Mini-cases in Supply Chain Engineering and Optimization

This document provides a variety of mini-cases in Supply Chain Engineering. The situations covered include: simple distribution and DC location, FTL and LTL vehicle routing, production and demand planning, inventory management, international sourcing in the face of foreign exchange risk and tariffs, and incentive compatibility in supply chain contracts. Data for each mini-case are provided in a spreadsheet. Many of the cases have a "think outside the box" wrinkle whereby one can do better if one violates an intuitive but unnecessary constraint. The cases come from two sources: a) Developed and tested in a Logistics/Supply Chain course, and b) based on providing optimization based solutions to industrial supply chain customers. For more complicated cases, partially developed models are provided. Where spreadsheet models are provided, good professional quality spreadsheet style is used. These cases have been useful in the classroom, to supplement standard textbook problems with bigger more realistic situations, and for potential industrial users as illustrations of what improvements are possible.

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Supplier and Quantity Selection at Discount Central Stores

13 October 2003

Discount Central Stores sells industrial products through 296 outlets scattered over North America. These outlets are served from 15 warehouse/distribution centers(DC) strategically located over North America. Most of the products are industrial consumption products such as cleaning products like "Janitor in a Drum®", high intensity light bulbs for in factories, etc. Discount Central likes to advertise itself as the low cost "hardware store for industry".

Given the consumption commodity nature of most of its products, the demand for any specific product at each DC appears to be fairly constant over time with only minor seasonal fluctuations, and minor trends as various products gain or lose popularity. As a result, most product inventories at the DC level are managed with an order quantity inventory policy. That is, each product at a given DC has a standard order quantity. When the inventory for particular product is about to become zero, an order for the standard order quantity is placed to the standard supplier for that product. Supplier lead times are quite reliable, so the order is placed so that the shipment arrives at the DC just before the inventory goes to zero. The choice of the order quantity is based on the attempt to strike a compromise between inventory costs and ordering costs. If order quantities are increased, then inventory costs(consisting mainly of cost of capital tied up in inventory) will go up, while order costs(consisting mainly of the cost of processing the orders and shipping costs) go down.

The Chief Operating Officer(COO) at Discount Central has called you in to help improve inventory management at Discount Central. The COO has suggested several ideas for trying to improve inventory management. One idea is to get the various DC managers together in a little management workshop to have them do a better job of exchanging ideas on how to manage inventories. The COO would like to have this effort headed by some of the managers who have shown themselves to be efficient inventory managers. In this regard, the COO has started to collect some cost data its DC's. Data on two of its DC's for the most recent fiscal year are shown below.

	Tooele, UT	Marietta, GA
Unit Volume	199,840	101,220
Ordering related costs	$2,154,099	$1,541,553
Inventory and holding costs/yr	$2,356,120	$1,539,047

Neither the Tooele nor the Marietta manager has control of marketing activities so neither has much control over the unit volume processed in the warehouse. Their only control is over operating costs. The ordering related costs consist of the personnel costs of the purchasing department, not including the salary of the chief purchasing officer, plus a per shipment cost of about $90 per order. The cost structure of most carriers used by Discount Central is that every shipment will cost at least $90, regardless of the quantity ordered. The personnel costs in the purchasing department are roughly proportional to the number of orders processed. The two DC's have similar labor cost rates, and both handle a similar mix of products. The inventory and holding costs are mainly the cost of capital tied up in inventory. Both DC's have spare storage capacity. It is not easy to change the capacity of either by rental or other means.

How would you evaluate these two managers with regard to being a good candidate to lead the little inventory management workshop that the COO is contemplating?

A second idea the COO proposed is to look more closely at how Discount Central deals with suppliers. The COO suggests a two-pronged approach: a) try to find lowest cost suppliers, and b) get suppliers to offer quantity discounts. Different suppliers offer different quantity discount structures so Discount Central would like to have a standardized procedure for "costing out" a pricing proposal from a supplier. In order to check out ideas the COO has assembled the data for a particular high wattage standard factory light bulb. The yearly demand at the Marietta DC is about 120,000 units, with a fixed order cost of about $100 per order. The two leading suppliers, Supplier G and Supplier W, were asked to provide quotes with quantity discounts based on order size. Here is the complete data set for company G in spreadsheet form.

	A	B	C	D
1				
2				
3	Parameters			
4	120000 = D = demand/year			
5	100 = K = setup cost			
6	0.2 = i = interest charge(cost of capital/year)			
8				
9	Discount schedule for supplier G			
10	Breakpoint	Cost/unit at or above this level		
11	0	3		
12	5000	2.96		
13	10000	2.92		
14	(Note this data set based, with permission, on Chopra & Meindl, chap. 10.)			

For example, if you place an order for 4000 units, you incur the $100 order charge and Supplier G will charge $3 per unit. If you place an order for 6000 units, Supplier G will charge $2.96 for each of the 6000 units, etc.

The corresponding quote from Supplier W is:

	A	B	C	D
1				
2				
3	Parameters			
4	120000 = D = demand/year			
5	100 = K = setup cost			
6	0.2 = i = interest charge(cost of capital/year)			
8				
9	Discount schedule for supplier G			
10	Breakpoint	Cost/unit at or above this level		
11	0	3.03		
12	4500	2.95		
13	9900	2.91		

There are several things to note about supplier G's quantity discount structure: a) it is more expensive for small quantities, e.g., $3.02 per unit rather than $3, b) the quantity discounts "kick in" sooner, e.g., at 4500 rather than 5000, c) above 5000 the cost per unit is less, and c) a minor difference in interpretation: Supplier W allows the lower price to apply only to the units above the break point. For example, if you order 6000 units from W, you will pay $3.03 for the first 4500 units, and $2.95 for the (6000-4500) = 1500 units above 4500.

a) What order quantity would you recommend if you were using supplier G?

b) Based on just qualitative arguments, if you used suppler W instead, would your order quantity be greater than that you would use for G?

c) Which supplier do you recommend using?

Professional Texts Publishing

13 October 2003

A publisher of a popular textbook on Supply Chain Management must decide upon the number of copies to print to last through the summer. The author will be providing a new edition that will be available for the autumn market, so the publisher need worry about only the demand until the Autumn. The printer charges $48 per copy printed. The publisher sells the book to bookstores for $96. The publisher estimates the mean demand from now until the autumn to be 10,000 copies, with a standard deviation of 1000. It is reasonable to assume that demand is Normal distributed. If demand exceeds the number printed, then the publisher estimates that lost future revenue due to customers switching to other texts, etc., is about $18 per lost sale. Leftover books can be sold on the used book and scrap market for $12 per book.

a) How many copies should the publisher print?

b) Just before the publisher acts upon your recommendation to (a), the printer calls from New Jersey and says: "Have I go a deal for you! If you will print 14,000 or more copies, I will give you a $12 discount, i.e., you may have every one of them for $36 per copy". What kind of advice can you give the publisher on this new option?

Weekend Chronicle Press Run Determination

9 February 2004

Rob Kornwall is the business manager at the Chronicle newspaper. He has been bothered by the rising per unit cost of publishing a newspaper. Paper and labor costs in particular have been increasing. Even though the Chronicle is the leading newspaper in the metropolitan area, the Herald Star is an able competitor and so if the Chronicle raised the per copy price or raised advertising rates, then the Chronicle would lose readership and advertising revenue to the competition. For the weekend edition, advertising contributes as much revenue as the revenue from sales. The advertising rate that the Chronicle is able to charge depends upon audited circulation, so losing circulation is doubly bad. As with many newspapers, the weekend edition is the big money maker for the Chronicle. The weekday sales are about 590,000 each day, whereas, the weekend edition typically sells about 1,000,000 copies. The weekend edition carries much more advertising and its selling price per copy is higher. Thus Rob has decided to first concentrate on the weekend edition to see if there are any opportunities to reduce costs or increase sales without raising prices. The Sunday Chronicle sells for $1.50 "on the street", the Chronicle, however, receives only $1.10 from its vendors, typically drugstores and newsstands scattered around the metropolitan area.

Each Monday afternoon Rob gets a report on sales at each outlet. This information comes as two numbers for each outlet: 1) sales, and 2) returns. For example, at a drugstore, late on a Sunday evening, a clerk at the drugstore tears off the front page of each unsold weekend Chronicle. These front pages are then returned to the Chronicle company on Monday morning. The drugstore has to pay the Chronicle for the number of copies received from the Chronicle minus any returns. Rob is particularly bothered by the high number of returns. For example, for the most recent weekend, the press run was 1,460,000 copies, while the sales were 1,020,318. The obvious thought is that he could reduce his variable costs by almost one third if he simply ran a shorter press run. Of course, Rob realizes that if he only printed 1,000,000 copies, average sales would probably be substantially less than 1,000,000. Because of the vagaries of random demand, some outlets will have copies left over while others will stock out and lose sales.

The weekend edition is distributed via direct home delivery as well as through about 3200 drugstores, newsstands, etc. At most outlets there is only one delivery of the weekend Chronicle, usually late Saturday afternoon. There are some outlets, close to the production facility on the northwest side, that can get a second (re)stocking, but for the time being Rob is concentrating only on the more common "choose your stock level and live with it" outlets. The marginal cost of a copy of the weekend Chronicle is estimated to be $0.31. This consists mainly of the cost of paper, ink, labor, and energy. Unsold papers have a very modest salvage value, say, $.01.

Rob has retrieved some sales data for the newsstand nearest his home. Based on the past six months, the sales of the weekend Chronicle had a mean of 109 copies per week with a standard deviation of 29. Suppose a) we attach no additional penalty to lost sales, other than the immediate lost revenue, b) we treat the wholesale price of $1.10/copy as the revenue. How many copies should be stocked at this newsstand?

If Rob had more time, he would like to look at several additional issues, such as, better estimates of: how many sales are being lost because of stockouts at each outlet, the penalty for a lost sale beyond just the immediate lost revenue, the true profit contribution of each additional sale? In preparation for doing a more detailed analysis, Rob has collected some more detailed sales data for one particular outlet, a drugstore in Shaker Heights. Because of fairly steady demand, this outlet used a simple stocking policy of stocking up to the same number every week.

Sales of Weekend Chronicle for 52 weeks
Stock level was 128

week	sales	week	sales
1	80	27	70
2	105	28	68
3	121	29	100
4	102	30	93
5	107	31	105
6	111	32	126
7	126	33	97
8	114	34	117
9	92	35	71
10	79	36	126
11	113	37	105
12	98	38	75
13	108	39	98
14	79	40	72
15	108	41	113
16	120	42	126
17	80	43	82
18	82	44	106
19	104	45	86
20	78	46	111
21	81	47	120
22	83	48	81
23	87	49	118
24	104	50	126
25	83	51	93
26	92	52	69
		Mean:	97.90385
		Std. Dev.:	17.69154

Rob is very interested in figuring out how to increase sales for a given press run size. Obviously if he could do a better job of forecasting demand at each outlet and/or if he could do a better job of setting stock level at each outlet, that should help increase sales. Along the same line, Rob would like to reduce the number of "wasted" copies at each outlet. A common practice at a drugstore is that when the weekend Chronicle is delivered, the store manager will "borrow" a copy for his desk to read during idle moments. He of course will return it to the stand by the end late Sunday evening. Also, some copies may get damaged so that customers may be reluctant to purchase that particular copy.

In the past year, data were collected at three outlets(staffed as opposed to simple news boxes), on what potential customers do if the Chronicle was out of stock. If a customer asked for a Chronicle but it was out of stock, the staffers found that 52% of the time, the customer asked for the Herald Star instead, and 11% of the time the customer switched to some other paper. A recent survey suggested that once a customer switchs brands, the customer remains loyal to the new brand for about one half year. If we use the Shaker Heights data as an example, how many copies of the weekend Chronicle would you recommend stocking at that outlet?

Useful spreadsheets for this case: Chronicle1.xls

Selecting Order Frequency at Vector Products Bicycle

13 October 2003

The Vector Products Company (VPC) of Gutenborg, Iowa, distributes a folding bicycle called the Brompton. Demand for the Brompton over the past year has been at the rate of 5.9 per month, fairly uniformly distributed over the year. The Brompton is imported from a manufacturer in the United Kingdom. For a variety of reasons, including customs processing, small size of the manufacturer, averages and ravages of ocean shipping, and getting the shipment from the port of entry to Iowa, the lead time from the manufacturer to VPC is about two months. The fixed cost of placing an order, taking into account international phone calls, shipping cost structure, and general order processing is $200. The cost and selling price per bicycle vary depending upon the features included, but a typical Brompton costs VPC $500. VPC sells a typical Brompton for $900. VPC uses a cost of capital of 12% per year.

(a) What order size, as a first approximation, do you recommend for VPC?

(b) VPC did a statistical analysis of their sales data for the past year and found the standard deviation in monthly demand to be 2.1. VPC estimates a customer who is ready to buy, but finds VPC out of stock, will buy from someone else with probability .8, rather than wait. Analysis of the last six shipments suggests that the lead time has a standard deviation of three weeks. What reorder point do you recommend for VPC?

(c) How much is the variability in lead time costing VPC?

(d) Suppose that spending a bit more money on expediting will help VPC reduce the lead time to one month, with a standard deviation of close to zero. How much is this worth in terms of reduced inventory related costs?

Pooling and Postponement at Packard Printers

13 October 2003

Packard Printers(PP) manufacturers and sells desktop printers around the world. A recent innovation is to combine the printing with the related capabilities of faxing(send and receive), scanning, copying, and photo printing. PP currently has two major printer platforms, the Valet and the OfficeMate, for providing these desktop printer related functions. The major difference between the two lines is that the Valet has a "Flash memory card" reader but not fax module, whereas the OfficeMate has a fax module but no memory card reader. The memory card reader is handy for printing photos directly from a memory card without having to copy the photos into a computer.

Lee Howard, located in Brussels, Belgium, is PP's manager of European distribution. Currently, there is no manufacturing facility for these printers in Europe. The must be shipped from the manufacturing plant in Mexico. The Brussels distribution operation is operated as a profit center, so Lee is very concerned about profit margins on these two printer lines. He is particularly concerned about inventory costs. In some months and some countries he may have a big overstock of the Valet, but be backordered on the OfficeMate, whereas, in the next month and a different country the situation is just reversed between the two printers. Lee is considering all kinds of ideas for trying to reduce inventory related costs. Demand at the moment is somewhat random, with no discernable trend as yet, although clearly the demand will decrease sometime in the future as new printing technology is developed. He has collected some possibly useful data on the two printers as follows:

Valet	OfficeMate	Description
9055	10045	Forecast demand per month,
4227	4388	Standard deviation in monthly demand,
79	81	Variable manufacturing cost,
4	4	Variable transport cost/unit,
300	300	Fixed order cost, i.e., per shipment,
7.1	7.3	Holding cost/month per unit,
118	121	Penalty cost/unit of unsatisfied demand,
1.1	1.1	Lead time in months,
.46152	.46152	Standard deviation in lead time,

For the time being, let us concentrate only on the OfficeMate printer for simplicity.

About how frequently should Lee be ordering, i.e., how many shipments per month should Lee plan, so as to strike a balance between inventory costs and the fixed cost of making a shipment?

Currently, Lee has to pay for the printers as soon as the leave the plant in Mexico. How much could he reduce his expected monthly costs if he could convince central management that he should not pay for the printers until they arrive at the Brussels delivery dock?

Randomness in both the demand and the lead time requires Lee to carry safety stock. How much could Lee save if he could switch to a perfectly reliable carrier, that is, the standard deviation in lead time is reduced to zero?

Various air cargo vendors regularly try to sell Lee on the benefits of shipping by air. The transportation cost would be higher, but the lead time would be a perfectly reliable one week. Disregarding the increased transportation cost, how much might Lee expect to save in lower inventory related costs(mainly safety stock) if he switched to air freight?

Occasionally Lee has had conversations with the printer design group and the manufacturing group about the possibility of combining these two printers in some fashion. One way would be to have them use an identical main module except that the Brussels DC could quickly plug in either a fax module or a card reader module as dictated by demand. An alternative, conceptually simpler solution would be to simply combine the two printer designs into a single "one size fits all" design. In either case, Lee could combine the two demand streams and carry only one printer type. Disregarding the costs of design changes and possibly higher manufacturing costs, how much could Lee save per month by simply carrying this one combined printer type?

References

Lee, H., C. Billington, and B. Carter(1993), "Hewlett-Packard Gains Control of Inventory and Service Through Design for Localization", *Interfaces*, vol. 23, no. 4, pp. 1-11.

Related spreadsheet: packardp.xls.

Guaranteed Service Level for Trackats Product Line

13 October 2003

One of the most fundamental decisions to be made by a firm that sells a physical product is:
Which products should we carry in inventory and which should we order from a supplier when demand occurs?
If the firm has multiple locations, then the question is doubly interesting in its more general form:
Which products should be stocked at which locations?
Let us first consider the single location setting, motivated by such firms as Caterpillar and Amazon.com, where a conscious decision is made to not stock certain items, even though Caterpillar and Amazon hope to sell the items by having the customer wait one or two days while the product is obtained from a supplier or central warehouse and perhaps dropped shipped to the customer. Here are some data for some low demand, high value items sold by Trackats in support of its products world-wide. The table below, lists for a particular store: the SKU, the expected demand per year, the holding cost/year, and the ratio of (holding cost)/(demand). For this particular set of products, Trackats wants to minimize holding costs while nevertheless satisfying at least 81% of demand over-the-counter, that is, with no wait.

Slow Moving Item Stocking Decision for Trackats (catservc.xls)

SKU	Demand per year	Holding cost per unit*year	H_cost/ demand	Desired service level. 0.81
b fluid	1.2	$37.00	$30.83	
brake	0.9	$115.00	$127.78	
clutch	3.1	$305.00	$98.39	
f filter	0.9	$80.00	$88.89	
f pump	0.6	$100.00	$166.67	
idler	1.1	$190.00	$172.73	
injector	2.6	$85.00	$32.69	
piston	0.75	$400.00	$533.33	
sleeve	1	$180.00	$180.00	
t fluid	2.1	$50.00	$23.81	
tread	0.4	$110.00	$275.00	
trk pin	2.1	$40.00	$19.05	

For extremely slow moving(though valuable) products such as those listed in the table, the inventory policy is very simple: you either do not carry the product, or you carry one unit of it. Because demand is so infrequent, whenever, a demand uses up the unit in stock, you reorder another immediately and with high probability it will arrive before another demand occurs.

a) Which of the above SKU's should be stocked so that at least 81% of demands are satisfied immediately from stock, and inventory costs are minimized?

b) Trackats notices that whenever a tread is ordered, an idler is also ordered. How would you change the stocking policy?

Martin-Steinberg Supplier Selection and Purchasing

13 October 2003

As the use of the internet/Web becomes more widespread, a number of purchasing markets are appearing on the Web. You would like to investigate the possibility of having a fairly sophisticated version of such a market, one that takes into account the kind of quantity discount structures that vendors typically offer. For prototyping you have identified a small company that buys supplies and raw materials regularly from a number of suppliers. Each supplier has its own prices and terms of payment and shipping. Traditionally, when you have had a set of supplies to be purchased, you have priced out the materials for each of the potential suppliers using the prices and terms of each and then purchased all of that set of needed supplies from that supplier for which the entire set of supplies can be purchased for the lowest total cost. It has been suggested that considerable cost savings might be possible by being more flexible in terms of how much of what is bought from whom. In order to test out ideas you are looking at today's purchasing needs. You have just learned that you need to purchase two(2) sawdust pumps, one(1) motor generator unit, and thirty(30) line stabilizers. There are two suppliers available, Martin Equipment and Steinberg Supplies, both carrying comparable versions of all of the above three items. Martin tends to have better prices, however, it always throws in a hefty $1000 shipping and handling charge on any order, regardless of size. Steinberg always tries to project an image of straightforward high quality, thus their prices tend to be higher, but they pay for all shipping and handling. The prices per unit for the three items are shown in the table below.

	Sawdust Pump	Motor generator	Stabilizer
Martin	$4450	$3100	$210
Steinberg	$4500	$3950	$290

a) If you just want to buy from one supplier, from whom would you buy?

b) If you take the perspective of minimizing the cost to the buyer, how would you order?

c) One detail of Steinberg's pricing policy is that it will give a 10% discount off the total on any order if the total before discount is at least $10,000. Which source is the cheaper source for each of the products, assuming you get the 10% discount from Steinberg? How would you now modify your analysis and results?

d) How would you "scale-up" your methodology to more than three products and more than two suppliers?

Component Sourcing at Digital International

13 October 2003

The Digital International is an integrated computer manufacturer. It manufacturers and sells complete computers as well as components that are used in the manufacture of computers. For purposes of appreciating some of the international sourcing issues faced by the company, we will concentrate on one product line, lap top computers, and two of the major components that go into a lap top computer, liquid crystal displays(LCD) and mother boards(MOB). One laptop computer requires one LCD and one MOB. Digital International has manufacturing facilities in Brazil, Europe, Japan, Taiwan, and the U.S. Although Digital International manufactures LCD's and MOB's, it does not currently plan to sell any LCD's or MOB's outside of the company. They are used only to make LAP's.

Some data related to costs, prices, demands, tariffs, capacities, and production cost are tabulated below. For example, Digital International must pay a tariff of .07 * 3600 for each LAP imported into Japan. Digital International must pay a tariff of .039 * 800 for each LCD imported into the U.S.

Nation:	Brazil	Europe	Japan	Taiwan	US	
						! By country....;
LAPDEM =	4000	11000	8000	5000	14000	! Laptop demand;
TARIFF =	.40	.049	.07	.05	.039	! Import tariff rates;
LAPPRC =	4950	3500	3600	3400	3200	! Laptop price;
LCDPRC =	800	850	800	750	800	! Tariff price;
MOBPRC =	900	1050	850	950	900	! Tariff price;
MOBCST =	0	1000	0	0	900	! MOB production cost;
LCDCST =	0	0	800	700	850	! LCD production cost;
LAPCST =	0	800	850	0	750	! Laptop prod cost;
LCDCAP =	0	0	20000	35000	5000	! LCD capacity;
MOBCAP =	0	11000	0	0	29000	! MOB capacity;
LAPCAP =	0	18000	8000	0	27000	! Laptop capacity;

No transport costs are listed in the table. A good approximation is that it costs $50 per component to move each component from one region(Brazil, Europe, Japan, Taiwan, and US) to another. The demand numbers are the most that Digital International can hope to sell in a country. Digital International could intentionally plan to sell less if it is unprofitable.

Digital International wants operate its supply chain, or more accurately, supply web, in the most profitable manner. Specifically, Digital International wants to decide: a) how many MOB, LCD, and LAP's to produce in each country, b) what shipments to make among countries, and c) how many LAP's to sell in each country. For each LAP produced in a country, Digital International must acquire one MOB and one LCD, either by import into or production in that country. Import tariffs must be paid for items imported into a country. With a bit of "paperwork" , however, these tariffs can be avoided in two ways. For a LAP produced in a country and exported, Digital International can get a *duty drawback* (or refund)on any tariffs paid on components in that LAP that were imported. For a LAP imported into a country, Digital International can obtain a *duty avoidance* to the extent that Digital International exported components from that country of the kind that are used in the imported product.

A consulting company has proposed the following shipments among countries. A shipment of an item from a country to itself represents the number manufactured in that country. For example, Europe manufactures 11,000 LAP's for sale in Europe.

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LAPSHP( EUROPE, EUROPE)        11000.
LAPSHP(  JAPAN,  JAPAN)         8000.
LAPSHP(     US,     US)        21000.
LAPSHP(     US, BRAZIL)         4000.
LAPSHP(     US, TAIWAN)         5000.
LCDSHP( TAIWAN, TAIWAN)        35000.
LCDSHP( TAIWAN, EUROPE)        11000.
LCDSHP( TAIWAN,  JAPAN)         3000.
LCDSHP( TAIWAN,     US)        21000.
LCDSHP( JAPAN,   JAPAN)         5000.
MOBSHP(    US,     US)        29000.
MOBSHP(    US,   JAPAN)         8000.
MOBSHP( EUROPE, EUROPE)        11000.
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Notice that in this solution, the US is the only exporter of lap tops. The US manufactures 21,000 lap tops, of which 4000 and 5000 are exported respectively to Brazil and Taiwan, leaving 12,000 for US demand. Because US demand is 14,000, this means 2000 units of US demand is not satisfied.

For final products, e.g., LAP's, the tariff is based on the selling price. For components, the tariff is applied to a somewhat arbitrary price determined by the tariff applying country. For example, if Digital International produces an LCD in Taiwan, it costs $700 per unit, however, if Digital International imports an LCD into Taiwan, Digital International has to pay a tariff of $750 * .05 = $37.50.

a) How much duty drawback does Digital International obtain for this set of shipments?

b) How much duty avoidance does Digital International obtain for this set of shipments?

c) Is this an optimal set of shipments if one takes into account all revenues, transportation costs, actual costs of production, and net tariffs? Note, any shipment among countries incurs a transportation cost of $50 per item, be it an LCD, MOB, or LAP. The actual cost of production in a country need not be the same as the tariff price in the country.

Incentive Supplier Contracts at Josco Food

Josco is a major supplier of grocery products. Josco's customers are grocery stores and super markets throughout the Eastern USA. Steve Patel is Manager of Marketing and Logistics at Josco and has been looking with a mixture of envy and concern at the inroads that Walmart has been making in the supermarket business. In particular, the kinds of innovative contracts that Walmart has had its suppliers, such as Proctor and Gamble, have been of interest. At the same time, Steve has been looking at Josco's business with one of Josco's biggest supermarket customers, Village Food. Steve is not completely satisfied with the current supply agreement between Josco and and Village Food, and is wondering about possible improvements. For example, Josco supplies Village Food with a certain kind of specialty bread, Bohemian Sourdough, for which Steve feels that both Josco and Village Food could benefit if Village Food would be willing to stock more, perhaps advertise it more, and perhaps sell it for slightly less. It costs Josco $20 per case to purchase required raw materials, prepare, and ship this product. This bread is a perishable product with just several days shelf life that Village Food purchases from Josco regularly. Village Food sells Bohemian Sourdough retail at a price that is equivalent to $50 per case. At the moment, Steve is not thinking about asking for a change in the retail price. There is enough competition in specialty breads so Village Food does not have a lot of freedom in changing the retail price. Village Food's own handling costs are $10 per case. Over the past several months, Village Food's has been ordering about 80 cases per week. Steve feels, however, that there is a lot of unmet demand and if Village Food carried a lot of stock, then the weekly demand for Bohemian Sourdough would in fact be about 100 cases, with a standard deviation of 25. After a bit of checking with various people at Village Food, Steve has verified that Village Food uses a simple newsvendor inventory model for deciding how much Bohemian Sourdough to buy from Josco. Transportation costs between Josco and Village Food are paid by Josco and are included in the Josco's cost per case. Village Food can dispose of unsold Bohemian Sourdough at no cost to an animal shelter.

a) Currently Josco charges Village Food $30 per case and give a no refund on unsold items. How much should Josco expect Village Food to order each week if it is following the newsvendor analysis?

b) What are the respective expected profits for Josco and Village Food under the conditions of (a)?

c) Steve feels that Village Food is not ordering enough of product Bohemian Sourdough each week. One reason that Village Food does not order any more is that it(Village Food) must eat(the cost of) any unsold bread. So Steve is contemplating giving a refund on unsold items in order to motivate Village Food to order more. As a starting point, suppose Steve wishes to maximize total profits for Josco and Village Food, without worrying just yet about how profits are split. What is total profit in this case? What wholesale price should Josco charge Village Food if Josco gives a full refund on unsold bread, and wants to maximize total profits? What are some of the operational hurdles of offering a full refund?

d) One thing that bothers Steve is that Village Food will not spend enough on forecasting if Josco gives a full refund, so Josco are thinking of giving only a partial refund. Josco feels that if Village Food spent a bit more money each week on forecasting, it could reduce the standard deviation(25 currently) in forecast error. What sort of arrangement with Village Food might be appropriate if poor forecasting is an issue?

e) What knowledge of Village Food's operation, costs, etc. do Josco need in order to structure the agreement appropriately?

f) Chief Financial Officer, Joe Shugan, is unhappy with the "Co-op" advertising program that Josco has with retailers such as Village Food. Heretofore, Josco has had a program similar to what General Motors

used through much of the 20th century. During a given year, Josco reimburses a retailer for all qualified advertising expenses up to 2% of their purchases from Josco in the preceding year. An example of qualified advertising is advertising of Josco products by the retailer in local wide circulation newspapers. Joe has heard a rumor that some newspapers give up to a 4% rebate at the end of the year to major advertisers. If this is true, it means that some retailers like Village Food might be making a modest amount of money from their advertising of Josco products. That is, the retailer rebills Josco(at least until the retailer hits the 2% limit) at full price for ads placed in the paper. So the ad effectively costs the retailer nothing, but then at the end of the year the retailer(at least according to the rumor) gets actual cash back. Joe is so angry that he is insisting that a) Josco reduce the Co-op support limit to at most 1.75% of purchases, and even further b) pay only 50% of each bill submitted by the retailer. E.g., if an ad invoice is for $1000, Josco will pay only $500 of it. Marketing manager Pete Ross is vigorously resisting this change, arguing that this advertising is very worthwhile for both parties, and he would hate to see Josco do something that would put more burden on the Village Food and cause Village Food to reduce advertising. Pete points out, for example, that some recent studies have indicated that for the modest levels currently used by the retailer, each dollar of advertising in fact generates about $1.50 of additional profit, exclusive of the advertising cost, for the entire system. At current wholesale prices, this profit in fact gets split approximately equally between the Village Food and Josco. How should we try to settle the argument between Joe and Pete?

g) Complicating life even further, Joe has been complaining about the $20 per case that Josco is getting from Village Food. As he phrases it in old American slang, "Josco may be baking the bread but Village Food is making the dough." Joe wants to raise to $22 per case the wholesale price that Village Food pays to Josco. Joe's argument is that Josco's costs have not been going down, while Village Food has been able to raise the retail price twice several times in the last few years. Ever the foil, Pete has warned Joe that Village Food may "walk" and switch to a different supplier if Josco arbitrarily raises the wholesale price.

Demand Planning at Mintendo Tools

31 May 2004

The following example is based, with permission, on the Red Tomato Tools and Mintendo Game Girl cases in Chopra and Meindl's book on supply chain management.

Mintendo Tools faces a situation common to many manufacturers of standard, high demand products such as breakfast cereals, beverages, and home appliances, namely, given demand forecasts for the next several months, how much should we plan to produce in each period?

Mintendo has recently started to do planning in a slightly more coordinated fashion, specifically, integrating the forecasting process with the pricing and production decisions. Historically, many companies would first make pricing decisions and do forecasting, and then turn the forecasts over to the people in operations with little thought of the cost impacts on production of the pricing decisions made by the marketing group. Mintendo uses the common term "Demand Planning" to describe the combined process of making pricing decisions and production decisions simultaneously.

The situation at Mintendo is that the month is June and Sandra and Bill are concerned about marketing and production plans for the next six months. Mintendo manufactures and sells the popular Game Girl(GG) electronic Toy. A summary of the manufacturing situation is listed below.

```
W0 = 300;   !Initial workforce size;
I0 = 50000; ! Initial inventory;
S0 = 0;     ! Initial backlog;
hpunit = .25;  ! Hours to produce a unit;
hpperd = 160;  ! Regular time hours per month/worker;
ovlim  = 40;   ! Overtime limit hours/worker per month;
chire  = $5000;  ! Cost of hiring a worker;
coff   = $3000;  ! Cost of laying off a worker;
wrate  = $15;    ! Wage rate/hour;
covt   = $22.50; ! Cost of over time/hour;
cinv   = 4;      ! Cost per unit of inventory/period;
crm    = $12;    ! Cost of raw materials/unit;
csubc  = $18;    ! Cost of subcontracting/unit;
invfin = 500;    ! Lower limit on final inventory;
psell  = $50;    ! Selling price/unit;
period = jul..dec; ! The periods;
! The demands;
 D = 100000 110000 130000 180000 250000 300000;
```

We see that demand is not constant, but rather increasing in a non-regular fashion. We expect demand to drop after December, so it is reasonable to plan up to December. There are several tactics that Mintendo Tools can use to meet the varying demand: i) a pure inventory policy would keep the work force constant but accumulate lots of inventory to meet the high demand in November and December; ii) alternatively, Mintendo could try to avoid inventory and simply use as much overtime as necessary in the high demand months; iii) an alternative to overtime would be to use subcontracting to cover demand in the high demand months; iv) and finally, Mintendo could hire additional workforce in preparation for the high demand months.

a) Given the four "tools" above for meeting varying demand, what is the best policy or mix of these tools to meet the above demand forecast?

Mintendo and its retailers sometimes use a very common marketing/demand planning idea, namely a "promotion". A promotion usually involves two things, a) lowering the price of a product for a short period of time, and b) advertising the product and its lower price. This usually attracts increased demand during the period of the promotion. The demand comes from three places: i) people who would have otherwise bought a competitor's product, ii) people who would have bought no product, or iii) people who would have bought our product later, but buy it now because of the lower price(so-called forward buying).

Sandra proposes lowering the price by $5 during September. Bill and Sandra both agree that demand would increase in September in two ways: i) demand would increase by 50% due solely to new customers who otherwise would not have bought GG, and ii) 30% of the GG demand during October and November would move forward to September due to forward buying. The people in production like Sandra's proposal because it results in a slightly smoother production plan.

Bill proposes instead, that the price be lowered by $5 during November. Bill and Sandra agree that demand during November would increase by 50% due to new demand, and 30% of the December demand would move to November because of forward buying.

b) Which plan delivers the most profit, i) no promotion, ii) running the price reduction promotion in September, or iii) running the price reduction promotion in November?

c) How would the results change if a discount of $10, rather than $5 must be given to achieve the desired demand increase?

d) Suppose the outsourcing costs increase to $22 per unit, although the $5 discount is still satisfactory. How do the recommendations change?

e) Because of continuous improvements in the product, it is not good to sell a GG that is more than one month old. Modify the model to include the feature that a GG cannot be carried in stock for more than one month. E.g., if a GG is manufactured in month t, it can be sold only in months t, or t+1. Test the effect of this requirement on November promotion proposal.

f) Hiring and Firing costs tend to be rather subjective estimates. What do you expect would be the effect on Bill's proposal of changing the Hiring and Firing costs to:
   Hiring and training costs are $4000 per worker,
   Layoff costs are $1000 per worker.

g) If you look at a typical production plan for a typical firm, you will almost never find backlogging of demand. Very infrequently might you find planned subcontracting of production. Nevertheless, the "Tomato" aggregate planning model from Chopra and Meindl has both of these features. How can you argue that, nevertheless, these are two useful features to have in a planning model?

h) Sometimes in the above we have referred to the September promotion alternative as "Sandra's plan" and the November alternative as "Bill's plan". What are some reasons why you might prefer one naming convention to the other in a practical setting?

Peapod/Webvan Delivery Route Planning

13 October 2003

Before Webvan's departure from the business scene, it competed with a number of other firms in the home delivery industry. In the Midwest, for example, it competed with Peapod. Just before its shutdown, Webvan merged with another quasi competitor, Home Grocer. A fundamental business question in any merger is the extent to which operational efficiencies can be obtained by merging two operations that serve much the same market. For example, in the inventory area, a crude first approximation is that doubling the volume through an operation increases the order processing and inventory costs by only about a factor of 1.4. You might expect that a similar economy of scale effect might exist for delivery operations such as Peapod, Webvan, Federal Express, and UPS. Let us try to answer this question with analysis of a simple Webvan/Peapod situation based on the data set below.

		Vehicle size=	200
Customer	X Coordinate	Y Coordinate	Delivery Quantity
1	0	12	48
2	6	5	36
3	7	15	43
4	9	12	92
5	15	3	57
6	20	0	16
7	17	-2	56
8	7	-4	30
9	1	-6	57
10	15	-6	47
11	20	-7	91
12	7	-9	55
13	2	-15	38

Data based, with permission, on
Chopra, A, and P. Meindl(2004), Supply Chain Management, chap. 14.

a) Suppose that Peapod's warehouse is at (X,Y) coordinates (0,0) and Webvan's warehouse is at coordinates (20, 3). Distances are in miles, and Euclidean/"Crow-fly" distances are appropriate. Variable cost per mile is $10. Further, suppose that Peapod serves customers 1, 3, 4, 7, 12, 13, while Webvan serves customers 2, 5, 6, 8, 9, 10, 11. The demands at each customer, in "mini-tote" baskets are as given in the table. Both firms have trucks with a capacity for 200 mini-totes. What are the delivery costs incurred respectively by Webvan and Peapod? You may find it useful to use the LINGO model peapod1.lg4. If you have not previously downloaded LINGO, see http://www.lindo.com.

b) Now suppose Peapod acquires Webvan's customers, but not Webvan's warehouse. Peapod serves all the customers out of it's original warehouse. Now what is the daily delivery cost for this set of customers?

c) What insights or observations can you make from these results from (a) and (b)?

d) When Webvan was operating, many of its customers were in the city of Chicago, nevertheless its warehouse was in the western suburb of Carol Stream. Continue with Peapod in (b); about what reduction might Peapod achieve(serving all 13 customers) if it moved its warehouse to a more central location?

e) One of the decisions a LTL distributor must make is the size of vehicle. Intuitively, using a larger vehicle should reduce the total number of miles, but for LTL deliveries the trade off is not clear. Suppose Peapod can lease vehicles with a capacity of 300 mini-totes, however, the variable cost increases to $11/per mile. Are these larger vehicles worthwhile? (Assume the setting of situation (b)).

f) Another firm that is in the grocery delivery business is "FreshDirect" in New York City, see for example, *Fortune*, 25 November, 2002. Most of its customers are in Manhattan. Considering the layout of Manhattan, disregarding Broadway, how might you change the formula you used for computing the distance matrix? You need not re-do (a)-(e).

g) With the popularity of GPS systems, the coordinates of locations are frequently given by latitude and longitude. Suppose that were the case here. How would the analysis need to be changed?

Related spreadsheet: Peapod1.xls
Related LINGO model: Peapod1.lg4

National Air Fleet Routing and Assignment

9 February 2004

National Airlines has an aging fleet of aircraft. The fuel efficiency of the fleet is not competitive with the aircraft that are being acquired by some of National's competitors. Frank Young, the chief operating officer of National, is looking for ways to improve the performance of his fleet within the constraints of his limited budget for upgrading the fleet. Frank has decided upon a three-pronged attack on the problem: a) do a better job of routing the current fleet so that more flights are covered by a limited number of aircraft, b) acquire a limited number of the newer, more fuel efficient and slightly larger aircraft, and c) assign the aircraft(new or old) to flights so as to best exploit the differing capabilities of the different aircraft. To try out ideas, Frank has gotten a list of the eleven most important flights in National's daily flight schedule.

The following set of flights serve Chicago (ORD), Denver (DEN), and Los Angeles (LAX)on a typical weekday:

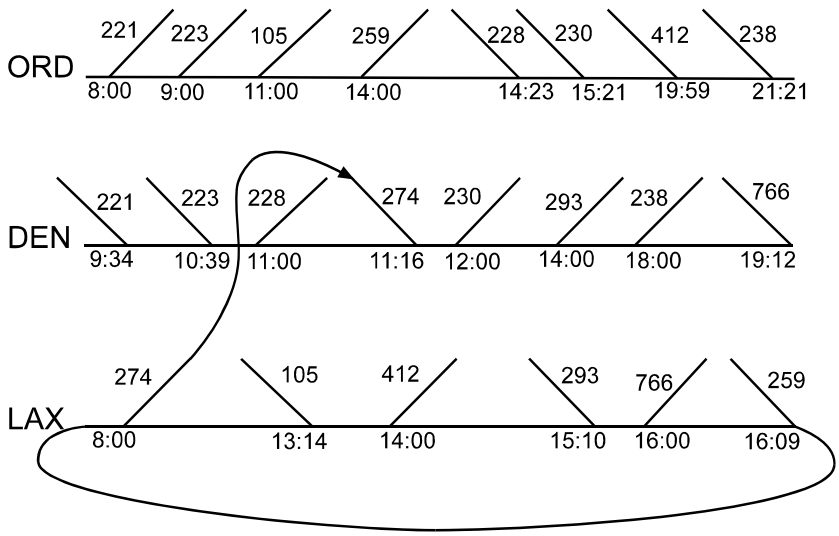
Daily Flight Schedule

		City		Time	
	Flight	Depart	Arrive	Depart	Arrive
1	221	ORD	DEN	0800	0934
2	223	ORD	DEN	0900	1039
3	274	LAX	DEN	0800	1116
4	105	ORD	LAX	1100	1314
5	228	DEN	ORD	1100	1423
6	230	DEN	ORD	1200	1521
7	259	ORD	LAX	1400	1609
8	293	DEN	LAX	1400	1510
9	412	LAX	ORD	1400	1959
10	766	LAX	DEN	1600	1912
11	238	DEN	ORD	1800	2121

Currently, seven aircraft are used to cover these eleven flights. Frank is wondering if he can do it with less. Frank has checked around and found that the trucking industry faces somewhat similar problems in moving truckloads of goods around the country. The basic problem is, given a set of shipments or flights to be made, the routing part is concerned with the path each vehicle takes. This is sometimes called the FTL(Full Truck Load) routing problem. In contrast to truck FTL routing, National, and most other airlines do not use "deadheading" or re-positioning links. Every movement of an aircraft from one city to another city is exploited as a direct revenue generating opportunity, -think of "red-eye" flights from the west coast of the U.S. around midnight to the east coast.

A traditional graphical way of looking at such problems is shown in Figure 1 below.

Figure 1: The Fleet Routing Network for National



The interpretation of this as a network is that we want find feasible flows through this network, where:

a) Each diagonal line (with the connection to its partner) corresponds to a flight;
b) each horizontal line or backloop corresponds to zero or more aircraft on the ground;
c) at each point of either an arrival or a departure, conservation of flow must be adhered to, i.e., in words:

(no. of aircraft on the ground at this city at this instant) + (arrivals at this instant)
= (no. of departures from this city at this instant)
+ (no. of aircraft on the ground after this instant).

Question: How many aircraft does National need, and how should Frank route them?

Fleet Assignment

The new aircraft, the B737-6, that Frank is contemplating, is substantially more fuel efficient per passenger mile than the current old aircraft, the MD90. The new aircraft is larger, however, so that on a typical flight, it actually uses slightly more fuel. It can be substantially more profitable on a flight, only if there is enough additional demand that can be attracted to use the additional capacity. Thus, on a low demand flight, the new aircraft will be less profitable, but on a high demand flight, where the additional capacity can be exploited, the new aircraft will be more profitable. The estimated relative profitabilities are shown in the table below.

Profitability of the B737-6 relative to the MD90:

Flight	Origin	Dest.	Depart	Arrive	Profit Improvement factor for B737-6
F221	ORD	DEN	800	934	.9652
F223	ORD	DEN	900	1039	1.1743
F274	LAX	DEN	800	1116	.8062
F105	ORD	LAX	1100	1314	.7407
F228	DEN	ORD	1100	1423	.8160
F230	DEN	ORD	1200	1521	.7955
F259	ORD	LAX	1400	1609	1.1518
F293	DEN	LAX	1400	1510	1.2476
F412	LAX	ORD	1400	1959	1.3107
F766	LAX	DEN	1600	1912	.8203
F238	DEN	ORD	1800	2121	.7891

For example, on flight 223 the B737-6 is more profitable than an MD90 by a factor of 1.1743.The above pattern of flights is to be covered every day. Suppose that we have seven MD90's available, but only one B737 available to cover these flights. As before, we assume no deadheading.

Question: If only oneB737-6 is acquired, what is the most profitable way to assign and route the MD90's and the B737 to flights?

(Note, in terms of absolute levels of profit contribution for the MD90, they are: F221: $11,500, F223: $10,900, F274: $12,900, F105: $13,500, F228: $12,500, F230: $13,200, F259: $11,200, F293: $10,500, F412: $10,300, F766: $12,800, F238: $12,800)

Other Notes

Other examples of airline fleet routing and assignment are described by Subramanian et al. (1994) in their discussion of fleet routing and assignment at Delta Airlines. A similar approach has been used at US Airways by Kontogiorgis and Acharya (1999). In the trucking industry, repositioning or deadhead legs are common. An air transport setting where repositioning links are also common is in the private or charter jet market.

Lexington DC Location

13 October 2003

The Lexington Corporation serves essentially two markets, East and West, and is contemplating the location of one or more distribution centers (DC) to serve these markets. A complicating issue is the uncertainty in demand in each market. The firm has enumerated three representative scenarios to characterize the uncertainty. The table below gives (i) the fixed cost per year of having a DC at each of three candidate locations, and (ii) the profit per year in each market as a function of the scenario and which DC is supplying the market. Each market will be assigned to that one open DC that results in the most profit. This assignment can be done after we realize the scenario that holds. The DC location decision must be made before the scenario is known.

Profit by Scenario/Region and Supplier DC

		Scenario One		Scenario Two		Scenario Three	
DC Location	Fixed Cost	East	West	East	West	East	West
Lexington	63750	150000	26250	26250	50000	137500	13750
Amarillo	61250	137500	35000	40000	115000	87500	87500
Ogden	65000	75000	48750	25000	136250	25000	110000

For example, if Scenario Three holds and we locate DC's at Lexington and Ogden, East would get served from Lexington, West from Ogden, and total profits would be 137,500 + 110,000 – 63,750 – 65,000 = 118750.

a) If Scenario One holds, what is the best combination of DC's to have open?

b) If Scenario Two holds, what is the best combination of DC's to have open?

c) If Scenario Three holds, what is the best combination of DC's to have open?

d) If all three scenarios are equally likely, what is the best combination of DC's to have open?

e) A reasonable question with decision making under uncertainty is: "How much is poor forecasting costing us?" One way of answering the question is to think as follows. Assume that the probability of each scenario remains unchanged, however, we have a perfect forecasting system, so that before we have to commit to where we locate our DC('s), we find out which scenario is going to occur. We can calculate our expected profit if we have a perfect forecasting system and compare that profit with the case where we have to choose our DC configuration before we find out which scenario holds. The difference in the two expected values is the value of a perfect forecast. This is an upperbound on the benefit of investing in improved forecasting. Note, when we say we have a perfect forecast, it does not mean we can choose our favorite scenario, it only means we find out which scenario will occur before we have to make our decision. The probability of each scenario remains as originally estimated. Do this analysis for the Lexington's problem to determine the expected value of a perfect forecast. This analysis is sometimes also known as the Expected Value of Perfect Information(EVPI). Note, your results from (a), (b), (c), and (d) can used to answer this question.

Covington Microwave Warehouse Management

15 October 2003

Covington Microwave(CM) sells a wide variety of consumer electronics products, mainly automotive accessories, to automotive hobbyists. For example, some of CM's most popular product families are customer installed car radios, and various other electronic and mechanical devices for cars. When Covington Microwave started it was strictly a mail order business. Next it started to receive more orders by phone on its 800 number. Now a significant fraction of its orders come in from its extensive and easy to use website. Because of its innovative and high quality products, CM has an international reputation and gets a modest number of international orders. From the beginning, Covington has advertised fast service as a strong point. All products are shipped from its single warehouse in Covington, KY.

Orders get shipped by a variety of modes including, but not limited to, U.S. mail, Fed Ex, UPS, and DHL for international orders. Almost any hour of the day, there is some carrier stopping by to pick up shipments. Historically, CM has picked orders in two "waves", one in the morning and one in the late afternoon. The warehouse manager, Tom Michaels is thinking of adding a third wave to further improve response time. Waves are used to strike a compromise between response time and high labor usage. If each order was picked as soon as it came in, the pickers would spend a lot of time walking about the warehouse to collect each of the line items in an order. By batching many orders into a wave, a picker can pick a large number of items as he or she walks along an aisle, thus substantially reducing the amount of walking time per item picked. All the items picked are then sorted by order in the shipping area before being loaded on the outgoing trucks.

In discussions with the chief executive, a target response time for the warehouse of four hours has been established. That is, CM would like to claim that the average time between receipt of an order to when it has been picked and ready to ship is less than four hours. Can Tom do it by adding only one more picking wave?

Data for an average day are shown below. Although not shown in the table, there are differences in the characteristics of the three different kinds of orders. Mail orders have an average of 3.1 line items per order; Phone orders have an average of 2.2 line items per order; and orders placed on the website have an average of 1.3 line items.

Hour	Mail orders	Phone orders	Web orders	Total Arriving Orders
1	0	0	2.8	2.8
2	0	0	4.6	4.6
3	0	4.4	5.4	9.8
4	0	6.7	6.4	13.1
5	0	12.1	5.6	17.7
6	0	14.5	11.8	26.3
7	0	17.4	12.2	29.6
8	6.4	14.8	10.2	31.4
9	44.3	12.9	16.6	73.8
10	16.9	18.8	14.8	50.5
11	0	22.9	12.2	35.1
12	0	24.1	18	42.1
13	11.5	17.2	21.2	49.9
14	29.2	14.9	19.4	63.5
15	7.2	12.7	16.4	36.3
16	0	16.5	14.2	30.7
17	0	20.9	7.2	28.1
18	0	26.6	7.8	34.4
19	0	23.4	19.1	42.5
20	0	18.6	22.4	41
21	0	16.6	24.8	41.4
22	0	11.1	15.2	26.3
23	0	8.1	12.6	20.7
24	0	4.6	9.8	14.4

See also the spreadsheet: Covington.xls

Acknowledgment:

Portions of this material are based, with permission, on the paper:

Gue, K.(2002), “Timing Picking Waves in a Warehouse”, working paper, Naval Postgraduate School.

Flo-Glass, Inc. Contract Analysis

It is contract renewal time at FLO-Glass, Inc. FLO is a major supplier of automotive glass to the major automobile manufacturers. Although it may be possible to make a lot of money from one of these contracts in a good year, these contracts can be risky. If FLO does not sign enough contracts and the automotive industry has a bad year, the volume may be so low that FLO is left with a lot of idle capacity and low profit. Surprisingly, if the automotive industry has an extremely good year, this also may be bad for FLO because of its limited capacity and the penalty clauses that are in a typical contract. Notable features of these "new car" supply contracts with the auto manufacturers are:

a) very high unit volume on average,
b) low margin per unit(a big customer can drive a hard bargain),
c) all or nothing nature, i.e., if FLO signs a supply contract, it is expected to supply all the glass needed for the entire production run,
d) high shortage penalties,
e) unspecified production run lengths(if the car involved has low sales, too bad for FLO, but if it has high sales, FLO is expected to deliver all the glass needed.)

In the short run, e.g., the next two years, it is not possible for FLO to increase its limited capacity. Although different customers buy different products from FLO, it a a good first approximation to simply use just a single measure of demand and capacity. A convenient unit is the approximate amount of glass needed for one vehicle. According to this measure, FLO has a capacity of 2 million units per year. Spare capacity can be sold to the "after-market" market, e.g., replacement glass for auto repair shops, if there happens to be sufficient demand there. This market has a higher profit per unit but the total demand available is substantially less than 2 million units. Also, it is a spot market, so there are no explicit(and essentially no implicit) shortage penalties for unmet demand, other than missed sales revenue. FLO is concerned about which contracts to sign with the major auto manufacturers. If it signs too many contracts and the demand is high, it could face substantial penalties. FLO has four possible contracts on the table that it is considering signing, GM Car, GM Light Truck, Honda Car, and Toyota Light Truck. These markets, as well as the after market, are summarized below.

Product	Profit Contribution/unit	Shortage Penalty/unit
GM Ltrk	$29	$53
Honda car	$27	$53
Toyota Ltrk	$26	$52
GM Car	$25	$51
After Mrkt	$40	$0

If FLO has insufficient capacity to satisfy an automotive manufacturer on contract, not only does FLO not get the revenue, it must also pay the shortage penalty. FLO is concerned about which contracts to accept.

Based partially on historical data as well planning meetings that look to the future, FLO has constructed the following sixteen scenarios that FLO thinks are representative of what might happen in the market next year.

Demands by Scenario and Contract

Scenario	GMTRK	HONDA	TOYTRK	GMCAR	AFTER
1	545377.	609195.	354601.	535385.	132709.
2	712269.	492170.	257670.	936099.	84107.
3	451587.	814142.	329591.	611454.	91386.
4	583456.	724199.	332920.	818098.	96964.
5	241442.	759158.	564812.	452093.	104367.
6	803935.	524053.	530819.	797459.	88489.
7	421792.	777425.	565341.	298634.	26941.
8	700756.	720928.	459036.	664503.	36673.
9	496134.	574435.	389440.	1071180.	79705.
10	559823.	657482.	185573.	1062185.	68398.
11	318898.	757431.	467412.	959270.	47408.
12	878921.	609571.	326202.	1120281.	57900.
13	376157.	691203.	498707.	771531.	107246.
14	632192.	608392.	536971.	1025865.	123693.
15	482043.	896929.	481163.	754764.	74491.
17	640950.	687033.	413539.	897730.	62782.

For references, some of the summary statistics of the above scenarios are:

Means:	552858.25	681484.13	418362.31	798533.19	80203.69
S.D.:	167769.22	105156.35	109782.91	230327.10	28759.49

Correlation matrix is:

GMTRK	1.000000				
HONDA	-0.601612	1.000000			
TOYTRK	-0.341202	0.290361	1.000000		
GMCAR	0.461087	-0.472725	-0.468730	1.000000	
AFTER	-0.095905	-0.276581	-0.024993	0.009610	1.000000

From the correlation matrix one can observe that the volumes of the GM Car and the Toyota Light Truck are quite negatively correlated, -0.472725. Thus, it might be sensible to have these two contracts in the same "portfolio". If one of them has low volume, the other is likely to have a high volume. Each scenario is considered equally likely.

a) Which contracts should FLO sign?

b) FLO is somewhat risk averse. In particular, its major shareholder has let it be known that he will be unhappy if the profit is less than $46,000,000 for the coming year. Just exactly how unhappy is subject to debate. Should FLO take this into account and if so, how might it affect the contract decision?

c) A possible issue that may arise in negotiating with GM is that it may say: "You either take both the GM Car and the GM Light Truck contracts or you do not get either". Is this a good idea for FLO?