OPRE 6366: Final on November 27, 2007

This is an open textbook and open lecture notes exam. You may use a calculator although leaving quantities as fractions, additions or products is perfectly acceptable and preferable. Do not forget to define any variables you introduce. Good luck ...

NAME (please print):

<table>
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<th>Question</th>
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1. Put T before a statement if you think that statement is true. Otherwise put X.

1. ( ) Buyback price formula in the lecture notes is valid only when demand has Normal distribution. X
2. ( ) Rationing game type set up will always lead to bullwhip effect with or without demand uncertainty. T
3. ( ) A quantity flexibility contract between a supplier and a retailer reduces the supplier’s risk of raw material availability. X
4. ( ) Postponement (delaying product differentiation) can increase production costs. T
5. ( ) In a quantity flexibility contract, a retailer must pay a smaller wholesale price to the supplier if it wants higher flexibility in altering its order quantities.
6. ( ) Information sharing in a supply chain can reduce the bullwhip effect. T
7. ( ) Product customization undercuts the applicability of buyback contracts. T
8. ( ) Offshoring facilitates multiple orders in a single selling season. X
9. ( ) Supply chain partners are not direct competitors of each other so they can share information without any reservation. X
10. ( ) Transshipments between retailers is a stock-out risk mitigation strategy. T
2. According to USDA (Department of Agriculture) April 2002 report, US bought about 100 kbs (=kilo bales=1000 bales) of cotton from Vietnam in 2001/2002 season. Suppose that there is a quota of 100 kilo bale/season on Vietnamese cotton and only JcPenny (J) and Sears (S) use this cotton. If Vietnam quota fills up before these companies fulfill their needs, they will have to buy from more expensive markets. The Union of Cotton Planters (UCP) in Vietnam takes orders of these companies at the beginning of every season. If total orders are less than the quota, each company gets exactly what they ordered. If total orders are larger than the quota, UCP fills company orders such that the ratio of order sizes is equal to the ratio of received orders. For example, if J orders 40 and S orders 120, J gets 25 and S gets 75 so that 120/40=75/25. Suppose that J determined its cotton need as 70 kilo bales for the next season and orders right after S.

[2P] a) If J hears that S will order $Q_S = 20$ kilo bales, how many kilo bales should J order?

\[ \text{Answer:} \quad \text{Only 70 kilo bales, quota is not restrictive.} \]

[4P] b) If J hears that S will order $Q_S = 50$ kilo bales, how many kilo bales should J order?

\[ \text{Answer:} \quad \text{If J orders } Q_J \text{ it will get } \frac{100Q_J}{Q_J + Q_S}. \text{ J wants this to be 70, so } 70 = \frac{100Q_J}{Q_J + 50} \text{ gives } Q_J = \frac{350}{3}. \]

[5P] c) Sensitivity analysis: Express J’s order size $Q_J$ in terms of $Q_S$ so that J always gets 70 kilo bales. Also draw $Q_J$ (y-axis) as a function of $Q_S$ (x-axis).

\[ \text{Answer:} \quad \text{From above, } 70 = \frac{100Q_J}{Q_J + Q_S} \text{ gives } Q_J = 70Q_S/30 \text{ when quota is restrictive and } Q_J = 70 \text{ when quota is not restrictive. When you graph these functions, you will see that} \]

\[ Q_J = \begin{cases} 70 & \text{if } 0 \leq Q_S \leq 30 \\ 70Q_S/30 & \text{if } 30 \leq Q_S \end{cases} \]
d) Suppose a third clothing company knows that J needs 70 kbs in the next season. But it does not know the exact value of $Q_S$ so it gathers from the past seasons that $S$ has ordered in uniformly distributed quantities from 0 to 50 kilo bales. From the third company’s perspective what is the probability of quota becoming a limitation.

ANSWER: Quota becomes a limitation only when $S$ orders more than 30 kbs, which happens with 40% probability.

7P e) What would the predicted (expected) value of $Q_J$ be from the third company’s perspective.

ANSWER: Let the predicted value be $\hat{Q}_J$.

Intuitive approach: With 60% probability quota is not limiting so $Q_J = 70$. Quota is limiting with 40% probability, when $30 \leq Q_S \leq 50$. When $Q_S = 30$, $Q_J = 70$. When $Q_S = 50$, $Q_J = 350/3$. Then over the range of $30 \leq Q_S \leq 50$, we expect $Q_S = (70 + 350/3)/2 = 93.3$. This expectation turns out to be just the average because the distribution is Uniform. Thus,

$$\hat{Q}_J = \begin{cases} 70 & \text{if } 0 \leq Q_S \leq 30 \text{ which happens with probability } 60\% \\ 93.3 & \text{if } 30 \leq Q_S \leq 50 \text{ which happens with probability } 40\% \end{cases}$$

Then in the overall $\hat{Q}_J = 0.6(70) + (0.4)93.3 = 79.3$ kbs.

Calculus-based approach:

$$\hat{Q}_J = E(\max\{70, 70Q_S/30\}) \text{ where } Q_S \sim U(0,50)$$

$$\hat{Q}_J = \int_{q=0}^{30} 70(1/50)dq + \int_{q=30}^{50} (70q/30)(1/50)dq = 2100/50 + (70/3000)q^2|_{q=50}^{q=30}$$

$$\hat{Q}_J = 2100/50 + (70/300)(2500 - 900) = 79.3 \text{ kbs}$$

3P f) J and S want US to increase the quota starting from 2004/2005 season. USDA asked them to evaluate the benefit of increasing the quota. However, J and S are not sure how to make this evaluation against their unpredictable needs in 2004/2005 season. Which model studied in the supply chain course will be useful to study for this purpose, explain? Do not do any computations.

ANSWER: When you take quota as capacity, and J and S as customers, we are in the capacitated newsvendor model realm. The analogy between increasing a restaurant’s capacity (of hw4) and quota limitations are apparent. Then the marginal benefit of increasing quota can be thought as the marginal benefit of increasing restaurant capacity. Both of these analyses are done against multiple uncertain demand streams.
3. Ford produces and sells in many countries. Among these, three are Argentina (A), Brazil (B) and Mexico (M). Depending on local market conditions, Ford expects to turn in profits in these countries with probabilities \( p_A = 0.1, p_B = 0.4 \) and \( p_M = 0.7 \).

[4P] a) What is the probability that Ford loses money in all three markets if market conditions were independent of each other? Compare this number against probability of making loss in each local market. What is the implication in terms of risk management?

**ANSWER:** Assuming the independence of markets, \( P(\text{loss in all markets}) = (1-p_A)(1-p_B)(1-p_C) = (0.9)(0.6)(0.3) = 16.2\% \). 16.2\% is significantly lower than loss probabilities in individual markets, 90\%, 60\% and 30\%. The implication is that international companies can reduce their risk by spreading out into different countries and performing a wide portfolio of operations in these countries.

[3P] b) If the only reason for globalization was risk management, does it make more sense to operate in \{Mexico, Madagascar, Malaysia\} than \{Mexico, Argentina, Brazil\}, why?

**ANSWER:** The risk is minimized when there is more independence and desirably negative correlation among random events. That is what we argued in demand aggregation. To minimize the risk, Ford should pick there countries far from each other in geographical and economical aspects (geographical connection implies more often an economical one than vice versa). Choosing three Latin American countries hardly minimizes the risk.

[3P] c) Does stronger globalization of countries and companies other than Ford help Ford with the objective of risk minimization by becoming global, explain?

**ANSWER:** No, globalization indeed eliminates independences by connecting national economies, which brings in positive correlation by design. When the globalization is completed, all national economies will enter and exit recession and growth cycles simultaneously. In other words, they will be perfectly correlated. Then when one country economically fails, all others will fail. Thus, operating in multiple countries cannot reduce economical risk.
4. Starbucks at Coit & Campbell sells gourmet Java coffee in bags. Each bag costs $10 and is sold at $25, excess demand is lost to competition. Stockouts cost lost profit and a goodwill cost of $3/bag. It costs $20 to Starbucks to place an order to its Java supplier. The replenishment lead time from the supplier is 3 months. Suppose that the demand during lead time has $N(50, 25^2)$ distribution.

\[3P\] a) If the internal rate of return for Starbucks is 20% per annum, what would the inventory holding cost approximately be? What is the underage cost?

**Answer:** \(H = hC = (0.2)10 = 2\) per bag per year. Underage cost = \(c_u = 25 - 10 + 3 = 18\) per bag. Note that the units are different.

\[3P\] b) What is the distribution of annual demand?

\(R = 4(50) = 200\), \(\text{StDev} = \sqrt{4 \times 25^2} = 50\), Annual demand is \(N(200, 50^2)\).

\[3P\] c) What is the EOQ lot size if we ignore the demand variability (uncertainty)?

**Answer:** \(Q = \text{EOQ} = \sqrt{\frac{2SR}{H}} = \sqrt{2 \times 20 \times 200/2} = 63.2\) bags
d) Let $T$ be the number of months EOQ lasts. What is $T$ if we ignore the demand variability (uncertainty)?

\[ T = \left( \frac{63.2}{200} \right) \times 12 \text{ months}. \]

e) Starbucks decides to order EOQ whenever its inventory reaches the reorder level of ROP. Why is this better than ordering EOQ every $T$ months?

\[ \text{Answer: Ordering EOQ every } T \text{ months fixes the ordering schedule and does not allow it to be responsive to high or low demand occurrences.} \]

f) What is the reorder point that achieves 96.5% of cycle service level? Write your answer in terms of Normal inverse cdf function norminv.

\[ F(ROP) = CSL. \quad ROP = \text{norminv}(0.965, 50, 25) = 50 + 25 \times \text{norminv}(0.965, 0, 1) \]

\[ \text{Answer: } SS = ROP - R = 25 \times \text{norminv}(0.965, 0, 1) \]

h) How does safety stock change with CSL, i.e. what happens to safety stock if we reduce CSL?

\[ \text{Answer: In view of the formula } \sigma \times \text{norminv}(CSL, 0, 1), \text{ the safety stock depends on how } \text{norminv}(CSL, 0, 1) \text{ changes with } CSL. \text{ Note that } \text{norminv}(CSL, 0, 1) = x \text{ means } P(\text{Standard Normal Variate} \leq x) = CSL. \text{ When CSL drops, we must also reduce } x \text{ to satisfy the equality. In other words, } x = \text{norminv}(CSL, 0, 1) \text{ is decreasing in CSL. This is inherited by the safety stock.} \]
5. Commercial airlines were suffering from drop in domestic and international travel during early 2001, which reached unprecedented levels after 9/11. Worldwide airline passenger traffic is positively correlated with GDP, it increased at an annual rate twice that of GDP from 1980 to 2000. Domestically there were two major downturns in the airline industry over 1979-1983 and 1989-1994. The major costs for the industry are fuel and labor costs. As exemplified by only 1 year of slight losses due to 1974-1975 oil crisis, the industry can absorb reasonable fuel cost increases without going into a major downturn. The airline industry’s downturns historically lasted 4 years and a typical economical cycle is as in Table 1. Airline industry will go through turbulent times in the coming years.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
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<tr>
<td>Bubble</td>
<td>Revenues and yields* peak</td>
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<tr>
<td></td>
<td>Profits stabilize and fall as labor actions increase labor costs</td>
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<td>New-aircraft orders peak about 1 year after profits</td>
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<td>Crash</td>
<td>GDP drops, so does the demand</td>
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<td>Yields fall as airlines sell tickets at low price to hold the demand from falling</td>
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<td>Cost-cutting measures are implemented</td>
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<td>New-aircraft orders are cancelled or deferred. Orders from previous months/years arrive.</td>
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<tr>
<td>Stabilization</td>
<td>GDP stabilizes and increases, so do revenues. Yields are still low.</td>
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<td>Losses are limited as cost-cutting measures are felt</td>
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<td>Unused and total fleet capacity is at maximum</td>
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<tr>
<td>Recovery</td>
<td>Strong GDP fuels the demand. Yields increase, revenue increases much faster</td>
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<tr>
<td></td>
<td>Profits increase with revenues and disciplined costs</td>
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<td>Unused fleet capacity drops with higher utilization</td>
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Table 1: Economical cycle for the airline industry. Yields*: Price per passenger per kilometer.

[5P] a) In 2001, revenue and yield for major US airlines dropped by 6.8% and 8.5% respectively, these pulled down the revenue to 91.5% of costs. Almost all US airlines declared losses. However US GDP did not drop drastically in 2001. What other factor(s) might have led to these losses given that GDP is not sufficient to explain losses? As of May 2002, where were we in the economical cycle?

**Answer:** After 9/11 passenger traffic dropped significantly not because of GDP, but because of security concerns and inconveniences caused by security checks. The airline industry was going through a minor downturn before 9/11, revenues were about 97% of costs. This number went down drastically after 9/11 to make the entire year’s average 91.5%. You may also argue that oil prices were high in 2001 and increased operating costs. This is a very very minor effect, as pointed out in the problem statement the industry is not bothered very much by the oil prices.

As of May 2002, the airline industry is in the Crash phase. The demand is low, airlines are cutting prices (suffering low yields) to fill up planes. At the same time they are implementing cost cutting measures as canceling several routes, reducing flight frequency, offering early retirement, reduced working hours, canceling airplane orders. These measures are not felt yet on company bottomlines and the passenger demand did not signal a return to its usual height so the industry is not in the Stabilization phase yet.

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<sup>1</sup> Table 1 is adapted from McKinsey Quarterly No.2, 2002

<sup>2</sup> This question was inspired by American Airlines CEO D. Carty’s interview for CEO Exchange titled “Dynamic leadership in turbulent times” filmed on April 29, 2002 in Richardson, see [www.pbs.org/wttw/ceoexchange](http://www.pbs.org/wttw/ceoexchange).
b) Challenges to traditional major airlines are not limited to slowing down economy, low-cost airlines (e.g. Southwest) are turning to be viable alternatives for traditional airlines (e.g. American). Traditional airlines have a hub-spoke (a.k.a. spider in lectures) business model. In this model passengers are collected at hubs and transported among hubs where links to smaller cities emanate like spokes. Low-cost airlines are too small to have hub-spoke model so they operate among big cities (hub-hub). Low-cost airlines are well known for “no-frills” policy for cabin food, buying and operating older air crafts, offering low wages to employees, no in-advance seat reservations, all of these factors drive down their costs. Leaving these factors aside, the question is if hub-hub business model costs less than hub-spoke model, if so why? Also explain which of these models are more useful/applicable as an airline grows and becomes national rather than regional.

**Answer:** Hub-hub model will lead to lower cost. Hub-hub model is easier to operate because it is transferring people from one location to another: no connecting flights via spokes to hubs, no delays for connections, no connecting flight scheduling restrictions, no ground crew for baggage transfer, simplified aircraft servicing and maintenance. In-advance seat reservation is not as necessary in the hub-hub model as it is in the hub-spoke model: travels always have 1-leg, so no such thing as stranding a passenger between the origin and the destination due to reservation mismatches.

In the hub-hub model, hubs must have sufficiently large traffic originating in the hubs and destined for the hubs: passengers cannot be brought in from / sent to close-by cities via spokes. Also hubs must be close to each other because low-cost airlines are too small to extend to various geographies. Furthermore, such an extension is costly. These observations should explain why Dallas-Houston trip is ideal for Southwest. However, there are few sufficiently close hub-hub locations with sufficient traffic. Hub-hub model is an option for smaller airlines at a regional level. To grow beyond that level, spokes would be necessary.

c) Another challenge to traditional airlines is fractional jet ownership model where companies either buy or share small jets for their business travel needs. Sharing jets makes this model accessible to small companies which cannot afford to support its own jet fleet. Does 9/11 terrorist attack enforce the viability of fractional jet ownership model, explain. Jet sharing is forecasted to take away 10% of business travel in US by 2005. Given that there are not many business travelers to begin with (at most 10-15% of cabin is for first-class travelers), is losing 10% of first-class travelers big issue for airlines, explain?

**Answer:** Business travelers want quick, easy and secure transportation. 9/11 revealed security lapses and led to the introduction of security measures which led to many inconveniences for travelers. Business travelers are bothered more from these inconveniences than leisure travelers. Thus, business travelers have a stronger urge to avoid inconveniences by opting for frictional jet ownership. Losing business travelers is a big issue. Business travelers pay substantially higher ticket prices so a 10% drop in their numbers will have a much larger effect on revenues.

d) In b)and c), we have focused on leisure and business travelers respectively. There seems to be two fundamentally different customer type. Leisure customers do not mind waits or low service and they seek low cost. The reverse is true for business travelers. For a highly responsive supply chain, forgetting about operating costs, what should American Airlines do to serve to these customers?

**Answer:** A brave suggestion is to split American into American Business and American Leisure airlines. The first could use small, new, reliable jets to serve business travelers. It could operate at restricted-access (to registered business travelers only) gates where security at the gate is relaxed. The second could offer a low-cost alternative to leisure travelers by using low-cost airline tricks while maintaining hub-spoke model. The service for the leisure travelers can be provided by aircrafts with propellers which are slightly slower but consume less fuel than jets. I do not expect you to make such a suggestion. But you must mention that American ought to customize its product for business and leisure travelers.
Remarks: Splitting American Airline is what would happen if we ignore operating costs. However, there are economies-of-scale and network externality issues which may undercut the soundness of the split according to customer base. On April 29 2002, American’s then CEO Donald Carty explained the significance of these issues and he seemed to believe in them wholeheartedly. He said “the bigger, the better”, then we did not expect a split in American Airlines. An airline can create network externalities and economies of scale by building alliances. During economic downturns, it would be easier for American to manage alliance capacity which tends to be less rigid. When this was brought up, American’s then CEO D. Carty mentioned that American’s pilots union did not like this idea: pilots were afraid that they would do long legs while allied pilots would do the short legs. This should not be a major concern as American must be able address such concerns satisfactorily via pilot contracts or union representatives. Actually, the D. Carty did not believe that the airline business model was not going to yield sustainable growth/profit. Donald Carty resigned in 2003.

It was not clear then and not clear now what would be a good business model for airlines. The fundamental problem in the industry is that the ticket prices we are used to do not compensate for the cost, especially with the increases in the oil prices. I personally see four ways to make the industry profitable:

- Supply side
  1. Exploitation of jet fuel economy of the propeller or turboprop aircrafts.
  2. Exploitation of economies of scale over long distances (such as DFW - Beijing flight) with larger aircraft such as A380 for passengers and A400 turboprop for cargo and military uses.

- Demand side
  1. Consolidation in the industry, after some airlines go bankrupt or bought by others, will lead to less competition and higher ticket prices.
  2. Contraction in the industry can happen when highspeed trains replace aircrafts flying short distances. For example, a good alternative in Texas is a highspeed train service among the cities of Dallas, San Antonio and Houston; see Figure 1. I personally would rather take a train to Houston if the train takes less than 2 hours (2 hours of travel time is well within reach even with aged highspeed train technology). The problem here is of course the big initial infrastructure investment which is beyond the means of the Texas budget. Creative ways of financing (like federal investment, government bonds) this undertaking is necessary. Note that places with poorer, smaller economies have opted for the highspeed train alternative. What is needed more than money is willingness to look at the problems over a long-term time horizon rather than to adapt quick, easy but incomplete fixes.

Update on Nov 28, 2007: A day after this final exam was given, American Airlines announced that it would shed American Eagle\(^3\). In the retrospect, a form of the brave suggestion above is implemented.

Update on Jul 07, 2008: Over the last eight months, the airlines have become more vulnerable as the gas prices have risen to record levels. They have reduced capacity and started to charge for previously-free services such as $15 for each checked bag at American Airlines. This trend has caused some to speculate that there are other services to charge for. One of those speculators is Phillippe Reines who listed the chargeable services in his Jul 7, 2009 opinion piece titled My Plan to Help the Airlines in Wall Street Journal. Some excerpts from his piece include:

- You could charge an extra $1.99 for the option of boarding the plane from the middle or back doors, rather than parading coach passengers through first class, only to be sneered at by people sipping Mimosas [cocktails].
- When the plane is on the ground, the lights work, the brakes work, the TVs work but not the air conditioning. The plane costs some $100 million and includes some of the most sophisticated technology known to man surely the engineers at Boeing can devise a way to cool the plane at sea level. I’d shell out an extra $9.99 for that amenity alone.

• Passengers don’t want to hear how we’re going to be delayed “a bit” because the starboard engine is a “little broken,” or told at 8 a.m. Saturday that the “pilots haven’t shown up yet” from wherever they were Friday night. Or how there are “Fifty ways to leave your lover, but only 10 to get off this aircraft.” I’ll cough up another $4.99 if we keep the cabin communications professional, concise and mundane.

• I like kids, I swear. But I’d pay almost anything not to sit in close proximity to one who is misbehaving. I will fork over $0.15 for every year of age over 10 for each passenger sitting directly next to me, in front of me, and behind me. So if I’m in a window seat, and the three passengers closest to me are each 50 years old for a combined 150 years, that’s an extra $18 [=120*0.15]. And I’d tack on another $5 to have my row and the rows in front and behind me completely child-free. That’s another $23 right there.

• My BlackBerry is not going to bring the plane down. I don’t know of a single documented case of a consumer electronic device interfering with a plane’s avionics. If they did, al Qaeda would just fly around with iPods. Since we don’t fear an iBomber, why not just let me use my BlackBerry as much as I want, whenever I want. (I do anyway.) This one would be free, because it would be offset by negating the need for the flight attendant to expend energy cruising the aisle before takeoff searching for perps, like a prison guard working the tiers of Sing Sing. [The use of electronic devices are regulated by Federal Aviation Administration not by airlines.]

• No plane has ever glided down and landed softly on its belly somewhere in the Atlantic, with the passengers bobbing around in rafts or clinging to seat cushions until help arrives. We’ve all got the intricacies of the seat belt down pat. So let’s better use that five minutes for safety instructions by holding a raffle to determine who gets to deplane first when we land. You can sell tickets at $2 a pop.

I am not sure if Mr. Reines penned this piece with sarcastic motives. Seriously speaking, making $1-2 more here and there will not help airlines to become financially sound. More substantial solutions are required.
Figure 1: A must for Texas: High-speed Railway a.k.a Texas T-Bone.