Name: ....

ISyE 3103 Introduction to Supply Chain Modeling: Logistics
Summer 2012
Exam 1
June 20, 2012

Instructions

1. There are 7 pages and 56 points.
2. No books, notes, computers, calculators, cell phones, or any other electronic equipment allowed within your reach.
3. No bathroom breaks during the exam allowed. Complete your bathroom visits before starting the exam.
4. Do your own work.
5. Show all calculations.

Question 1 (4 points)

1.1 Explain the difference between active and passive radio frequency identification. (2)
Answer: Active RFID has a power source in the RFID tag, and passive RFID does not have a power source, but only reflects part of incoming energy.

1.2 Give an advantage of active radio frequency identification over passive radio frequency identification, and an advantage of passive radio frequency identification over active radio frequency identification. (2)
Answer: Active RFID can be detected over a larger distance. Passive RFID is cheaper, and does not run out of power.

Question 2 (36 points)

1. (a) In the article on the value of experts in forecasting, it was mentioned that it was observed in studies that the quality of forecasts may actually deteriorate as the level of expertise increased. What was the explanation given for this phenomenon? (2)

   (b) The article gives an explanation why companies continue to hire so-called experts to do their forecasting. What was the explanation? (2)

   Answer:

   (a) People who think they are experts tend to be stubborn when it comes to learning new things and admitting their errors.

   (b) Managers want to avoid responsibility for potentially bad forecasts.

2. An ocean carrier that transports containers among various ports in the Atlantic Ocean wants a model to forecast fuel consumption for each voyage in gallons. At each port visit, the fuel consumption for the preceding voyage is recorded.

   (a) Can exponential smoothing be used to develop such a model? If so, describe the data that you would want to develop a model. If not, then explain why not. (2)

   (b) Can regression be used to develop such a model? If so, describe the data that you would want to develop a model. If not, then explain why not. (2)

   (c) Fuel prices vary significantly among different ports (mostly because of differences in fuel taxes imposed by the applicable governments). However, the cost of carrying extra fuel is relatively small.

      i. Do you always want to completely fill up the fuel tanks of the ship before the next voyage? Why or why not? (2)

      ii. Do you want to fill the fuel tanks of the ship to the level of average forecasted fuel consumption for the next voyage? Why or why not? (2)

      iii. Describe how you would manage the fuel replenishment of your ship. (2)

   Answer:

   (a) No. Exponential smoothing extrapolation is inappropriate for such forecasting. A good forecast cannot be obtained by ordering the observed values of the amount of fuel consumed on different voyages in the order of the voyages and then extrapolating the sequence with an exponential smoothing method. Fuel consumption is strongly affected by distance and ocean currents, and this should be taken into account.

   (b) Yes. Want data of the dependent variable, namely the amount of fuel consumed, and data on relevant explanatory variables, such as distance, component of ocean current in the direction of the voyage, component of wind force in the direction of the voyage.

   (c) i. No. When fuel is expensive and the next voyage is short, you want to buy less fuel.

      ii. No. Want to forecast a larger quantity, say the 99% quantile of the amount of fuel used, to reduce the probability of running out of fuel and having to request in-ocean refuelling.

      iii. When fuel is cheap in a port, fill up the fuel tanks completely. When fuel is expensive, fill up to the 99% quantile for the next voyage. In general, solve a dynamic program.

3. Suppose that we want to estimate a model to forecast the time to unload palletized loads from an inbound trailer at a crossdock. Each pallet in the trailer is picked up by a forklift truck (one at a time of course), and then either moved to the appropriate outbound trailer for that pallet and loaded onto the trailer, or if no outbound trailer is ready for that pallet, then the pallet is just stacked in a holding area at the crossdock.

Remember that after the forklift truck has dropped off the pallet, either inside the outbound trailer or at the holding area, it has to return to the inbound trailer before the next pallet cycle can start. Let

Y_i = time to unload palletized loads from inbound trailer i, in minutes.

X_{1i} = number of pallets to be moved to holding area.

X_{2i} = number of pallets to be moved to and loaded onto outbound trailers.

X_{3i} = the total distance to be traveled by forklift truck between inbound trailer and the outbound trailers, in meters.

X_{4i} = the total distance to be traveled by forklift truck between inbound trailer and the holding area, in meters.

$$X_{5i} = \begin{cases} 1 & \text{if newer, faster type forklift truck is used} \\ 0 & \text{if older, slower type forklift truck is used} \end{cases}$$

Suppose that we estimate the following model:

$$\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}_1 X_{1i} + \hat{\beta}_2 X_{2i} + \hat{\beta}_3 X_{3i} + \hat{\beta}_4 X_{4i} + \hat{\beta}_5 X_{3i} X_{5i} + \hat{\beta}_6 X_{4i} X_{5i}$$

(a) In terms of the $\hat{\beta}$s, how would you estimate the following quantities?

i. The time it takes a forklift truck to pick-up a pallet in the inbound trailer, plus the time it takes a forklift truck to put down the pallet in the holding area. (2)
Answer: $\hat{\beta}_1$

ii. The time to move a pallet from the inbound trailer to an outbound trailer 40 meters away, and load the outbound trailer, if the older, slower forklift truck is used, in minutes. (2)
Answer: $\hat{\beta}_0 + \hat{\beta}_2 + \hat{\beta}_3(40)$

iii. The time to move a pallet from the inbound trailer to the holding area 20 meters away, and drop off the pallet, if the older, slower forklift truck is used, in minutes. (2)
Answer: $\hat{\beta}_0 + \hat{\beta}_1 + \hat{\beta}_4(20)$

iv. You forgot to collect data about the time it takes to move pallets from the holding area to the outbound trailers. Give your best estimate of the time to move a pallet from the holding area to an outbound trailer 20 meters away, and load the outbound trailer, if the newer, faster forklift truck is used, in minutes. (2)
Answer: $\hat{\beta}_0 + \hat{\beta}_1 + (\hat{\beta}_3 + \hat{\beta}_5)(20)$ or $\hat{\beta}_0 + \hat{\beta}_1 + (\hat{\beta}_4 + \hat{\beta}_6)(20)$

v. The speed, in meters per minute, of the older, slower type forklift truck between inbound and outbound trailers. (2)
Answer: $\frac{1}{\hat{\beta}_3}$

vi. The difference in speed, in meters per minute, between the newer, faster type forklift truck, and the older, slower type forklift truck between inbound and

outbound trailers. (2)
Answer: $\frac{1}{\hat{\beta}_3+\hat{\beta}_5} - \frac{1}{\hat{\beta}_3}$

(b) Use your common sense.

i. What sign do you expect β_4 to have, and why? (2)
Answer: $\hat{\beta}_4 > 0$. The greater the distance between inbound trailer and holding area, the longer it takes the older, slower type forklift truck to travel the distance.

ii. What sign do you expect β_6 to have, and why? (2)
Answer: $\hat{\beta}_6 < 0$. The incremental time it takes the older, slower type forklift truck to travel 1 meter between inbound trailer and holding area is $\hat{\beta}_4$. The incremental time it takes the newer, faster type forklift truck to travel 1 meter between inbound trailer and the holding area is $\hat{\beta}_4 + \hat{\beta}_6 < \hat{\beta}_4$, thus $\hat{\beta}_6 < 0$.

(c) Suppose that we obtained data with 30 observations from various forklift operators and pallets, and that we estimated the following from these data. We assumed that the error terms ε_i are independent $N(0, \sigma^2)$ distributed.

$$
\begin{array}{rclrcl}
\hat{\beta}_0 & = & 3.5 & \hat{\text{Var}}(\hat{\beta}_0) & = & 2.65 \times 10^{0} \\
\hat{\beta}_1 & = & 0.63 & \hat{\text{Var}}(\hat{\beta}_1) & = & 1.22 \times 10^{-2} \\
\hat{\beta}_2 & = & 0.85 & \hat{\text{Var}}(\hat{\beta}_2) & = & 3.55 \times 10^{-2} \\
\hat{\beta}_3 & = & 8.4 \times 10^{-3} & \hat{\text{Var}}(\hat{\beta}_3) & = & 3.2 \times 10^{-5} \\
\hat{\beta}_4 & = & 9.4 \times 10^{-3} & \hat{\text{Var}}(\hat{\beta}_4) & = & 2.4 \times 10^{-5} \\
\hat{\beta}_5 & = & -1.3 \times 10^{-3} & \hat{\text{Var}}(\hat{\beta}_5) & = & 4.7 \times 10^{-4} \\
\hat{\beta}_6 & = & 1.2 \times 10^{-3} & \hat{\text{Var}}(\hat{\beta}_6) & = & 9.7 \times 10^{-4}
\end{array}
$$

i. Construct a 95% confidence interval for β_2. You do not have to simplify your expressions, but remember to specify the units. (2)
Answer: $(0.85 - 2.069 \times \sqrt{3.55 \times 10^{-2}}, 0.85 + 2.069 \times \sqrt{3.55 \times 10^{-2}})$ minutes per pallet

ii. Suppose that we have to unload a trailer with 16 pallets. Of the 16 pallets, 8 have to be moved to an outbound trailer 10 meters away, 3 have to be moved to an outbound trailer 30 meters away, and 5 have to be moved to the holding area 20 meters away. The newer, faster forklift truck will be used. Write an expression to forecast the time to unload the trailer. You do not have to simplify your expression, but remember to specify the units. (2)
Answer: $\hat{Y} = 3.5 + (0.63)(5) + (0.85)(11) + (8.4 \times 10^{-3} - 1.3 \times 10^{-3})(8 \times 20 + 3 \times 60) + (9.4 \times 10^{-3} + 1.2 \times 10^{-3})(5 \times 40)$ minutes

iii. We estimate the variance of the forecast to be

$$\hat{\text{Var}}(\hat{Y}) = 4.7 \times 10^{0}$$

To allow for the variability among forklift operators, we want to make an estimate such that the probability that an operator will complete the unloading of the trailer in the estimated time is approximately 0.7. Write an expression for such a time estimate. You do not have to simplify your expression, but again remember to specify the units. (2)

Answer: $\hat{Y} + 0.532 \times \sqrt{\hat{\text{Var}}(\hat{Y})}$ minutes

Question 3 (16 points)

Carpet is shipped from a manufacturing plant in Dalton, GA to a retailer's distribution center in Topeka, KS. The forecasted demand is 20,000 m^2 of carpet for the next year. We want to determine if it is more economical to ship by truckload carriers or by rail. A truck can hold 1000 m^2 of carpet, and a truckload from Dalton to Topeka costs \$1328. The journey by truck takes 2 days on average (door to door). A rail car can hold 5000 m^2 of carpet, and sending a rail car from Dalton to Topeka costs \$4000. The journey by rail takes 10 days on average (door to door).

The sales contract specifies free-on-board origin. Thus ownership transfers from the manufacturer to the retailer as soon as the carpet is loaded onto the vehicle at the manufacturer's facility. Also, the retailer chooses the carrier, and pays for transportation.

Carpet is valued at \$15 per m^2 in transit and \$21 per m^2 at the distribution center. The inventory holding cost rate is estimated at 20% of value per year, including funds tied up in inventory, spoilage, and loss. In addition, cost of storage at the distribution center is \$1 per m^2 per year.

1. Order processing at the plant takes 3 days, that is, order lead time is equal to 3 days plus the transportation time. Assume that the *daily* demands are independent normally distributed with mean given above and standard deviation $\sigma_d = 25\ m^2$. Determine the safety stock required for truck shipping and the safety stock required for rail shipping so that the probability that the distribution center runs out of stock during a cycle between replenishments is 1%. You do not have to simplify your expressions, but remember to specify the units. (4)

   Answer: Truck:
   Variance of demand over $3 + 2 = 5$ days $= 5 \times 25^2\ m^4$.
   Standard deviation of demand over 5 days $= \sqrt{5 \times 25^2} = \sqrt{5} \times 25\ m^2$.
   Safety stock to cover demand over 5 days with probability $0.99 = 2.326 \times 25\sqrt{5}\ m^2$.
   Rail:
   Variance of demand over $3 + 10 = 13$ days $= 13 \times 25^2\ m^4$.
   Standard deviation of demand over 13 days $= \sqrt{13 \times 25^2} = \sqrt{13} \times 25\ m^2$.
   Safety stock to cover demand over 13 days with probability $0.99 = 2.326 \times 25\sqrt{13}\ m^2$.

2. As before, order processing at the plant takes 3 days, that is, order lead time is equal to 3 days plus the transportation time. Also, as before, the daily demands are normally distributed with mean given above and standard deviation $\sigma_d = 25\ m^2$. However, daily demands are not independent. Instead, daily demands are positively correlated. Assume that the correlation coefficient between demand on any two days during the lead time is 0.4. Determine the safety stock required for truck shipping and the safety stock required for rail shipping so that the probability that the distribution center runs out of stock during a cycle between replenishments is 1%. You do not have to simplify

your expressions, but remember to specify the units. (4)

Answer: Truck:

Variance of demand over $3+2=5$ days $= 5\times 25^2 + 5\times 4\times 0.4\times 25^2 = 5\times 2.6\times 25^2\ m^4$.

Standard deviation of demand over 5 days $= \sqrt{5\times 2.6\times 25^2} = \sqrt{5\times 2.6}\times 25\ m^2$.

Safety stock to cover demand over 5 days with probability 0.99 $= 2.326\times 25\sqrt{5\times 2.6}\,m^2$.

Rail:

Variance of demand over $3+10 = 13$ days $= 13\times 25^2 + 13\times 12\times 0.4\times 25^2 = 13\times 5.8\times 25^2\ m^4$.

Standard deviation of demand over 13 days $= \sqrt{13\times 5.8\times 25^2} = \sqrt{13\times 5.8}\times 25\ m^2$.

Safety stock to cover demand over 13 days with probability 0.99 $= 2.326\times 25\sqrt{13\times 5.8}\,m^2$.

3. Consider the possibility of shipping vehicles that are only partially full. Let q_T denote the shipment size in m^2 by truck, and let q_R denote the shipment size in m^2 by rail. For the case with independent daily demands, and for each mode, write expressions for the retailer's cost components (transportation costs and inventory costs) as a function of the shipment sizes q_T and q_R. You do not have to simplify your expressions, but remember to specify the units. (4)

Answer: Truck:

Transportation cost $= \$1328\times 20000/q_T$ per year.

Holding cost in transit $= \$20000\times 0.2\times 15\times 2/365$ per year.

Storage and Holding cost at distribution center $= \$(1)(2.326\times 25\sqrt{5}+q_T) + (0.2\times 21)(2.326\times 25\sqrt{5}+q_T/2)$ per year.

Rail:

Transportation cost $= \$4000\times 20000/q_R$ per year.

Holding cost in transit $= \$20000\times 0.2\times 15\times 10/365$ per year.

Storage and Holding cost at distribution center $= \$(1)(2.326\times 25\sqrt{13}+q_R) + (0.2\times 21)(2.326\times 25\sqrt{13}+q_R/2)$ per year.

4. For the case with independent daily demands, and for each mode, write an expression for the optimal (least cost for retailer) shipment size q_T and q_R. You do not have to simplify your expressions, but remember to specify the units. (4)

Answer: Truck:

Total cost

$$
\begin{aligned}
f_T(q_T) &= \frac{1328\times 20000}{q_T} + \frac{20000\times 0.2\times 15\times 2}{365} \\
&\quad + (1)(2.326\times 25\sqrt{5}+q_T) + (0.2\times 21)(2.326\times 25\sqrt{5}+q_T/2) \\
f_T'(q_T) &= -\frac{1328\times 20000}{q_T^2} + 1 + \frac{0.2\times 21}{2} \\
\Rightarrow \quad q_T^* &= \min\left\{1000, \sqrt{\frac{1328\times 20000}{3.1}}\right\} m^2
\end{aligned}
$$

Rail:

Total cost

$$
f_R(q_R) = \frac{4000\times 20000}{q_R} + \frac{20000\times 0.2\times 15\times 10}{365}
$$

$$
\begin{aligned}
& & & +(1)(2.326 \times 25\sqrt{13} + q_R) + (0.2 \times 21)(2.326 \times 25\sqrt{13} + q_R/2) \\
& f'_R(q_R) & = & -\frac{4000 \times 20000}{q_R^2} + 1 + \frac{0.2 \times 21}{2} \\
\Rightarrow \quad & q_R^* & = & \min\left\{5000, \sqrt{\frac{4000 \times 20000}{3.1}}\right\} m^2
\end{aligned}
$$