**Supply Chain Modeling and Analysis**
**(Q,R) Final Project**

The central warehouse of a large manufacturer of heavy machinery and engines stocks three different engine oil products. The central warehouse orders these three products from the company's manufacturing operations division and stocks them to meet demands of the company's dealers, which serve customer demand for these engine oil products. The lead time and fixed order costs are about the same for each order, regardless of the quantity or product type ordered; it is safe to assume that lead time is about one month and fixed order costs are $7,500 per order.

The following table includes information on various costs and demand for each of the products.

| Product | Annual Demand ~ Normal (mean, std dev) | | Costs | |
|---|---|---|---|---|
| | Mean | Std. Dev. | Holding cost ($/unit/yr) | Stock-out cost ($/unit) |
| Diesel Engine Oil - DE495 | 1,000,000 | 450,000 | 1 | 2 |
| Gas Engine Oil - GE275 | 400,000 | 140,000 | 5 | 10 |
| Natural Gas Engine Oil – NG645 | 500,000 | 65,000 | 5 | 15 |
| | | | | |

If the central warehouse does not have the item in stock when a dealer puts in an order, the order is recorded and is delivered to the retailer as soon as the next shipment arrives from the manufacturing division. The warehouse estimates the stock-out cost to be equal to the same-day shipping costs that they incur as a result of the stock-out incident (given in the table above).

## Questions:

1. **EOQ Model:** The company management has indicated a desire to adopt a very simple inventory control policy for the three engine oil products. In particular, they have heard that the economic order quantity model is easy to understand due to the constant and known demand assumption. Determine the EOQ and reorder level for each of the three engine oil products and calculate the inventory costs (fixed order, and holding costs) under this constant demand scenario.

2. **(Q,R) Model:** A new member of the management team, Alex Hamm, has an MBA and is eager to see how much of an impact modeling uncertainty may have on the inventory control policy used. In particular, he would like to see the stockout costs factored into the calculation of the inventory control policy since he feels that the estimated stockout costs are not negligible, especially in comparison to the estimated holding costs. Now determine the optimal order quantity and reorder level using a (Q,R) policy designed to consider the stochasticity of demand explicitly. First check that all of the (Q,R) policy assumptions are met in this case.

3. Compare the order quantity and reorder levels you found in parts (1) and (2) using the below table, and comment on the reasons for the differences you observe.

| Product | Deterministic Demand | | Stochastic Demand | |
|---|---|---|---|---|
| | *Q** | *R** | *Q** | *R** |
| Diesel Engine Oil - DE495 | | | | |
| Gas Engine Oil - GE275 | | | | |
| Natural Gas Engine Oil – NG645 | | | | |

4. **EOQ and (*Q,R*) Policy Comparison:** Compare the two policies with respect to the expected inventory costs (compare separately the holding, fixed cost and stockout under each policy), stockout probability (type I service level) and fill rate (type II service level). Comment on the differences between the two policies.

5. The management team is now thinking "outside-the-box," and has raised the question of why the manufacturing division is charging the central warehouse a fixed order cost of $7,500 each time the warehouse puts in an order. The manufacturing division has indicated that the reason is that each time the central warehouse puts in an order for the oils, they have to schedule a team to put together the order, and send out a truck to deliver the order to the central warehouse, which is costly. To discourage very frequent ordering of the engine oils, they decided to implement the fixed order cost, which they claimed to "work just fine so far."

   The management, however, is still questioning how the $7,500 per order figure was determined, and arguing that the fixed order is creating "false economics" for this very basic order fulfillment function between two divisions of the same company. As a compromise, the manufacturing division has agreed to accommodate monthly orders for each product (i.e., at most 12 orders per year) with the condition that orders of all products be coordinated so that manufacturing can send orders for all products to the central warehouse with the same truck. Calculate the order quantity and the reorder level to be used in this case. Does it make sense for the central warehouse to order less frequently than 12 orders per year? Why? How does the performance measures you calculated in part (4) change for this new inventory control policy?

6. Continuing their "thinking outside-the-box," the management team is now asking you to calculate the inventory control implications of developing a single engine oil product that they can sell for all types of engines -diesel, gas and natural gas. That is, this single product will be a substitute for all of the three products, and in fact, will have superior properties in reducing friction (thanks to the addition of boric acid to the formulation), and will eventually take over market share of the other products. The marketing team thinks that there will be a transitionary period during which the company will also be selling the previous three fuel-specific products, but within a year or so they expect the new engine oil to wipe out the other products off the market. Alex Hamm is particularly interested in demonstrating the inventory control impacts of this idea in the long-run, since he has learned in his Operations Management class that standardizing inventories would yield risk pooling benefits. He has asked for your help in calculating the optimal (Q,R) policy and its costs and performance (fill rate and stock-out probability) in this case. How does the performance of this policy compare to that of the policy you calculated for Part (2), for three different engine oil products?

7. **(OPTIONAL Bonus 10 pts)** Alex Hamm is very pleased about his prospects of rising up in the management team, thanks to your efforts… He is now asking you to come up with an "innovative" alternative on how to run the supply chain. For example, he has asked you to think about the relationship between the central warehouse and the retailers. Does it make sense to have a central warehouse, rather than shipping directly to retailers from the manufacturing plant? Considering the six retailers (located in Phoenix, Las Vegas, Los Angeles, Salt Lake City, Albuquerque and Denver) that the central warehouse serves, and the demand at each retailer is as follows (so that the total demand that the warehouse sees is an aggregate of the retailers' demand) construct an argument (and any necessary data that you would need) in support of the current, or an alternative supply chain design.

   Assume that the manufacturing plant is at Springfield, MO, and you are considering to locate a warehouse in Flagstaff, AZ. Find average cost per mile values on the internet for distribution costs, make proper assumptions on the type of transportation method used (truck load, less than truck load, train, small package, etc.) so that your cost approximations are appropriately selected.

| | Phoenix | | Las Vegas | | Los Angeles | | Salt Lake City | | Albuquerque | | Denver | | TOTAL DEMAND | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | stdev |
| Diesel oil | 150000 | 159099 | 75000 | 183712 | 230000 | 150000 | 147000 | 225000 | 175000 | 170084 | 223000 | 203430 | 1000000 | 450000 |
| Gas oil | 25000 | 52915 | 9000 | 49497 | 34000 | 57155 | 28000 | 42212 | 67000 | 62610 | 237000 | 73359 | 400000 | 140000 |
| Nat. Gas oil | 48000 | 21667 | 47500 | 32500 | 38000 | 22981 | 54000 | 19598 | 68000 | 24568 | 244500 | 34402 | 500000 | 65000 |