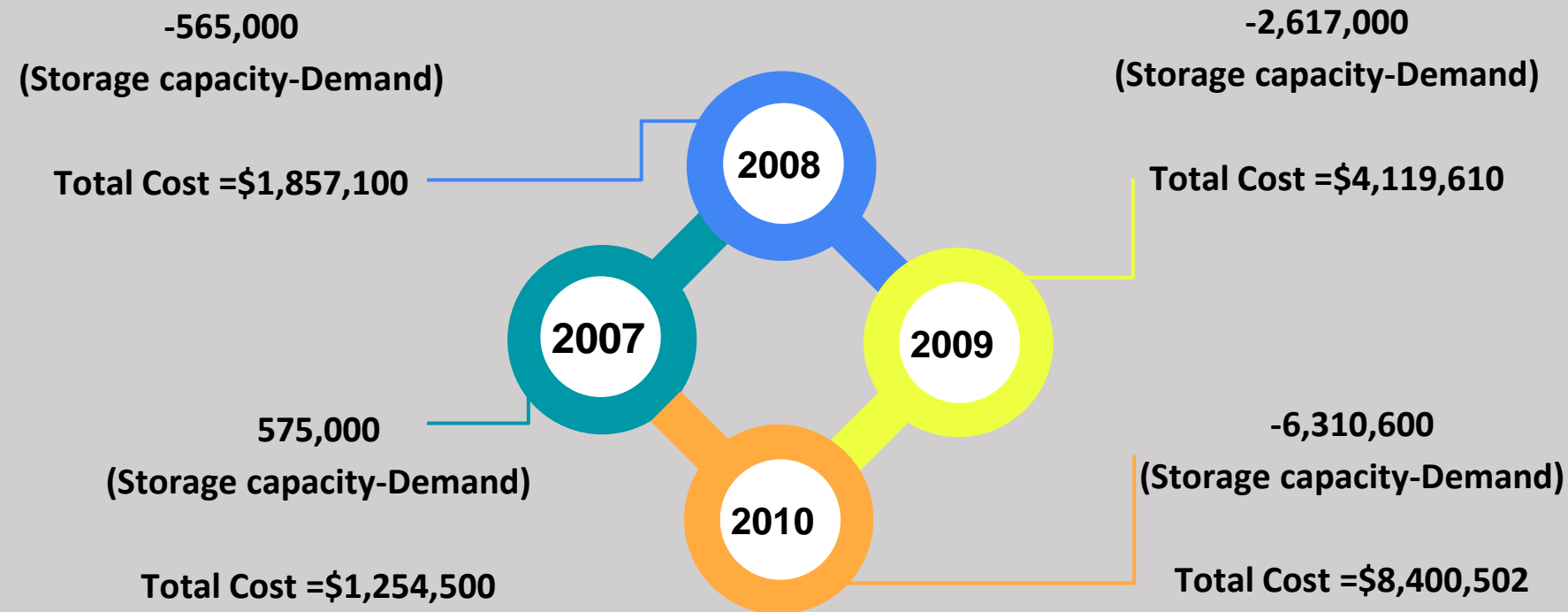
- The costs of the company would grow faster than the revenues if the demand continue to grow and the supply chain network is not redesigned.
- The company needs more warehouse space in order to cope with the anticipated demand growth.
- We proposed the solution of decentralisation of warehouse network of the company as this would help to lower the transportation cost to great extent.

# Recommended Plan of Action:

The above analysis explains the ideal condition for each year. Our recommended plan for Sanjay is to use the small warehouse in St. Louise in 2007 ( instead of a large warehouse)as a large warehouse is required to meet the 2008 demand.

Therefore:

- 2007 - Use the existing warehouse in St. Louis.
- 2008 - Close the St. Louis warehouse and open a large warehouse.
- 2009 - Open the small warehouse again and use the existing large warehouse.
- 2010 - Open another large warehouse, hence we operate 3 warehouses for 2010.

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QUESTION 2

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

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|----------|-----------------|-----------------|-----------------|-----------------|
| | Fixed Cost ($/year) | Variable Cost ($/Unit Flow) | Fixed Cost ($/year) | Variable Cost ($/Unit Flow) |
| Seattle | 300,000 | 0.20 | 500,000 | 0.20 |
| Denver | 250,000 | 0.20 | 420,000 | 0.20 |
| St. Louis | 220,000 | 0.20 | 375,000 | 0.20 |
| Atlanta | 220,000 | 0.20 | 375,000 | 0.20 |
| Philadelphia | 240,000 | 0.20 | 400,000 | 0.20 |

**Table 5-17** UPS Charges per Shipment (Four Units)

| | Northwest | Southwest | Upper Midwest | Lower Midwest | Northeast | Southeast |
|---|-----------|-----------|---------------|---------------|-----------|-----------|
| Seattle | $2.00 | $2.50 | $3.50 | $4.00 | $5.00 | $5.50 |
| Denver | $2.50 | $2.50 | $2.50 | $3.00 | $4.00 | $4.50 |
| St. Louis | $3.50 | $3.50 | $2.50 | $2.50 | $3.00 | $3.50 |
| Atlanta | $4.00 | $4.00 | $3.00 | $2.50 | $3.00 | $2.50 |
| Philadelphia | $4.50 | $5.00 | $3.00 | $3.50 | $2.50 | $4.00 |

## QUESTIONS TO ANSWER

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

- ❑ What supply chain network configuration do you recomment for SportStuff.com? Why?

- ❑ Any other recommendations?

If you can handle only a single linear inventory cost, you should use $475{,}000Y + 0.165F$. For each facility, $Y=1$ if the facility is used, 0 otherwise.

# LINEAR PROGRAMMING MODEL

**DECISION VARIABLES:**

$Xij$ : $Demand\ Satisfied\ by\ warehouse\ i\ to\ customer\ zone\ j$

$Yij$ : $i \rightarrow Warehouse, j = \{0\ if\ small\ warehouse, 1\ if\ large\ warehouse\}$

**OTHER VARIABLES:**

$Fij$ : $Fixed\ Cost\ of\ Warehouse\ \ i \rightarrow Warehouse\ , j = \{0\ if\ small\ warehouse, 1\ if\ large\ warehouse\}$

$Cij$: $Cost\ of\ UPS\ charge\ to\ shift\ 1\ unit\ from\ warehouse\ i\ to\ customer\ zone\ j.$

$Dij$: $\ \ Demand\ of\ each\ customer\ zone.$

$Lij$: $Capacity\ of\ i\ warehouse,$ j= $\{0\ if\ small\ warehouse, 1\ if\ large\ warehouse\}$

# MATHEMATICAL FORMULATION

*MINIMIZING:*

$$\sum C_{ij} X_{ij} \quad + \quad (\, 475000 \sum Y_{ij} \quad + \quad 0.165 \sum D_j \,) \quad + \quad (\, \sum F_{ij} Y_{ij} + 0.2 \sum D_j \,) \quad - \frac{3}{4} \sum D_j$$

CONSTRAINTS:

$X_{ij} \geq 0 \ \& \ X_{ij} \in I$ 　　　　(Demand fulfilled by each warehouse should be greater than or equal to zero)

$Y_{ij} \geq 0 \ \& \ Y_{ij} \in I$ 　　　(Number of small or large warehouse should be greater than or equal to zero)

$\sum_i Y_{ij} L_{ij} - \sum_i X_{ij} \geq 0$ 　　(Total left-over space in warehouses should be greater than or equal to zero)

$\sum_j X_{ij} - D_j = 0$ 　　(Total Demand fulfilled to a zone by all warehouses should be equal to its demand

# SOLVING THE MODEL USING EXCEL SOLVER

C30 | =(I22*J14)+(J22*L14)-SUM(C22:H22)

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | DEMAND(2008) | 576000 | 360000 | 288000 | 396000 | 630000 | 315000 | 2565000 | | | | | |
| 12 | | UPS Charges Per Unit(In dollars) | | | | | | | Fixed and Variable Costs of Potential Warehouse | | | | | |
| 13 | | | Nortwest | Southwes | Upper Midwest | Lower midwest | Norteast | Southeast | Small Warehouse | Capacity(sma | LargeWarehouse | Capacity(large) | | |
| 14 | | Seattle | 0.5 | 0.625 | 0.875 | 1 | 1.25 | 1.375 | 300,000 | 2000000 | 500000 | 4000000 | | |
| 15 | | Denver | 0.625 | 0.625 | 0.625 | 0.75 | 1 | 1.125 | 250,000 | 2000000 | 420000 | 4000000 | | |
| 16 | | St.Louis | 0.875 | 0.875 | 0.625 | 0.625 | 0.75 | 0.875 | 220000 | 2000000 | 375000 | 4000000 | | |
| 17 | | Atlanta | 1 | 1 | 0.75 | 0.625 | 0.75 | 0.625 | 220000 | 2000000 | 375000 | 4000000 | | |
| 18 | | Philadelphia | 1.125 | 1.25 | 0.75 | 0.875 | 0.625 | 1 | 240000 | 2000000 | 400000 | 4000000 | | |
| 19 | | | | | | | | | | | | | | |
| 20 | | Decision Variables | | | | | | | Fixed and Variable Costs of Potential Warehouse | | | | | |
| 21 | | | Nortwest | Southwes | Upper Midwest | Lower midwest | Norteast | Southeast | SmallWarehouse | LargeWareh | Total | | | |
| 22 | | Seattle | | | | | | | | | 0 | | | |
| 23 | | Denver | | | | | | | | | 0 | | | |
| 24 | | St.Louis | | | | | | | | | 0 | | | |
| 25 | | Atlanta | | | | | | | | | 0 | | | |
| 26 | | Philadelphia | | | | | | | | | 0 | | | |
| 27 | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | |
| 29 | | Capacity | | | | | | | | | | | | |
| 30 | | Seattle | 0 | | | | | | | | | | | |
| 31 | | Denver | 0 | | | | | | | | | | | |
| 32 | | St.Louis | 0 | | | | | | | | | | | |
| 33 | | Atlanta | 0 | | | | | | | | | | | |
| 34 | | Philadelphia | 0 | | | | | | | | | | | |

## Demand Constraint

| | Nortwest | Southwes | Upper Midwest | Lower midwest | Norteast | Southeast |
|---|---|---|---|---|---|---|
| | 0 | 0 | 0 | 0 | 0 | 0 |

`=C11-SUM(C22:C26)`

## OBJECTIVE FUNCTION

| | | |
|---|---|---|
| Shipping cost | 1994625 | `=SUMPRODUCT(C22:H26,C14:H18)` |
| Inventory Holding | 898225 | `=475000*SUM(K22:K26)+0.165*SUM(C11:H11)` |
| Ware House | 888000 | `=SUMPRODUCT(I22:I26,I14:I18)+SUMPRODUCT(J22:J26,K14:K18)+SUM(C11:H11)*0.2` |
| Shipping Charges | 1923750 | `=(SUM(C11:H11)/4)*3` |
| Total Cost($) | 1857100 | `=SUM(C41:C43)-C44` |

## Solver Parameters                                                    ✕

Se_t Objective:                    $C$45                              ⬆

To:        ◯ Max          ⦿ Min          ◯ Value Of:        [ 0 ]

_By Changing Variable Cells:

$C$22:$J$26                                                           ⬆

Subject to the Constraints:

```
$C$22:$H$26 = integer
$C$22:$H$26 >= 0
$C$30:$C$34 >= 0
$C$38:$H$38 = 0
$I$22:$J$26 = binary
$K$22:$K$26 <= 1
```

[ Add ]

[ Change ]

[ Delete ]

[ Reset All ]

[ Load/Save ]

☑ Make Unconstrained Variables Non-Negative

Select a Solving Method:     [ Simplex LP        ▾ ]        [ Options ]

### Solving Method

Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

[ Help ]                        [ Solve ]                  [ Close ]

# REPORT FOR YEAR 2008

## Decision Variables

| | Nortwest | Southwes | Upper Midwest | Lower midwest | Norteast | Southeast |
|---|---|---|---|---|---|---|
| Seattle | 0 | 0 | 0 | 0 | 0 | 0 |
| Denver | 0 | 0 | 0 | 0 | 0 | 0 |
| St.Louis | 576000 | 360000 | 288000 | 396000 | 630000 | 315000 |
| Atlanta | 0 | 0 | 0 | 0 | 0 | 0 |
| Philadelphia | 0 | 0 | 0 | 0 | 0 | 0 |

## Fixed and Variable Costs of Potential Warehouse

| | SmallWarehouse | LargeWarehouse | Total |
|---|---|---|---|
| Seattle | 0 | 0 | 0 |
| Denver | 0 | 0 | 0 |
| St.Louis | 0 | 1 | 1 |
| Atlanta | 0 | 0 | 0 |
| Philadelphia | 0 | 0 | 0 |

## OBJECTIVE FUNCTION

| | |
|---|---|
| Shipping cost | 1994625 |
| Inventory Holding | 898225 |
| Ware House | 888000 |
| Shipping Charges | 1923750 |
| Total Cost($) | 1857100 |

- So, we see that the total cost has reduced to $1,857,100.
- So, for year 2008, we lease a large warehouse in St. Louis.

# REPORT FOR 2009

| DEMAND(2009) | 1036800 | 648000 | 518400 | 712800 | 1134000 | 567000 | 4617000 | | |
|---|---|---|---|---|---|---|---|---|---|

## UPS Charges Per Unit(In dollars)

### Fixed and Variable Costs of Potential Warehouse

| | Nortwest | Southwest | Upper Midwest | Lower midwest | Norteast | Southeast | Small Warehouse | Capacity(small) | LargeWarehouse | Capacity(large) |
|---|---|---|---|---|---|---|---|---|---|---|
| Seattle | 0.5 | 0.625 | 0.875 | 1 | 1.25 | 1.375 | 300,000 | 2000000 | 500000 | 4000000 |
| Denver | 0.625 | 0.625 | 0.625 | 0.75 | 1 | 1.125 | 250,000 | 2000000 | 420000 | 4000000 |
| St.Louis | 0.875 | 0.875 | 0.625 | 0.625 | 0.75 | 0.875 | 220000 | 2000000 | 375000 | 4000000 |
| Atlanta | 1 | 1 | 0.75 | 0.625 | 0.75 | 0.625 | 220000 | 2000000 | 375000 | 4000000 |
| Philadelphia | 1.125 | 1.25 | 0.75 | 0.875 | 0.625 | 1 | 240000 | 2000000 | 400000 | 4000000 |

## Decision Variables

### Fixed and Variable Costs of Potential Warehouse

| | Nortwest | Southwest | Upper Midwest | Lower midwest | Norteast | Southeast | SmallWarehouse | LargeWarehouse | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Seattle | 1036800 | 648000 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | |
| Denver | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| St.Louis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Atlanta | 0 | 0 | 518400 | 712800 | 1134000 | 567000 | 0 | 1 | 1 | |
| Philadelphia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

## OBJECTIVE FUNCTION

| | |
|---|---|
| Shipping cost | 2962575 |
| Inventory Holding | 1711805 |
| Ware House | 1598400 |
| Shipping cost | 3462750 |
| **Total Cost($)** | **2810030** |

So, in year 2009, we are getting better total cost as $2,810,030.

So, we choose to have 1 small warehouse is Seattle and 1 large warehouse in Atlanta.

# REPORT FOR YEAR 2010

| DEMAND(2010) | 1866240 | 1166400 | 933120 | 1283040 | 2041200 | 1020600 |
|---|---|---|---|---|---|---|

## UPS Charges Per Unit(In dollars)

| | Nortwest | Southwest | Upper Midwest | Lower midwest | Norteast | Southeast |
|---|---|---|---|---|---|---|
| Seattle | 0.5 | 0.625 | 0.875 | 1 | 1.25 | 1.375 |
| Denver | 0.625 | 0.625 | 0.625 | 0.75 | 1 | 1.125 |
| St.Louis | 0.875 | 0.875 | 0.625 | 0.625 | 0.75 | 0.875 |
| Atlanta | 1 | 1 | 0.75 | 0.625 | 0.75 | 0.625 |
| Philadelphia | 1.125 | 1.25 | 0.75 | 0.875 | 0.625 | 1 |

## Fixed and Variable Costs of Potential Warehouse

| | Small Warehouse | Capacity(sma | LargeWarehouse | Capacity(large) |
|---|---|---|---|---|
| | 300,000 | 2000000 | 500000 | 4000000 |
| | 250,000 | 2000000 | 420000 | 4000000 |
| | 220000 | 2000000 | 375000 | 4000000 |
| | 220000 | 2000000 | 375000 | 4000000 |
| | 240000 | 2000000 | 400000 | 4000000 |

## Decision Variables

| | Nortwest | Southwest | Upper Midwest | Lower midwest | Norteast | Southeast |
|---|---|---|---|---|---|---|
| Seattle | 1866240 | 1166400 | 0 | 0 | 0 | 0 |
| Denver | 0 | 0 | 0 | 0 | 0 | 0 |
| St.Louis | 0 | 0 | 0 | 0 | 0 | 0 |
| Atlanta | 0 | 0 | 933120 | 1283040 | 41200 | 1020600 |
| Philadelphia | 0 | 0 | 0 | 0 | 2000000 | 0 |

## Fixed and Variable Costs of Potential Warehouse

| | SmallWarehouse | LargeWareho | Total |
|---|---|---|---|
| | 0 | 1 | 1 |
| | 0 | 0 | 0 |
| | 0 | 0 | 0 |
| | 0 | 1 | 1 |
| | 1 | 0 | 1 |

## OBJECTIVE FUNCTION

| | |
|---|---|
| Shipping cost | 5082635 |
| Inventory Holding | 2796249 |
| Ware House | 2777120 |
| Shipping Charges | 6232950 |
| Total Cost($) | 4423054 |

So, in year 2010, we are getting total costs as $4,423,054.

So, we choose 1 large warehouse in Seattle, 1 large warehouse in Atlanta and 1 small warehouse in Philadelphia.

# CostChart
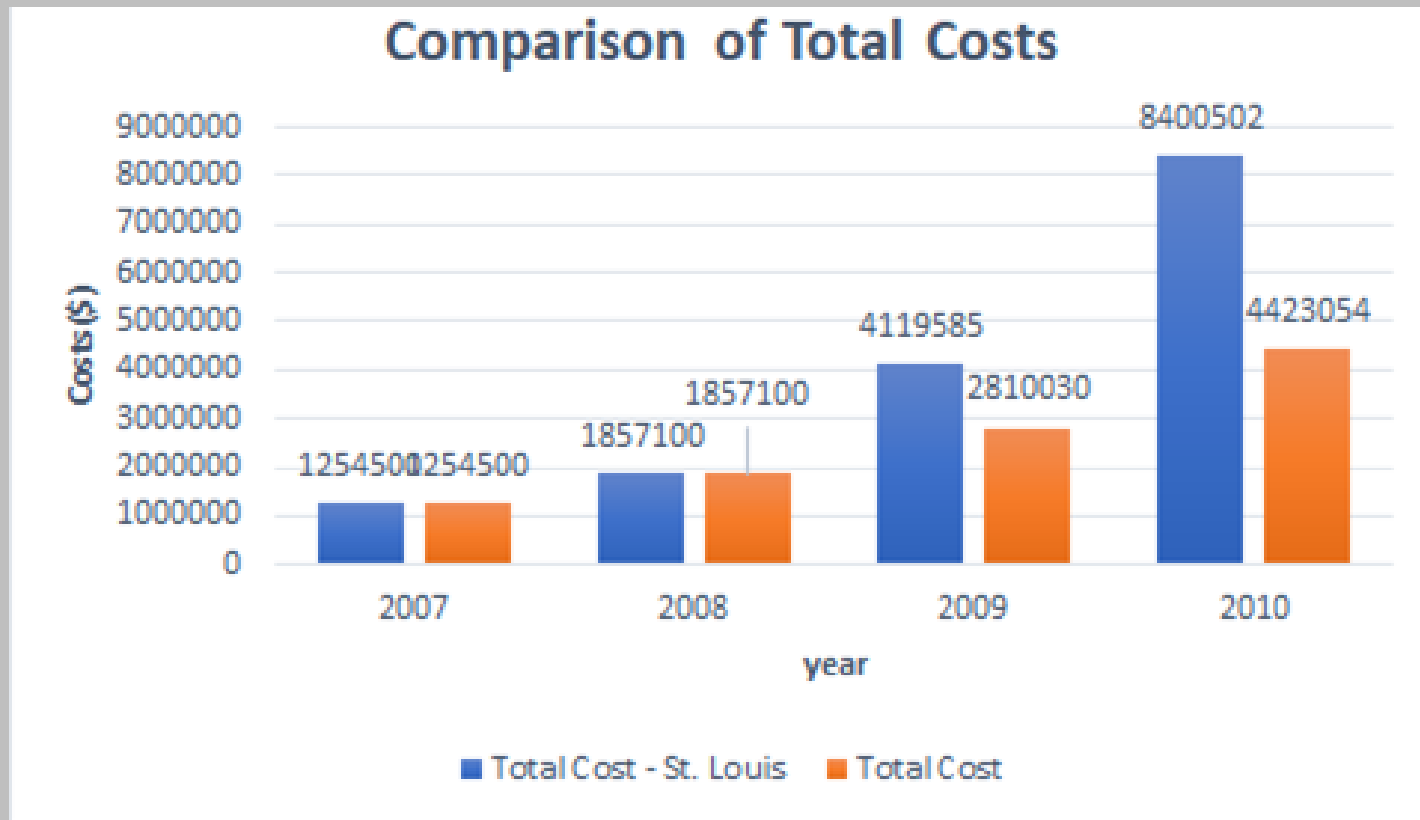


| Year | Total Cost - St. Louis | Total Cost |
|------|------------------------|------------|
| 2007 | 1254500 | 1254500 |
| 2008 | 1857100 | 1857100 |
| 2009 | 4119585 | 2810030 |
| 2010 | 8400502 | 4423054 |

# Summary

Single large warehouse in Atlanta — 2008

Small warehouses in seattle , St.Louis and Atlanta — 2009

Small warehouses in Seattle and Atlanta and large    warehouses in Denver and Philadelphia — 2008

SPORT STUFF

How would your recommendation change if transportation costs were twice those shown in Table 5-17?

# Total Cost Calculation For Year 2008

- Below table shows the resulting UPS charges and the formulation

| | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | UPS Charges Per Unit(In dollars) | | | | | | | Fixed and Variable Costs of Potential Warehouse | | | |
| 13 | | Nortwest | | Southwest | Upper Midwest | Lower midwest | Norteast | Southeast | Small Warehouse | Capacity(sma | LargeWarehouse | Capacity(large) |
| 14 | Seattle | | 1 | 1.25 | 1.75 | 2 | 2.5 | 2.75 | 300,000 | 2000000 | 500000 | 4000000 |
| 15 | Denver | | 1.25 | 1.25 | 1.25 | 1.5 | 2 | 2.25 | 250,000 | 2000000 | 420000 | 4000000 |
| 16 | St.Louis | | 1.75 | 1.75 | 1.25 | 1.25 | 1.5 | 1.75 | 220000 | 2000000 | 375000 | 4000000 |
| 17 | Atlanta | | 2 | 2 | 1.5 | 1.25 | 1.5 | 1.25 | 220000 | 2000000 | 375000 | 4000000 |
| 18 | Philadelphia | | 2.25 | 2.5 | 1.5 | 1.75 | 1.25 | 2 | 240000 | 2000000 | 400000 | 4000000 |

| OBJECTIVE FUNCTION | |
|---|---|
| Shipping cost | =SUMPRODUCT(C22:H26,C14:H18) |
| Inventory Holding | =475000*SUM(K22:K26)+0.165*SUM(C11:H11) |
| Ware House | =SUMPRODUCT(I22:I26,I14:I18)+SUMPRODUCT(J22:J26,K14:K18)+SUM(C11:H11)*0.2 |
| Shipping cost | =(SUM(C11:H11)/4)*3 |
| Total Cost($) | =SUM(C41:C43)-C44 |

SPORT STUFF

# Total cost calculation 2008

| | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | Decision Variables | | | | | | | Fixed and Variable Costs of Potential Warehouse | | | |
| 21 | | Nortwest | Southwest | Upper Midwest | Lower midwest | Norteast | Southeast | SmallWarehouse | LargeWarehc | Total | |
| 22 | Seattle | 576000 | 360000 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | |
| 23 | Denver | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 24 | St.Louis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 25 | Atlanta | 0 | 0 | 288000 | 396000 | 630000 | 315000 | 1 | 0 | 1 | |
| 26 | Philadelphia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 27 | | | | | | | | | | | |
| 28 | | | | | | | | | | | |
| 29 | **Capacity** | | | | | | | | | | |
| 30 | Seattle | 1064000 | | | | | | | | | |
| 31 | Denver | 0 | | | | | | | | | |
| 32 | St.Louis | 0 | | | | | | | | | |
| 33 | Atlanta | 371000 | | | | | | | | | |
| 34 | Philadelphia | 0 | | | | | | | | | |
| 35 | | | | | | | | | | | |
| 36 | Demand Constraint | | | | | | | | | | |
| 37 | | Nortwest | Southwest | Upper Midwest | Lower midwest | Norteast | Southeast | | | | |
| 38 | | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| 39 | | | | | | | | | | | |
| 40 | OBJECTIVE FUNCTION | | | | | | | | | | |
| 41 | Shipping cost | 3291750 | | | | | | | | | |
| 42 | Inventory Holding | 1373225 | | | | | | | | | |
| 43 | Ware House | 1033000 | | | | | | | | | |
| 44 | Shipping charge | 1923750 | | | | | | | | | |
| 45 | Total Cost($) | 3774225 | | | | | | | | | |

**Cost Chart(2008)**

- Q1: 1857100
- Q2: 1857100
- Q3: 3774225

cost(2008)
□ Q1  □ Q2  □ Q3
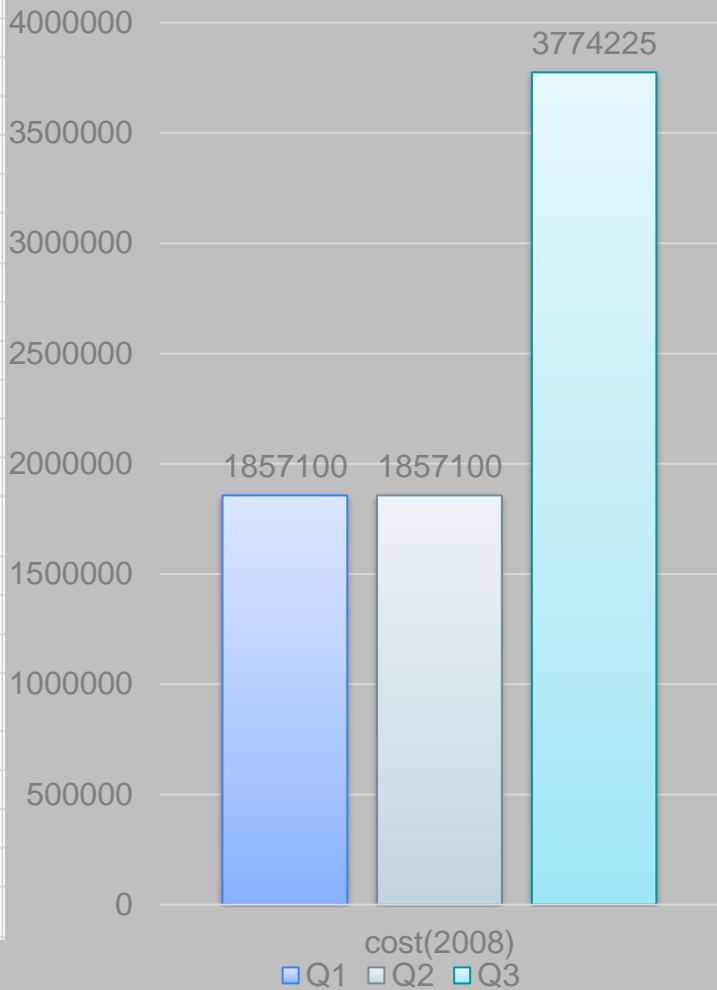
- Total cost incurred in 2008 after doubling transportation costs is $3774225

# Total Cost Calculation For Year 2009

- Below excel sheet is the formulation for the Total cost calculation in 2009



| | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|
| 17 | Atlanta | =C8/4 | =D8/4 | =E8/4 | | | | |
| 18 | Philadelphia | =C9/4 | =D9/4 | =E9/4 | | | | |
| 19 | | | | | | | | |
| 20 | Decision Variables | | | | | | | |
| 21 | | Nortwest | | Southwest | Upper Midwest | | | |
| 22 | Seattle | 1036800 | | 648000 | 0 | | | |
| 23 | Denver | 0 | | 0 | 0 | | | |
| 24 | St.Louis | 0 | | 0 | 0 | | | |
| 25 | Atlanta | 0 | | 0 | 518400 | | | |
| 26 | Philadelphia | 0 | | 0 | 0 | | | |
| 27 | | | | | | | | |
| 28 | | | | | | | | |
| 29 | Capacity | | | | | | | |
| 30 | Seattle | =(I22*J14)+(J22*L14)-SUM(C22:H22) | | | | | | |
| 31 | Denver | =(I23*J15)+(J23*L15)-SUM(C23:H23) | | | | | | |
| 32 | St.Louis | =(I24*J16)+(J24*L16)-SUM(C24:H24) | | | | | | |
| 33 | Atlanta | =(I25*J17)+(J25*L17)-SUM(C25:H25) | | | | | | |
| 34 | Philadelphia | =(I26*J18)+(J26*L18)-SUM(C26:H26) | | | | | | |
| 35 | | | | | | | | |
| 36 | Demand Constraint | | | | | | | |
| 37 | | Nortwest | | Southwest | Upper Midwest | | | |
| 38 | | =C11-SUM(C22:C26) | | =D11-SUM(D22:D26) | =E11-SUM(E22:E26) | | | |
| 39 | | | | | | | | |
| 40 | OBJECTIVE FUNCTION | | | | | | | |
| 41 | Shipping cost | =SUMPRODUCT(C22:H26,C14:H18) | | | | | | |
| 42 | Inventory Holding | =475000*SUM(K22:K26)+0.165*SUM(C11:H11) | | | | | | |
| 43 | Ware House | =SUMPRODUCT(I22:I26,I14:I18)+SUMPRODUCT(J22:J26,K14:K18)+ | | | | | | |
| 44 | Shipping Charge | =(SUM(C11:H11)/4)*3 | | | | | | |
| 45 | Total Cost($) | =SUM(C41:C43)-C44 | | | | | | |
| 46 | | | | | | | | |
| 47 | | | | | | | | |
| 48 | | | | | | | | |
| 49 | | | | | | | | |

**Solver Parameters**

Set Objective:  $C$45

To:  ○ Max   ● Min   ○ Value Of:  0

By Changing Variable Cells:
$C$22:$J$26

Subject to the Constraints:
```
$C$22:$H$26 = integer
$C$22:$H$26 >= 0
$C$30:$C$34 >= 0
$C$38:$H$38 = 0
$I$22:$J$26 = binary
$K$22:$K$26 <= 1
```

Add
Change
Delete
Reset All
Load/Save

☑ Make Unconstrained Variables Non-Negative

Select a Solving Method:  Simplex LP     Options

**Solving Method**

Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Help     Solve     Close

# Total cost calculation For 2009

|    | B | C | D | E | F | G | H | I | J | K | L |
|----|---|---|---|---|---|---|---|---|---|---|---|
| 20 | Decision Variables | | | | | | | Fixed and Variable Costs of Potential Warehouse | | | |
| 21 | | Nortwest | Southwest | Upper Midwest | Lower midwest | Norteast | Southeast | SmallWarehouse | LargeWareho | Total | |
| 22 | Seattle | 1036800 | 648000 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | |
| 23 | Denver | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 24 | St.Louis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 25 | Atlanta | 0 | 0 | 518400 | 712800 | 1134000 | 567000 | 0 | 1 | 1 | |
| 26 | Philadelphia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 27 | | | | | | | | | | | |
| 28 | | | | | | | | | | | |
| 29 | **Capacity** | | | | | | | | | | |
| 30 | Seattle | 315200 | | | | | | | | | |
| 31 | Denver | 0 | | | | | | | | | |
| 32 | St.Louis | 0 | | | | | | | | | |
| 33 | Atlanta | 1067800 | | | | | | | | | |
| 34 | Philadelphia | 0 | | | | | | | | | |
| 35 | | | | | | | | | | | |
| 36 | Demand Constraint | | | | | | | | | | |
| 37 | | Nortwest | Southwest | Upper Midwest | Lower midwest | Norteast | Southeast | | | | |
| 38 | | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| 39 | | | | | | | | | | | |
| 40 | OBJECTIVE FUNCTION | | | | | | | | | | |
| 41 | Shipping cost | 5925150 | | | | | | | | | |
| 42 | Inventory Holding | 1711805 | | | | | | | | | |
| 43 | Ware House | 1598400 | | | | | | | | | |
| 44 | Shipping Charge | 3462750 | | | | | | | | | |
| 45 | Total Cost($) | 5772605 | | | | | | | | | |

## COST CHART

- Q1  ■ Q2  ■ Q3

Q1: 4119585
Q2: 2810030
Q3: 5772605
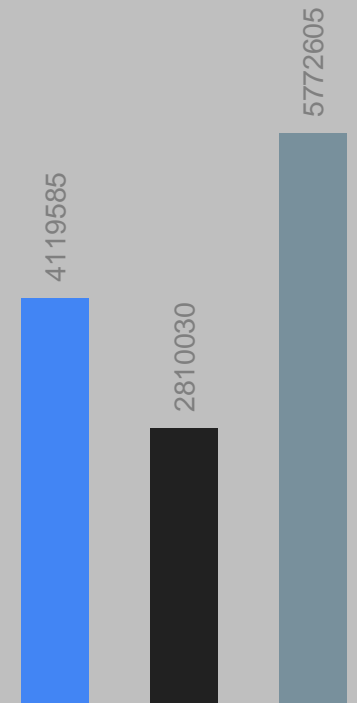
COST (2009)$

- Total cost incurred in 2009 after doubling transportation costs is $5772605

# Total Cost Calculation For Year 2010

- Below excel sheet is the formulation for the Total cost calculation in 2010



| | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|
| 19 | | | | | | | | | | |
| 20 | Decision Variables | | | | | | | Fixed and Variable Costs of Po | | |
| 21 | | | Nortwest | Southwest | Upper Midwest | Lower midwest | Norteast | Southeast | SmallWarehouse | LargeWarehouse | Total |
| 22 | Seattle | 1866240 | 1166400 | 0 | 0 | 0 | 0 | 0 | 1 | =I22+J22 |
| 23 | Denver | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | =I23+J23 |
| 24 | St.Louis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | =I24+J24 |
| 25 | Atlanta | 0 | 0 | 933120 | 1283040 | 41200 | 1020600 | 0 | 1 | =I25+J25 |
| 26 | Philadelphia | 0 | 0 | 0 | 0 | 2000000 | 0 | 1 | 0 | =I26+J26 |
| 27 | | | | | | | | | | |
| 28 | | | | | | | | | | |
| 29 | Capacity | | | | | | | | | |
| 30 | Seattle | =(I22*J14)+(J22*L14)-SUM(C22:H22) | | | | | | | | |
| 31 | Denver | =(I23*J15)+(J23*L15)-SUM(C23:H23) | | | | | | | | |
| 32 | St.Louis | =(I24*J16)+(J24*L16)-SUM(C24:H24) | | | | | | | | |
| 33 | Atlanta | =(I25*J17)+(J25*L17)-SUM(C25:H25) | | | | | | | | |
| 34 | Philadelphia | =(I26*J18)+(J26*L18)-SUM(C26:H26) | | | | | | | | |
| 35 | | | | | | | | | | |
| 36 | Demand Constraint | | | | | | | | | |
| 37 | | | Nortwest | Southwest | Upper Midwest | Lower midwest | No | | | |
| 38 | | =C11-SUM(C22:C26) | =D11-SUM(D22:D26 | =E11-SUM(E22:E26) | =F11-SUM(F22:F26) | =G | | | | |
| 39 | | | | | | | | | | |
| 40 | OBJECTIVE FUNCTION | | | | | | | | | |
| 41 | Shipping cost | =SUMPRODUCT(C22:H26,C14:H18) | | | | | | | | |
| 42 | Inventory Holding | =475000*SUM(K22:K26)+0.165*SUM( | | | | | | | | |
| 43 | Ware House | =SUMPRODUCT(I22:I26,I14:I18)+SUMF | | | | | | | | |
| 44 | Shipping cost | =(SUM(C11:H11)/4)*3 | | | | | | | | |
| 45 | Total Cost($) | =SUM(C41:C43)-C44 | | | | | | | | |

**Solver Parameters** ✕

Set Objective: $C$45 ⬆

To: ◯ Max  ◉ Min  ◯ Value Of: 0

By Changing Variable Cells:
$C$22:$J$26 ⬆

Subject to the Constraints:

$C$22:$H$26 = integer
$C$22:$H$26 >= 0
$C$30:$C$34 >= 0
$C$38:$H$38 = 0
$I$22:$J$26 = binary
$K$22:$K$26 <= 1

[Add] [Change] [Delete] [Reset All] [Load/Save]

☑ Make Unconstrained Variables Non-Negative

Select a Solving: Simplex LP

[Options]

# Total cost calculation For 2010

| | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | DEMAND(2007) | 320000 | 200000 | 160000 | 220000 | 350000 | 175000 | | | | |
| 11 | DEMAND(2010) | 1866240 | 1166400 | 933120 | 1283040 | 2041200 | 1020600 | | | | |

| | UPS Charges Per Unit(In dollars) | | | | | | Fixed and Variable Costs of Potential Warehouse | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | | Nortwest | Southwest | Upper Midwest | Lower midwest | Norteast | Southeast | Small Warehouse | Capacity(sma | LargeWarehouse | Capacity(large) |
| 14 | Seattle | 1 | 1.25 | 1.75 | 2 | 2.5 | 2.75 | 300,000 | 2000000 | 500000 | 4000000 |
| 15 | Denver | 1.25 | 1.25 | 1.25 | 1.5 | 2 | 2.25 | 250,000 | 2000000 | 420000 | 4000000 |
| 16 | St.Louis | 1.75 | 1.75 | 1.25 | 1.25 | 1.5 | 1.75 | 220000 | 2000000 | 375000 | 4000000 |
| 17 | Atlanta | 2 | 2 | 1.5 | 1.25 | 1.5 | 1.25 | 220000 | 2000000 | 375000 | 4000000 |
| 18 | Philadelphia | 2.25 | 2.5 | 1.5 | 1.75 | 1.25 | 2 | 240000 | 2000000 | 400000 | 4000000 |

| | Decision Variables | | | | | | | Fixed and Variable Costs of Potential Warehouse | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 21 | | Nortwest | Southwest | Upper Midwest | Lower midwest | Norteast | Southeast | SmallWarehouse | LargeWarehc | Total |
| 22 | Seattle | 1866240 | 1166400 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 23 | Denver | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | St.Louis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | Atlanta | 0 | 0 | 933120 | 1283040 | 41200 | 1020600 | 0 | 1 | 1 |
| 26 | Philadelphia | 0 | 0 | 0 | 0 | 2000000 | 0 | 1 | 0 | 1 |

| | Capacity | |
|---|---|---|
| 30 | Seattle | 967360 |
| 31 | Denver | 0 |
| 32 | St.Louis | 0 |
| 33 | Atlanta | 722040 |
| 34 | Philadelphia | 0 |

| | Demand Constraint | | | | | | |
|---|---|---|---|---|---|---|---|
| 37 | | Nortwest | Southwest | Upper Midwest | Lower midwest | Norteast | Southeast |
| 38 | | 0 | 0 | 0 | 0 | 0 | 0 |

| | OBJECTIVE FUNCTION | |
|---|---|---|
| 41 | Shipping cost | 10165270 |
| 42 | Inventory Holding | 2796249 |
| 43 | Ware House | 2777120 |
| 44 | Shipping Charges | 6232950 |
| 45 | Total Cost($) | 9505689 |

**COST CHART**

■ Q1  ■ Q2  ■ Q3

8400502   4423054   9505689

COST(2010)$
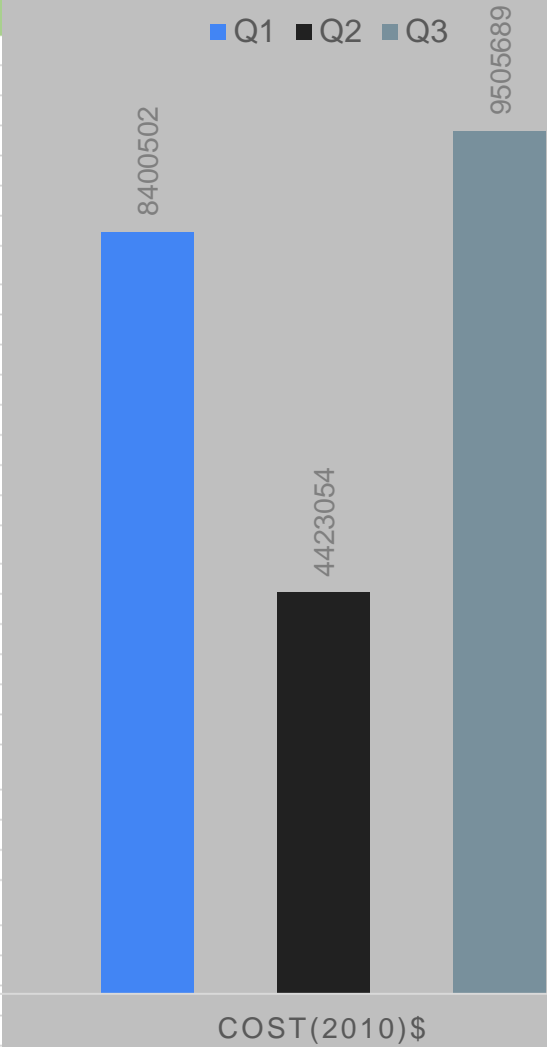
- Total cost incurred in 2009 after doubling transportation costs is $9505689

# Greedy Algorithm Based Solution Approach

- The Linear Programming solution mentioned above is not feasible in a constantly changing market in real life.
- That is to say, when solving each subproblems of the original problem, we always make a local optimal solution, until the end of the final problem. Because greedy algorithm does not consider a problem as a whole, the final solution often tends to be a local optimal solution to some extent.

**Greedy algorithm for most problems can be summarized as the following main steps:**

- Express the original problem in the form of mathematical models, and make its goal and initial state clear.
- Starting from the initial state, look for the the local optimal solution in this state.
- Repeat until the end of the algorithm, finally get the solution.



SPORT STUFF

# Insights and Approximations

To make the greedy algorithm continue to work, the concentration is focused on how to convert the fixed costs to transport costs in a reasonable way. Suppose each warehouse holds average storage inventory (generally half of the maximum inventory), we can calculate the average fixed cost which per unit of inventory holds, then add it to the the original transport costs, thus forming a new transportation cost table.

The fixed cost is evened out throughout the expected demand from the warehouse for the particular year i.e. converting the fixed cost to variable cost and updating the transportation table

# First of all, we will share the fixed costs equally into the transportation costs

| | | | |
|---|---|---|---|
| **Small Warehouse Capacity** | 2000000 | **Large Warehouse Capacity** | 4000000 |

| | Small Warehouse | | Large Warehouse | |
|---|---|---|---|---|
| | **Fixed Cost** | **Average Fixed Cost** | **Fixed Cost** | **Average Fixed Cost** |
| Seattle | 300000 | 1.2 | 500000 | 1 |
| Denver | 250000 | 0.5 | 420000 | 0.84 |
| St. Louis | 220000 | 0.88 | 375000 | 0.75 |
| Atlanta | 220000 | 0.88 | 375000 | 0.75 |
| Philadelphia | 240000 | 0.96 | 400000 | 0.8 |
| **Average** | 246000 | | 2070000 | |

The Average fixed cost is calculated by the formula,

*Avg FC = Fixed Cost * Price per unit Shipment / Capacity*

- **By comparing the costs, we can presuppose the kind of warehouse we will rent or build, and according to the final usage we can change big warehouse to small warehouse**

| Seattle | Denver | St. Louis | Atlanta | Philadelphia |
|---|---|---|---|---|
| LARGE | SMALL | LARGE | LARGE | LARGE |

- **Add the average fixed costs to transportation costs, we can get the new transportation cost table.**

| NEW TRANSPORTATION COST TABLE | | | | | | |
|---|---|---|---|---|---|---|
| | NorthWest | SouthWest | Upper MidWest | Lower MidWest | NorthEast | SouthEast |
| Seattle | 3 | 3.5 | 4.5 | 5 | 6 | 6.5 |
| Denver | 3 | 3 | 3 | 3.5 | 4.5 | 5 |
| St. Louis | 4.2 | 4.25 | 3.25 | 3.25 | 3.75 | 4.25 |
| Atlanta | 4.75 | 4.75 | 3.75 | 3.25 | 3.75 | 3.25 |
| Philadelphia | 5.3 | 5.8 | 3.8 | 4.3 | 3.3 | 4.8 |
| MINIMUM | 3 | 3 | 3 | 3.25 | 3.3 | 3.25 |

- # Year 2008

*The solution is to rent __small__ warehouse in*
*__Denver, Atlanta and Philadelphia__*

*Total cost = **$2528535***

| | Zone | New Demand |
|---|---|---|
| 1 | **Zone** | **New Demand** |
| 2 | Northwest | 576,000 |
| 3 | Southwest | 360,000 |
| 4 | Upper Midwest | 288,000 |
| 5 | Lower Midwest | 396,000 |
| 6 | Northeast | 630,000 |
| 7 | Southeast | 315,000 |
| 8 | **Total Demand** | **2,565,000** |

| | NorthWest | SouthWest | Upper MidWest | Lower MidWest | NorthEast | SouthEast |
|---|---|---|---|---|---|---|
| Seattle | | | | | | |
| Denver | 576000 | 360000 | 288000 | 396000 | | |
| St. Louis | | | | | | |
| Atlanta | | | | | | 315000 |
| Philadelphia | | | | | 630000 | |

- **Year 2009**

*The solution is to rent **small** warehouse in*
**Denver, St.Louis, Atlanta and Philadelphia**

*Total cost =* **$3967984**

| | A | B | C | D |
|---|---|---|---|---|
| 1 | **Zone** | **Demand in 2008** | **Increased Demand** | **New Demand** |
| 2 | Northwest | 576,000 | 460,800 | 1,036,800 |
| 3 | Southwest | 360,000 | 288,000 | 648,000 |
| 4 | Upper Midwest | 288,000 | 230,400 | 518,400 |
| 5 | Lower Midwest | 396,000 | 316,800 | 712,800 |
| 6 | Northeast | 630,000 | 504,000 | 1,134,000 |
| 7 | Southeast | 315,000 | 252,000 | 567,000 |
| 8 | **Total Demand** | **1,425,000** | | **4,617,000** |

| | NorthWest | SouthWest | Upper MidWest | Lower MidWest | NorthEast | SouthEast |
|---|---|---|---|---|---|---|
| Seattle | | | | | | |
| Denver | 1036800 | 648000 | 315200 | | | |
| St. Louis | | | 203200 | 712800 | | |
| Atlanta | | | | | | 567000 |
| Philadelphia | | | | | 1134000 | |
| | | | | | | |

*Solution -*
- *rent **small** warehouse in Seattle, Denver, St.Louis,*
- *rent **large** warehouse in Atlanta*

*Total cost =* **$5360012**

| | A | B | C | D |
|---|---|---|---|---|
| 1 | Zone | Demand in 2009 | Increased Demand | New Demand |
| 2 | Northwest | 1,036,800 | 829,440 | 1,866,240 |
| 3 | Southwest | 648,000 | 518,400 | 1,166,400 |
| 4 | Upper Midwest | 518,400 | 414,720 | 933,120 |
| 5 | Lower Midwest | 712,800 | 570,240 | 1,283,040 |
| 6 | Northeast | 1,134,000 | 907,200 | 2,041,200 |
| 7 | Southeast | 567,000 | 453,600 | 1,020,600 |
| 8 | Total Demand | 4,617,000 | | 8,310,600 |

| | NorthWest | SouthWest | Upper MidWest | Lower MidWest | NorthEast | SouthEast |
|---|---|---|---|---|---|---|
| Seattle | | 1032760 | | | | |
| Denver | 1866240 | 133760 | | | | |
| St. Louis | | | 933120 | | 344840 | |
| Atlanta | | | | 1283040 | 1696360 | 1020600 |
| Philadelphia | | | | | | |

# Conclusion

Firstly, this is because greedy algorithm usually chooses the local optimal choice, instead considering it as a whole.

Secondly, in the operation process of the greedy algorithm, due to the limitation of algorithm itself and ignorance of holding costs and variable costs, it will have some impact on the results to some extent.

But, it does not mean that those algorithms which didn't give out a fine solution is useless, after some adjustments and improvements, they could also be efficient and effective.

# CONCLUSIONS
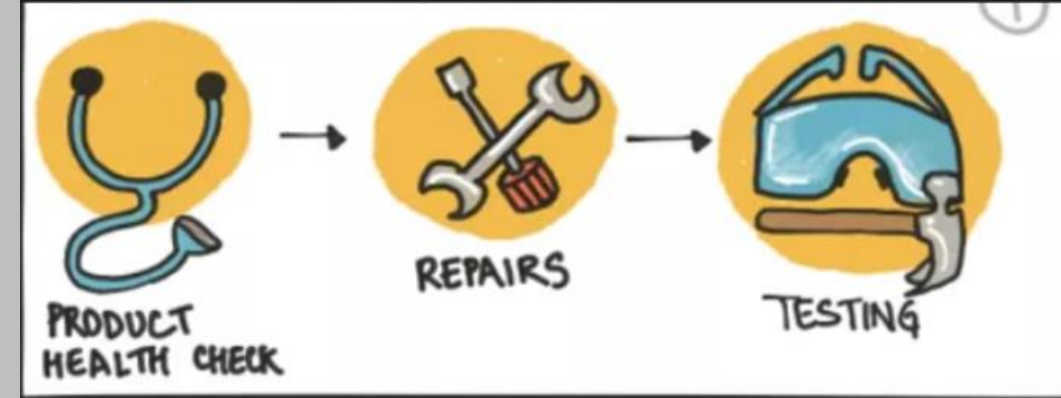


Sportstuff.com one advantage was it has divided the customer demands from different cities into customer zones (or clustering) which has saved the time and information for calculating the best network for the supply chain.

The specified both algorithms (linear programming and greedy algorithm) do not guarantee the optimal solution but these give us the nearest optimal solution.

Further, more algorithms can be developed considering heuristics, when the demands and number of warehouse locations become huge in number.

**THANK YOU**

It was a great learning experience