MIE 578
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Consolidation Project Report

**Model**
We felt a (Q,r) Model, specifically a backorder (Q,r) Model, was the best way to assess the Inventory of the stores, since there are fixed costs involved in the ordering. We used this model to assess all 4 locations, as well as pooling the 2 locations for each product. We included the calculations of Q, r and the costs, as well as the excel spreadsheets we used to aid us. However, in order to use the (Q, r) Model we had to make some assumptions.

**Assumptions:**

- Bike backorder cost is equal to price of $150 because that is the amount of money they would lose backordering.
- Ski backorder cost is equal to price of $1800 because that is the amount of money they would lose backordering.
- There is no stockout cost in this model for any location/product.
- Demand during lead time follows Poisson.
- Originally, CF = 0.95 because this is the current service level the managers use.

1. **<u>E. Longmeadow Bikes - Marijane</u>**

**Given**:

L = lead time = 2 weeks
A = trucking cost = $300 (trucking cost)
c = bike cost = $100/bike
p = bike selling price = $150
I = 20%
h = holding cost = ic = 0.2 (100) = $20/bike
D = total demand per year = 970 bikes
$\theta$ = demand of lead time = (970*2)/52 = 37.308 bikes

**Assumptions**:

b= backorder cost = $150
CR = 0.95
k = 0

**Solution for 95%:**

<u>Q and r:</u>
Q = sqrt((2AD)/h) = sqrt((2(300)(970)/20) = 170.6 ~ **171 bikes**
CF = 0.95
From Excel → **reorder point = r= 48**
Formula:
$\theta(z) = 0.95 \rightarrow z = 1.645$
$\sigma$ = sqrt($\theta$) = 6.12
$r^* = \theta + z\sigma = 37.308 + (1.645)(6.12) = 47.4 \sim 48$ units

**Costs**:

Fixed Setup Cost: AF(Q) = 300 * 5.673 = $1701.90

F(Q) = 970/171 = 5.673

Stockout Cost: kD(1-S(Q,r)) = $0 → no stockout cost

Backorder Cost: bB(Q,r) = 150 * 0.002 = $0.30

B(Q,r) → excel

Inventory Carrying Costs: hI(Q,r) = 20 * 96.002 = $1920.04

I(Q,r) → excel

Total Cost = $1701.90 + $0.30 + $1920.04 = **$3622.24**

**Optimal Service Level:**

G(R*) = b/ (b+h) = 150/(150+20) = 0.882 ~ **88%**

**Solution for 88%:**

<u>Q and r:</u>

Q = sqrt((2AD)/h) = sqrt((2(300)(970)/20) = 170.6 ~ **171 bikes**

CF = 0.88

From Excel → **r = reorder point = 45**

**Costs:**

From Excel → F(Q) = 5.673, B(Q,r) = 0.006, I(Q,r) = 93.006

Fixed Setup Cost: AF(Q) = 300 * 5.673 = $1701.90

Stockout Cost: kD(1-S(Q,r)) = $0 → no stockout cost

Backorder Cost: bB(Q,r) = 150 * 0.006 = $0.90

Inventory Carrying Costs: hI(Q,r) = 20 * 93.006 = $1860.12

Total Cost = $1701.90 + $0.90 + $1860.12 = **$3562.92**

**Final Solutions:**

Q = 171 bikes

95% → r = 48 bikes

Total Cost = $3622.24

G(R*) = 88%

88% → r = 45 bikes

Total Costs = $3562.92

2. **<u>E. Longmeadow Skis - Marijane</u>**

**Given:**

D=37 skis/year

c= $1000/ski

i= 30%

h= ic = 0.30(1000)=300

L= 5 weeks

A = $100

b = $1800/ski

σ= sqrt(3.558)=1.886

θ = demand of lead time = (37*5)/52 = 3.557 skis ~ 4 skis

**Assumptions:**

b= backorder cost = $1800

CR = 0.95

k = 0

**Solution for 95%:**

Q and r:

Q = sqrt((2AD)/h) = sqrt((2(100)(37)/300) = **5 skis**

CF = 0.95

From Excel → **r = reorder point = 7**

**Costs:**

From Excel → F(Q) = 7.4, B(Q,r) = 0.010, I(Q,r) = 6.01

Fixed Setup Cost: AF(Q) = 100 * 7.4 = $740

Stockout Cost: kD(1-S(Q,r)) = $0 → no stockout cost

Backorder Cost: bB(Q,r) = 1800 * 0.010 = $18

Inventory Carrying Costs: hI(Q,r) = 300 * 6.01= $1803

Total Cost = $740 + $18 + $1803 = **$2588**

**Optimal Service Level:**

G(R*) = b/ (b+h) = 1800/(1800+300) = 0.857 ~ **86%**

**Solution for 86%:**

Q and r:

Q = sqrt((2AD)/h) = sqrt((2(100)(37)/300) = **5 skis**

CF = 0.86

From Excel → **r = reorder point = 6**

**Costs:**

From Excel → F(Q) = 7.4, B(Q,r) = 0.0272, I(Q,r) = 5.0272

Fixed Setup Cost: AF(Q) = 100 * 7.4 = $740

Stockout Cost: kD(1-S(Q,r)) = $0 → no stockout cost

Backorder Cost: bB(Q,r) = 1800 * 0.0272 = $48.96

Inventory Carrying Costs: hI(Q,r) = 300 * 5.0272 = $1803

Total Cost = $740 + $18 + $1803 = **$1506.60**

**Final Solutions:**

Q = 5 skis

95% → r = 7 skis

Total Cost =  $2588

G(R*) = 86%

88% → r = 6 skis

Total Costs = $1506.60

3. **Easthampton Bikes - Zach**

**Given:**

D = 758bikes/year

c = $100/bike

h = ic = 0.20(100) = $20/yr

L = 2 weeks

θ = (758*2)/52 = 29.154 bikes during replenishment lead time

A = $300 (trucking cost)
b = $150/bike
σ = sqrt(29.154) = 5.399

**Assumptions:**

b = backorder cost = $150
CR = 0.95
k = 0 (no stock outs exist)

**Solution w/ Given Service Level:**

Q = sqrt((2AD)/h) = sqrt((2*300*758)/20) = 150.798 = **151 bikes**
CR = 0.95
θ(z) = 0.95 → z = 1.645
σ = sqrt(θ) = 6.12
r* = θ + zσ = 29.154 + (1.645)(5.399) = 38.04 ~ 38 units which matches excel
From excel → **r = 38**, **F(151)= 5.01986755, B(151,38) = 0.001729808, I(151,38) = 84.84772981**
Fixed Setup Cost: AF(Q) = 300*5.01986755 = 1505.96
Stockout Cost: kD(1-S(Q,r)) = 0
Backorder Cost: bB(Q,r) = 150*0.001729808 = 0.259
Inventory Carrying Costs: hI(Q,r) = 20*84.84772981 = 1696.955
Total Cost = 1505.96 + 0 + 0.259 + 1696.955 = **$3203.17**

**Solution w/ Optimal Service Level:**

G(R*) = b/ (b+h) = 150/(150+20) = 0.882 ~ **88%**
Q = sqrt((2AD)/h) = sqrt((2*300*758)/20) = 150.798 = **151 bikes**
From excel → **r = 35, F(151) = 5.01986755, B(151,35) = 0.006003666, I(151,35) = 81.85200367**
Fixed Setup Cost: AF(Q) = 300*5.01986755 = 1505.96
Stockout Cost: kD(1-S(Q,r)) = 0
Backorder Cost: bB(Q,r) = 150*0.006003666 = 0.901
Inventory Carrying Costs: hI(Q,r) = 20*81.85200367 = 1637.04
Total Cost = 1505.96 + 0 + 0.901 + 1637.04 = **$3143.90**

**Final Solutions:**

Q = 151 bikes
95% → r = 38 bikes
Total Cost = $3203.17
G(R*) = 88%
88% → r = 35 bikes
Total Costs = $3143.90

4. <u>**Easthampton Skis - Sarthak**</u>

**Given:**

L = lead time = 5 weeks
A = trucking cost = $100 (trucking cost)
c = ski cost = $1000/ski
p = ski selling price = $1800
I = 30%
h = holding cost = ic = 0.3 (1000) = $300/ski

D = total demand per year = 24 skis

θ = demand of lead time = (24*5)/52 = 2.308 skis

**Assumptions:**

b= backorder cost = $1800

CR = 0.95

k = 0

**Solution for 95%:**

Q and r:

Q = sqrt((2AD)/h) = sqrt((2(100)(24)/300) = **4 skis**

CF = 0.95

From Excel → **r = reorder point = 6**

**Costs:**

Fixed Setup Cost: AF(Q) = 100 * 6 = $600

Stockout Cost: kD(1-S(Q,r)) = $0 → no stockout cost

Backorder Cost: bB(Q,r) = 1800 * 0.006 = $10.8

Inventory Carrying Costs: hI(Q,r) = 300 * 5.506 = $1651.8

Total Cost = $600 + $10.8 + $1651.8 = **$2262.6**

**Optimal Service Level:**

G(R*) = b/ (b+h) = 1800/(1800+300) = 0.857 ~ **86%**

**Solution for 86%:**

Q and r:

Q = sqrt((2AD)/h) = sqrt((2(100)(24)/300)= **4 skis**

CF = 0.86

From Excel → **r = reorder point = 4**

**Costs:**

From Excel → F(Q) = 6, B(Q,r) = 0.033,

I(Q,r) = 3.533

Fixed Setup Cost: AF(Q) = 100 * 6 = $600

Stockout Cost: kD(1-S(Q,r)) = $0 → no stockout cost

Backorder Cost: bB(Q,r) = 1800 * 0.033 = $59.4

Inventory Carrying Costs: hI(Q,r) = 300 * 3.533 = $1059.9

Total Cost = $600+$59.4+1059.9 = **$1719.3**

**Final Solutions:**

Q = 4 skis

95% → r = 6 skis

Total Cost = $2262.60

G(R*) = 86%

86% → r = 4 skis

Total Costs = $1719.30

5. **Pooled Inventory - Bikes - Marijane:**

**Given:**

L = lead time = 2 weeks

A = trucking cost = $300 (trucking cost)

c = bike cost = $100/bike

p = bike selling price = $150

I = 20%

h = holding cost = ic = 0.2 (100) = $20/bike

D = total demand per year = 970 + 758 = 1728 bikes

θ = demand of lead time = (1728*2)/52 = 66.46 bikes ~ 67 bikes

**Assumption:**

b = backorder cost = $150

CR = 0.95

k = 0

**Solutions for 95%:**

<u>Q and r:</u>

Q = sqrt((2AD)/h) = sqrt((2(300)(1728))/20) = 227.68 ~ **228 bikes**

CF = 0.95

From Excel → **r = reorder point = 80**

**Costs:**

From Excel → F(Q) = 7.6, B(Q,r) = 0.003, I(Q,r) = 127.50

Fixed Setup Cost: AF(Q) = 300 * 7.6 = $2280

Stockout Cost: kD(1-S(Q,r)) = $0 → no stockout cost

Backorder Cost: bB(Q,r) = 150 * 0.003 = $0.45

Inventory Carrying Costs: hI(Q,r) = 20 * 127.50 = $2550

Total Cost = $2280 + $0.45 + $2550 = **$4831.20**

**Solution for our optimal service level, 88%:**

<u>Q and r:</u>

Q = sqrt((2AD)/h) = sqrt((2(300)(1728))/20) = 227.68 ~ **228 bikes**

CF = 0.88

From Excel → **r = reorder point = 76**

**Costs:**

From Excel → F(Q) = 7.6, B(Q,r) = 0.008, I(Q,r) = 123.5

Fixed Setup Cost: AF(Q) = 300 * 7.6 = $2280

Stockout Cost: kD(1-S(Q,r)) = $0 → no stockout cost

Backorder Cost: bB(Q,r) = 150 * 0.008 = $1.20

Inventory Carrying Costs: hI(Q,r) = 20 * 123.5 = $2470

Total Cost = $2280 + $1.20 + $2470 = **$4751.20**

**Final Solutions:**

Q = 228 bikes

95% → r = 80 bikes

Total Cost = $4831.20

G(R*) = 88%

88% → r = 76 bikes

Total Costs = $4751.20

6. **<u>Pooled Inventory - Skis- Zach and Sarthak:</u>**

**Given:**

D = 37+24 = 61 skis/year

$c = \$1000$/skis

$h = ic = 0.30(1000) = \$300$/yr

$L = 5$ weeks

$\theta = (61*5)/52 = 5.87$ skis during replenishment lead time

$A = \$100$

$p = \$1800$/skis

$\sigma = \text{sqrt}(5.87) = 2.422$

**Assumptions:**

b = backorder cost = \$1800

CR = 0.95

k = 0 (no stock outs exist)

**Solution w/ Given Service Level:**

Q = sqrt((2AD)/h) = sqrt((2*100*61)/300) = 6.377 ~ **6 bikes**

CF = 0.95

$\theta(z) = 0.95 \rightarrow z = 1.645$

$\sigma = \text{sqrt}(\theta) = 6.12$

$r^* = \theta + z\sigma = 5.87 + (1.645)(2.422) = 9.95 \sim 10$ units which matches excel

From Excel → **r = reorder point = 10, F(6) = 10.16666667, B(6,10) = 0.008177619, I(6,10) = 7.638177619**

**Costs:**

Fixed Setup Cost: AF(Q) = 100 * 10.16666667 = \$1016.667

Stockout Cost: kD(1-S(Q,r)) = \$0 → no stockout cost

Backorder Cost: bB(Q,r) = 1800 * 0.008177619 = \$14.72

Inventory Carrying Costs: hI(Q,r) = 300 * 7.638177619 = \$2291.453

Total Cost = 1016.667 + 14.72 + 2291.453 = **\$3322.84**

**Solution w/ Optimal Service Level:**

CR = b/(h+b)= 1800/(300+1800) =0.857 → 86% optimal service level

Q = sqrt((2AD)/h) = sqrt((2*100*61)/300) = 6.377 ~ **6 bikes**

From Excel → **r = reorder point = 8, F(6) = 10.16666667, B(6,8) = 0.043053182, I(6,8) = 5.673053182**

**Costs:**

Fixed Setup Cost: AF(Q) = 100 * 10.16666667 =\$1016.667

Stockout Cost: kD(1-S(Q,r)) = \$0 → no stockout cost

Backorder Cost: bB(Q,r) = 1800 *0.043053182 = \$77.496

Inventory Carrying Costs: hI(Q,r) = 300 * 5.673053182 = \$1701.916

Total Cost = 1016.668+77.496+1701.916 = **\$2796.079**

**Final Solutions:**

Q = 6 skis

95% → r = 10 skis

Total Cost = \$3322.84

G(R*) = 86%

86% → r = 8 skis

Total Costs = \$2796.079

**Analysis**

- Total cost of bikes at separate locations w/ 95% service level = 3622.24 + 3203.17 = $6825.41
- Total cost of bikes at separate locations w/ 88% service level = 3562.92 + 3143.90 = $6706.82
    - Savings under optimal service level = 6825.41 - 6706.82 = **$118.59**
- Total cost of skis at separate locations w/ 95% service level = 2262.6 + 2588 = $4850.60
- Total cost of skis at separate locations w/ 86% service level = 1719.3 + 1506.60 = $3225.9
    - Savings under optimal service level = 4850.60 - 3225.9 = **$1624.7**
- Total cost of pooling bikes w/ 95% service level = $4831.20
    - Savings of pooling with original service level = 6825.41 - 4831.20 = **$1994.21**
- Total cost of pooling bikes w/ 88% service level = $4751.20
    - Savings of pooling with optimal service level = 6825.41 - 4751.20 = **$2074.21**
- Total cost of pooling skis w/ 95% service level = $3322.84
    - Savings of pooling with original service level = 4736.38 - 3322.84 = **$1413.54**
- Total cost of pooling skis w/ 86% service level = $2796.079
    - Savings of pooling with optimal service level = 4736.38 - 2796.079 = **$1940.30**

Based on the analysis above, the current system has two separate locations ordering their own inventory for bikes and skis has a combined total cost of 6825.41 + 4736.38 = $11,561.79. When both managers operate their respective stores at the same service level of 95%, that is how much money is being spent on the sum of fixed setup costs, backorder costs, and inventory costs. When all the inventory is pooled together in the potential warehouse facility in Holyoke, the total cost for bikes and skis is now 4831.20 + 3322.84 = $8154.04. This generates an estimated savings of $3407.75 just by pooling all the inventory together instead of shipping directly to each store. It is also imperative to note that there is a different service level that proves to be optimal depending on the product being sold. For bikes, the optimal service level is 88% and for skis the optimal service level is 86%. At these respective levels, the total costs decrease once more. The total estimated savings of pooling all the inventory for both products at the warehouse facility in Holyoke, with optimal service levels for both products, comes out to $4014.51. Additionally, not only is pooling better for Bike & Ski Co., consolidating everything could be better for the environment as well as it will reduce transportation emissions.

**Recommendations**

As previously stated in the previous section, the optimal estimated savings was determined to be $4014.51. Therefore, we recommend implementing the warehouse facility in Holyoke because pooling the inventory will save the company money. We also recommend a decrease in service level for both bikes and skis because it decreases total cost as well. From 95%, change bikes to 88% and skis to 86% to see best results.

<u>Questions:</u>

1. Is their service level target appropriate? Does it make sense to increase it or decrease it? Should it be different for the different products?

The current service level target of 95% is not appropriate. It makes sense to decrease the service level because they are spending too much in inventory, so the potential savings should be explored. After some calculations, we see that the new target service levels are different for the two products. This makes sense due to their variability in their demand. For example, the optimal service level for bikes comes out to 88% while the skis optimal service level is 86%. So, no it is not appropriate, it should be decreased and different for the 2 products.

2. Should they be looking at the cycle service level or the fill rate when measuring their performance and calculating their optimal policies? What difference does it make? How does it change the ordering policies to follow?

When considering service, it is more relevant to look at the fill rate. The fill rate measures the satisfaction of customers as it is the proportion of customers that are satisfied, and in this case, did not have to backorder. The cycle service level is the probability of not running out of stock during a cycle, but does not consider the customer demand. The order policy would change because we would be holding the model to a different level of satisfaction, so depending on this systems' fill rates the reorder point would either increase or decrease. To find these specific levels and ordering policies new calculations would need to be done.

3. What are the benefits of pooling the ordering and inventory of both locations?
    a. What should be the inventory policy to follow for each product with and without pooling?
    b. How does the target service level affect the benefits associated with pooling the inventory of both locations?

The new target service level is nothing but beneficial with pooling the inventory of both locations. Pooling the inventory of both locations already proved to save the company money, but by also implementing the new optimal service levels for both products, the savings only gets higher. It is important to note that the service levels are different for bikes and skis because it ensures the best result when it comes to the savings generated from this plan.