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Instructor's Notes for Llenroc Plastics: Market Driven Integration of Manufacturing and Distribution Systems[1]

by

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LLENROC PLASTICS:
MARKET-DRIVEN INTEGRATION
OF MANUFACTURING AND DISTRIBUTION SYSTEMS

INSTRUCTOR'S NOTES
JANUARY, 1994

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CASE 1 PROGRESS REPORT MEETING

The Case 1 Progress Report Meeting is usually scheduled within one week of the case being assigned. The students need at least one weekend to begin work on the case. The meeting is informal. Typically, the students have finished assignments 1 and 2 by the time of the meeting. The goal of the meeting is to make sure that the students understand the issues involved in the case. The personal contact between students and faculty keeps both groups motivated. The meeting takes about 25-30 minutes per team.

Discussion 1.

What are the important features of the Atlanta Transportation System?

How are the goals of the manager and the dispatcher in conflict?

Assignment 1.

We provide substantial guidance on this assignment.

How did you classify costs into truck-related, mileage-related, and driver-related?

Use a discounted cash flow approach for the truck-related costs but not for the mileage or driver costs. The most accurate treatment of truck costs requires an after-tax analysis. Since one cost category is treated after-tax, make sure that all other costs (i.e. mileage and driver) are expressed on an after-tax basis, as well.

What terminal value did you use in order to compute depreciation?

What terminal value did you use for the cash inflow associated with disposing of the truck at the end of its economic life?

Is there a taxable gain or loss on the sale of the truck? This should be included in the after-tax cash flow.

What assumptions did you make for the timing of cash flows? (Truck purchase occurs at the beginning of the year. Tax benefit of depreciation is end-of-year. Truck sale is at the end of the fifth year. Registration and insurance are beginning-of-year cash flows.)

How are you going to handle the traffic manager's salary? (Don't allocate to any of the volume-based cost measures. Keep it separate as a fixed cost for the purpose of the assignments in this case.)

Assignment 2

What assumptions are you making about the weekend and the following week? (Allow two days of driving on the weekend. Allow weekend deliveries. Make sure trucks are available for use on Monday and Tuesday of the following week. Otherwise, you will understate the number of trucks your solution really requires.)

Assume returning trucks (even after a 2 hour run) cannot be sent out until 2 hours later (i.e. assume 2 hour loading and driver changeover time). Assume a 10 hour day (to be consistent with the graphical version of Transportation game).

Don't spend too much time on this assignment. Its purpose is to acquaint you with the dispatching problem and the cost and customer service implications of dispatching. Possible discussion: what real-world factors are ignored in the game?

Assignment 3

How easy is it to find an optimal solution to the dispatcher's problem? (It is NP hard. N is small in this game, but in reality there were lots of customers.)

Many heuristics are possible for this problem. Students are frequently quite creative on this one. The chief difficulty is in explaining your algorithm. You may use a flowchart to express it but statements such as "select a route" or "pick the best order to add to the route" are too vague. You will be graded on the clarity, completeness, and robustness of your algorithm.

Discussion 2

In assignment 1 we focused on customer wait time as the transportation time. To what does customer wait time refer now? (If orders are being consolidated, then we should include the review cycle time. Customer wait time will increase. On the other hand, later cases will concentrate upon improving the fill rate so customer service should improve.)

Will customers change their order patterns if we practice demand management? (If we always ship to a certain city on the same day, some customers will synchronize their order cycles with our shipping cycle.)

Assignment 4

As in assignment 2, don't spend too much time on this. Recognize that there should be a cost savings to demand management. What is the impact on customer service? If it is negative, can you think of ways to counteract the negative features in order to achieve the cost benefit.

Assignment 5

Note that for this version of the problem the routes have already been selected. The problem is to select from among these routes and to allocate demand to the different routes. This is an easier problem and worthwhile exploring a formal mathematical programming formulation.

Would it make sense to generate all possible routes from which to choose? (No. It is very unlikely that Tampa, Alexandria, and Memphis will ever be on the same route in an optimal solution. Assume there are N routes pre-selected as likely candidates.)

There are different formulations of this problem depending on whether you want to emphasize customer service or cost and depending on how detailed you want to model truck scheduling.

Your algorithm to find an initial solution may be the only algorithm that is implemented. Look for a greedy heuristic.

Discussion 3

The questions in this discussion are very important for determining your overall strategy. If there are patterns in the way customers order or in the distribution of customers then perhaps the transportation system can be tailored to exploit them. For example, look at the data of Table 1.9. Note that this unscaled data; data associated with the game of assignments 2, 4, and 6 have been scaled down.

Is there any pattern in the way Herman Miller places orders? (Once per week, generally on Wednesday.)

How many sheets does Jackson Supplies order per order? (One sheet: 3'x8' = 24 sq. ft.) What does one of these sheets sell for? (A sheet sells for about $12.48 [=$.52/sq ft x 24 sq ft], see introduction chapter.) How much money do we make on these orders? (We lose money: cost of driver time, fuel and truck costs, and paperwork costs would outweigh the gross margin.) How do you think the sales manager is measured? (Number of square feet sold.)

Assignment 6

The issue this assignment raises is "should Llenroc Plastics be in the trucking business?" Historically, companies such as Llenroc Plastics set up their own transportation systems because the alternatives were so expensive. The trucking business was deregulated in the early 1980's leading to increased competition and lower trucking rates. Companies that maintain fleets of delivery trucks for their own products now have economic alternatives and should reconsider the design of their transportation systems.

Why could a common carrier achieve a lower cost than Llenroc Plastics? After all, they face the same or similar costs of trucks, mileage, and drivers. (Llenroc Plastics faces the backhaul problem: even if its trucks go out full, they return empty, often from considerable distances. The real company upon which this case is based attempted to find shipping business to fill trucks on the return trip to Atlanta. Imagine the dispatcher's problem for that!)

What impact would the use of common carrier have on customer service? (The carrier takes time to consolidate shipments just as in the demand management assignment. This time needs to be included in measures of customer wait time.)

Assignment 7

You may assume that the fill rate problem (the unavailability of stock to completely fill orders) will be solved by the time your recommendations for the transportation system are implemented. This fill rate problem motivates many of the remaining cases in this casebook.

We are looking for a verbal response to this question. That is, don't try to estimate the cost of disposing of the existing fleet of trucks or the level of customer service that will be achieved. Instead, review the issues of the case, identify patterns of demand that can be exploited and propose ways to improve the profitability (both short and long term) of the business.

LLENROC PLASTICS

INSTRUCTOR'S NOTES

CASE 1 ORAL REPORTS

The oral report session should last 30 minutes and needs to be tightly timed. The students should be given 20 minutes to present their results with minimal interruptions. In the remaining 10 minutes, the instructor should critique their approach. This critique will be based primarily on the written report that was submitted in advance of the oral presentation.

Common problems in case 1 are:

- Incorrect economic analysis in assignment 1
- Failure to include truck costs in assignments 2 or 4
- Vague or incomplete description of heuristic in assignment 3
- Failure to reduce number of trucks in assignment 4 (one of the chief advantages of demand consolidation)
- Incorrect MILP in assignment 5
- Failure to recognize simple heuristic to get initial solution in assignment 5
- Failure to focus on transportation-related issues in assignment 7. (Some teams start focussing on warehouse location and inventory-related issues and have little to say about transportation.)
- Failure to exploit the observations raised in discussion 3 as part of assignment 7

Note that there are at least two approaches to the math. prog. problem of assignment 5. One approach is just to worry about assigning demand to routes. This formulation has a simple heuristic associated with it (pick route that serves that city with lowest cost). For extra credit, another approach is concerned with truck scheduling and attempts to assign a single truck to more than one route. Truck availabilities by day of the week are constraints in that formulation.

In discussing assignment 7 with the students, I will suggest a variety of strategies that they could have considered. In particular, the common carrier alternative is so much cheaper than running a trucking system, the economics drives one to the solution of selling all the trucks and using common carrier for all shipments. The concern then is with customer service. The case mentions that common carrier consolidation time is 3-5 days. I ask the students what would make it 3 days rather than 5 days. They typically recognize at that point that if we provided the common carrier with a full truckload for a particular destination, then the common carrier could be expected to ship it immediately.

When one notes that the very large customers tend to order close to full truckload quantities, that they account for 80% of the business, and they place orders on a regular basis, the common carrier strategy would likely result in very good customer service for most of our business. For the remaining customers, a consolidation time of 5 days plus a 4 day transportation time would still place our delivery performance less than Wilson's 10 days, assuming the fill rate problem is solved.

The small customers are not ordering in economic quantities. We could allow them to suffer the common carrier delays or pay a premium for small order rapid service. It is an unrevealed fact of the case that a single sheet of laminate can be rolled up, placed in a large cardboard tube, and shipped using UPS (United Parcel Service).

When considering the issue of customer service, it is useful to ask the students to identify "who is the customer." As pointed out to them in the progess report meeting, the large customers are OEMs who use MRP systems and place orders on a regular basis. One day delivery service is not likely to be important to them in their current environment. As long as we have the material in stock and can get it to them within the week, they are likely to be satisfied with our service. Strategies to improve fill rate will drive our market share with these types of customers. Assuming the fill rate performance becomes competitive, common carrier should be more than adequate delivery service for these customers.

If students strongly favor keeping trucks (and most do), I note that the fixed routes they arrived at in assignment 5 could be used on a regular basis with good customer service and truck utilization even without knowing all the demands in advance. What has to be abandoned is the policy of sending a truck to satisfy every customer order on the day it is ready for shipment. Note that a fixed route solution is likely to service Tampa and Raleigh twice or more per week. If these trips are staggered in time, then a major customer is unlikely to have to wait very long for a shipment.

What did the company do in reality? They got out of the trucking business. They established a special relationship with what is called a contract carrier. Unlike a common carrier, a contract carrier is willing to provide specialized service depending on the client's needs (Llenroc Plastics is the client). Llenroc was able to negotiate the kind of customer service it wanted the carrier to provide for a contract price that was considerably below their current cost of operating the fleet of trucks. Analysis similar to that conducted in this case was the basis for their negotiations. Note that the contract carrier is in the trucking business: it has many opportunities for backhaul and it can afford sophisticated data management and decision support software.

The oral critique should also encourage the students. Most teams put an extraordinary effort into case1 and they should be praised for their efforts.

Ballpark answers to case 1 assignments:

1. Truck costs in $164-173/week range (assumptions vary).

   Mileage costs = $0.1348/mile

   Driver cost = $8.22/ hour

2. Use all ten trucks, approximately 17,000 miles, approximately 448 driver hours, with an after-tax cost around $7800. Check to ensure that at least three trucks are available on the following Tuesday, assuming similar demands to the first week.

3. Heuristic solutions for this assignment are legion. Focus on clarity of expression.

4. Use 4 to 6 trucks, approximately 7600 miles, approximately 190 driver hours, with an after-tax cost around $3700.

5. Formulation on next page.

6. Common carrier cost is $1722. Note that the cost of serving Atlanta is unrealistically low. The common carrier is unlikely to accept local business. Ignore that for the analysis.

5. Simple formulation:

Decision variables:

Let w_k = number of trips using route k each cycle:

x_{ik} = number of square feet shipped to location i using route k

z = overtime per cycle

Parameters:

Let c = capacity of truck

M_{ik} = M (large number) if location i is not on route k; 0 otherwise;

l_k = length of route k in hours of driver time

a_k = cost of route k: fuel cost and driver cost:

g = overtime cost per hour (driver overtime premium)

f = number of regular time driver hours per cycle.

Formulation (for fixed number of trucks and drivers):

$$\min \sum_k a_k w_k + \sum_{i,k} M_{ik} x_{ik} + gz$$

$$s.t.$$

$$\sum_k x_{ik} = d_i; \quad \forall i \quad \text{(demand satisfaction)}$$

$$\sum_i x_{ik} \le c w_k; \quad \forall k \quad \text{(truck capacity per cycle)}$$

$$\sum_k l_k w_k - z \le f; \quad \text{(driver overtime)}$$

$$x_{ik} \ge 0; \forall ik$$

$$w_k \in \{0,1,2,3,\dots\}; \forall k$$

$$z \ge 0.$$

Heuristic solution: every location will be assigned to one route: for location i, pick the route with the smallest a_k/l_k ratio for which M_{ik} =0.

A more complicated formulation is possible that tracks the day on which trucks leave, the route they follow, and the day they return. Variables include y_{jt} (number of trucks following route j beginning trip on day t) and x_{ijt} (amount shipped to location i on route j with trip initiated on day t). Constraints include demand satisfaction, truck capacity, and daily truck availability. The objective function can include the total capital cost based on the number of trucks required.

LLENROC: CASE 1, ASSIGNMENT 1

EOY	BTCF	DEP.DED.	TI	CFIT	ATCF	Weeks	NPV
0	($39,000)				($39,000)	0	($39,000)
0	($2,300)		($2,300)	$1,035	($1,265)	0	($1,265)
1	($2,300)	$6,240	($8,540)	$3,843	$1,543	52	$1,342
2	($2,300)	$6,240	($8,540)	$3,843	$1,543	104	$1,167
3	($2,300)	$6,240	($8,540)	$3,843	$1;543	156	$1,015
4	($2,300)	$6,240	($8,540)	$3,843	$1,543	208	$882
5	$0	$7,040	($7,040)	$3,168	$3,168	260	$1,575
5	$7,000				$7,000	260	$3,480
					NPV=		($30,804)

EQUIVALENT WEEKLY= ($164)

TAX RATE= 45%
AFTER TAX COST CAP.= 15%
Effective Weekly= 0.002691

NOTE:

1) Insurance and registration expenses are incurred at the beginning of a year while depreciation and capital losses are incurred at the end of a year.
2) Depreciation is computed using the straight line method, the purchase price and the end of term book value.
3) The $800 discrepancy between the book value and wholesale value is absorbed as a capital loss at the end of year 5.

VARIABLE OPERATING EXPENSES:

PER MILE: (0.125 + 0.12) * (1 - 0.45)= 0.13475

PER HOUF 13.00 * 1.15 *(1 - 0.45) = 8.2225

Possible solution for trucking schedule TRUCKS.WK1

Truck #	Mon.	Tue.	Wed.	Thu.	Fri.	Mon.	Tue.	Wed.	Thu.	Fri.
1	1.1	1.1	1.1	1.1	1.1	1.1	2.1	2.1	2.1	2.1
2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1
3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	2.1
4		2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
5		3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
6		3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2
7		3.2	3.2	3.2	~~~~	3.3	3.3	3.3	3.3	3.1
8			2.1	2.1	2.1	2.1	2.1	2.1	3.2	3.2
9			3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
10				1.2	1.2	1.2	1.2	1.2	1.2	1.2

Groups	Routes	# of Days	Depart Day
1.1	12-11-1-5	2.3	[R]
1.2	10-8-9-13-7-14	3.9	[M]
1.3	6-2-3-4	2.7	[T,R]
2.1	)-8-9-14-13-7-12-11-1	5.8	[W]
2.2	6-2-3-4	2.7	[M]
3.1	12-11-1-6-5	2.8	[W]
3.2	10- 8- 9	2.4	[F]
3.3	14- 13- 7	3.2	[M]
3.4	2- 3- 4	2.6	

Route Code	City
1	Birmingham
2	Jacksonville
3	Orlando
4	Tampa
5	Atlanta
6	Macon
7	Baltimore
8	Charlotte
9	Raleigh
10	Columbia
11	Memphis
12	Nashville
13	Alexandria
14	Richmond

Possible solution for trucking schedule MGMT.WK1

Truck #	Mon.	Tue.	Wed.	Thu.	Fri.	Mon.	Tue.	Wed.	Thu.	Fri.
1	3.1	3.1	3.1	2.2	2.2	2.2	2.2	3.2	3.2	3.2
2	2.1	2.1	2.1	1.1	1.1	1.1	2.2	2.2	2.2	2.2
3	4.1	2.2	2.2	2.2	2.2	3.1	3.1	3.1	2.2	2.2
4		4.1	2.3	2.3	2.3	2.3	4.1	2.3	2.3	2.3
5			3.2	3.2	3.2	2.1	2.1	2.1	1.1	1.1
6					3.3	3.3	3.3	4.1		3.3

Groups	Routes	# of Days	Depart Day	Max. Wait
1.1	5-1-11-12	2.3	[R]	1.4
2.1	9- 8- 10	2.4	[M]	
2.2	9-14-13-7	3.3	[T,R]	1.5
2.3	14-9-8-10-5	3.3	[W]	
3.1	3- 4	2.4	[M]	
3.2	6-2-3-4	2.7	[W]	
3.3	5- 4	2.3	[F]	1.1
4.1	5	0.2	[M]	

Route Code	City
1	Birmingham
2	Jacksonville
3	Orlando
4	Tampa
5	Atlanta
6	Macon
7	Baltimore
8	Charlotte
9	Raleigh
10	Columbia
11	Memphis
12	Nashville
13	Alexandria
14	Richmond

Llenroc Plastics

Instructor's Notes

Case 2 Oral Progress Reports

This meeting should only last about 20 minutes. The purpose of the meeting is to get the students to look at the data of the case. The overall purpose of the case is to help the students understand why fill rates are so poor at the Atlanta Distribution Center. The students do not need to recommend a strategy to improve fill rate performance yet. They should return to this question in case 7. The requirements for case 2 are satisfied with a written report that addresses the four assignments of the case. If time is limited, the instructor can make assignment 4 optional and restrict assignment 2 to graduate students only. If time is severely limited, the instructor can choose to cover the main points of the case in a lecture and not assign any work with the case.

Assignment 1 asks the students to conduct different A-B-C analyses. We typically provide a handout describing A-B-C analysis for students who have not been exposed to the concepts. The discussion in the text by Silver and Peterson referred to in the case is usually sufficient. Caution the students that they will be performing many different A-B-C analyses in Llenroc Plastics and they need to keep them straight in their minds. For example, in case 1 we looked at an A-B-C analysis of customers. This is an A-B-C analysis of items by two different measures of volume. Later, they will group items by sheet dimensions (case 6) and conduct an A-B-C analysis of dimensions.

Different textbooks give different rules for where to break the parts into A, B, and C categories. The students may choose their own breakpoints as long as they are consistent when comparing the two measures of volume.

Direct the students' attention to Table 2.6. Explain that the coefficient of variation is the ratio of the standard deviation of demand to the mean demand. It is a unit-less measure of variability. From the table note that the c.v.'s are quite high. In modelling the distribution of demand, we would not want to use the normal distribution for c.v.'s much higher than 0.5. The reason is that the normal distribution is a thin-tailed distribution and a high c.v. typically indicates that the true distribution has a thick tail. In fact, with the c.v.'s of Table 2.6, we will not be confident of any classical distribution model of demand. We love to teach nice inventory models but most of them will likely understate the amount of safety stock required in such a system.

Next, direct the students' attention to Table 2.2. Note how hard it would be to plan production or to maintain adequate safety stock with these order patterns.

In Table 2.3, we show how much of the previous table orders is explained by the orders placed by large customers. This illustrates that when a small number of customers accounts for a large portion of your demand, you can expect a more variable demand stream. Why are most of the orders in multiples of 50? The reason is that Llenroc Plastics encourages orders in groups of 50. (The manufacturing plant groups the sheets in lots of 50 and shrink-wraps them.) Observe, how this causes lumpy demand, particularly among lower demand items.

In Table 2.4, we show the order patterns of smaller customers. In the aggregate it is smoother than the order patterns from the larger customers.

In Table 2.5, we look at the real demand of the customers. The story here is that we talked with our customers and collected data on their actual consumption rates of the product. Note that this is much smoother than in the previous tables. The conclusion is that the lot sizing rules of the customers are causing much of the variability in demand for our product.

In assignment 2, we study Table 2.5 in more detail. Ask the students how the standard deviation of a Poisson process is related to its mean. The answer is that it is the square root of the mean. In Table 2.5, we observe that the standard deviation of demand is approximately the square root of the mean demand which suggests that the underlying distribution is Poisson. So a classical demand model works for the real consumption rate data. When we study order data however, lot sizing rules make it much more difficult to model.

The appendix describes how to perform a test for the Poisson distribution but as stated it is not adequate for high demand rate items. Consequently, the appendix has been amended showing the students how to group the observations into cells. Note that with only a few degrees of freedom it will be difficult to reject even the uniform distribution. Do the students expect that they will have more than 36 months of data to test such hypotheses in practice? This illustrates the practical point that it is very difficult to fit distributions to actual demand data.

Finally, it is not necessary to test every part number: select three or four part numbers to test.

In Assignment 3, students should note that the coefficient of variation increases with the square root of the lead time. They should also observe that safety stock increases with the coefficient of variation and that low volume items (high coefficient of variation items) require more safety stock per unit of sales than high volume items. They should also realize that item proliferation causes dramatic increases in safety stock requirements. This is why vending machines may store different flavors but will standardize on package size. (All soft drink cans are the same size.)

LLENROC PLASTICS

INSTRUCTOR'S NOTES

CASE 2 ORAL FINAL REPORTS

This case is quite straightforward. There are a variety of ways of conducting the ABC classification. Students do recognize that the classification by number of sheets shipped makes more sense for inventory policies than a cost or square-foot measure of volume. One team didn't think ABC classification was a good idea and wanted to treat each item equally importantly and make stocking policies sensitive to more information than just average demand. I pointed out that it is simply a practical technique to cope with large amounts of data involved and that it does suggest different strategies to follow.

Not all teams have a good explanation for why the Pareto curve based on inventory investment will be flatter than the curves based on volume measures. The explanation can be constructed by looking at the inventory policies in place. For A items, the company orders every two weeks with a safety stock of two weeks of demand. Hence, average cycle stock is one week of demand and average cycle plus safety stock is 3 weeks of demand for A items. For B and C items, the corresponding figure is 6 weeks of demand. Hence even though B and C items account for only 20% of demand volume, they will account for $33\frac{1}{3}$% of the inventory investment. (Let A denote the inventory investment in A items, B denote the inventory investment in B and C items, D denote the total demand for all items per week. Then A = 3*.8*D and B = 6*.2*D. Hence B/(A+B) = 6*.2/(3*.8+6*.2)=1/3.)

When asked about the power saw (Discussion 2), most teams focus on the waste involved. However, when presented with the situation that, say, most of the demand for a certain pattern is in the 4'x8' size with occasional demand for a 3'x8' size, the waste is less and the possibility exists to carry no safety stock in the 3'x8' size. Students will also worry that the information system won't be alerted that a 4'x8' sheet was substituted for a 3'x8' sheet. This is a valid concern.

The appendix seems to be sufficient for the students to conduct the Chi-squared test of the Poisson distribution (Assignment 2) correctly. Many students also performed a lexis test (to test if the mean is approximately equal to the variance) and some students produced P-P plots. At the 95% level it is difficult to reject the Poisson distribution. (In fact, these data were generated using a Poisson distribution but WE never mention that to the students.) We emphasize with students how difficult it will be to conduct these tests in practice (see notes for oral progress report.) This is a discouraging realization for the students, but one goal of this series of cases is to direct the students away from planning safety stock on an item by item basis. We are leading the students toward a re-design of the system in which B and C items can be made to order.

The main lesson to draw from Assignment 2 and the examination of Tables 2.2-2.5 is that even if the ultimate demand is fairly smooth (Poisson) the lot sizing that our customers perform induces a considerable degree of variability into our order stream. There are legimate reasons for them to batch their demand for Llenroc's products. It has to do with the transactions costs of placing orders, receiving invoices and packing slips, and matching these invoices with original orders to authorize payment. The promise of EDI (electronic document interchange) is that these transactions costs should decline significantly thereby permitting customers to order more frequently and in smaller quantities. Having worked Assignment 3 which establishes the relationship between safety stock and the coefficient of variation, students immediately perceive the benefit in reduced safety stock that smaller order quantities will provide. We note to students that many of them will likely be working in the area of EDI in the coming decade. Some students ask if Llenroc has to buy the hardware and software to install in customers' purchasing departments. The answer is no. There are emerging standards for EDI and it is in the interests of both manufacturers and distributors to purchase equipment for themselves to communicate with both customers and vendors. If EDI can be expanded to permit the transmission of production schedules and/or current inventory levels, then Llenroc Plastics will be better able to anticipate demand for its products, at least by the large customers.

Assignment 3 did not explicitly explore the relationship of the length of the lead time to safety stock requirements. Students intuitively know that increasing the lead time will increase the coefficient of variation and therefore increase the safety stock needed. We ask what would happen if the lead time is cut in half, would safety stock be cut in half? According to the simple model of safety stock the answer is that safety stock is proportional to the square root of lead time. Many students are also very aware that they performed Assignment 3 assuming a constant lead time, when in fact Case 1 indicated that it was quite variable. Students seem to be impressed with how much safety stock is going to be required to achieve good fill rates. If that happens, Case 2 is a success.

Students also recognize that increasing the number of items for a fixed total demand will increase the safety stock required. We did not explain risk pooling to all of the teams we talked to. Case 3 will provide a good opportunity to discuss that.

All the teams saw how much variability the preferential treatment of lot sizes of 50 induced. We didn't belabor this point.

Assignment 3 clearly shows that the A items do not require very much safety stock. With current lot sizes, Almond D satifies an 88% fill rate without any safety stock.

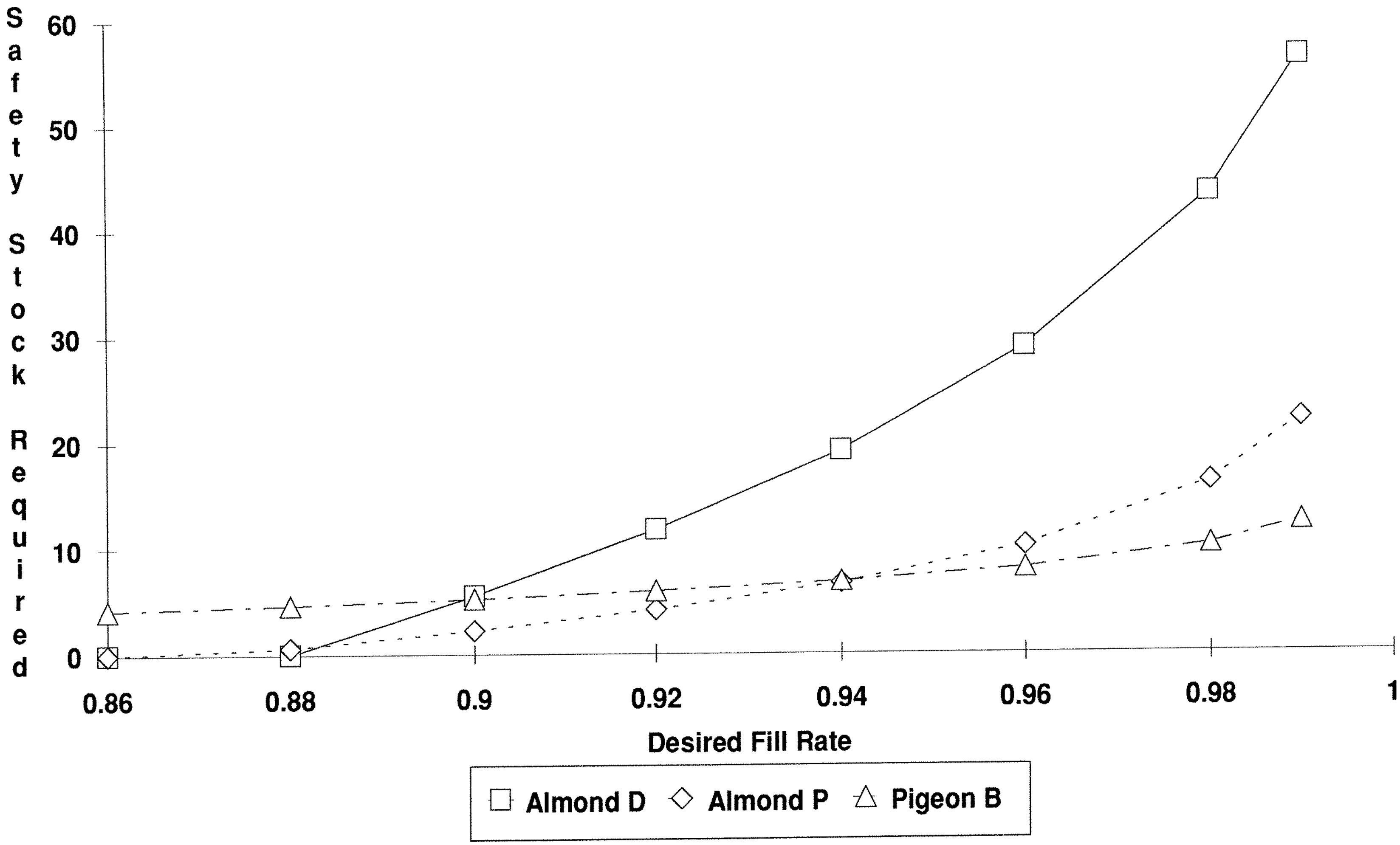
The attached graphs are solutions to assignments 3 and 4. A printout of the spreadsheet used to solve these assignments is labelled C2A3SOLN.XLS.

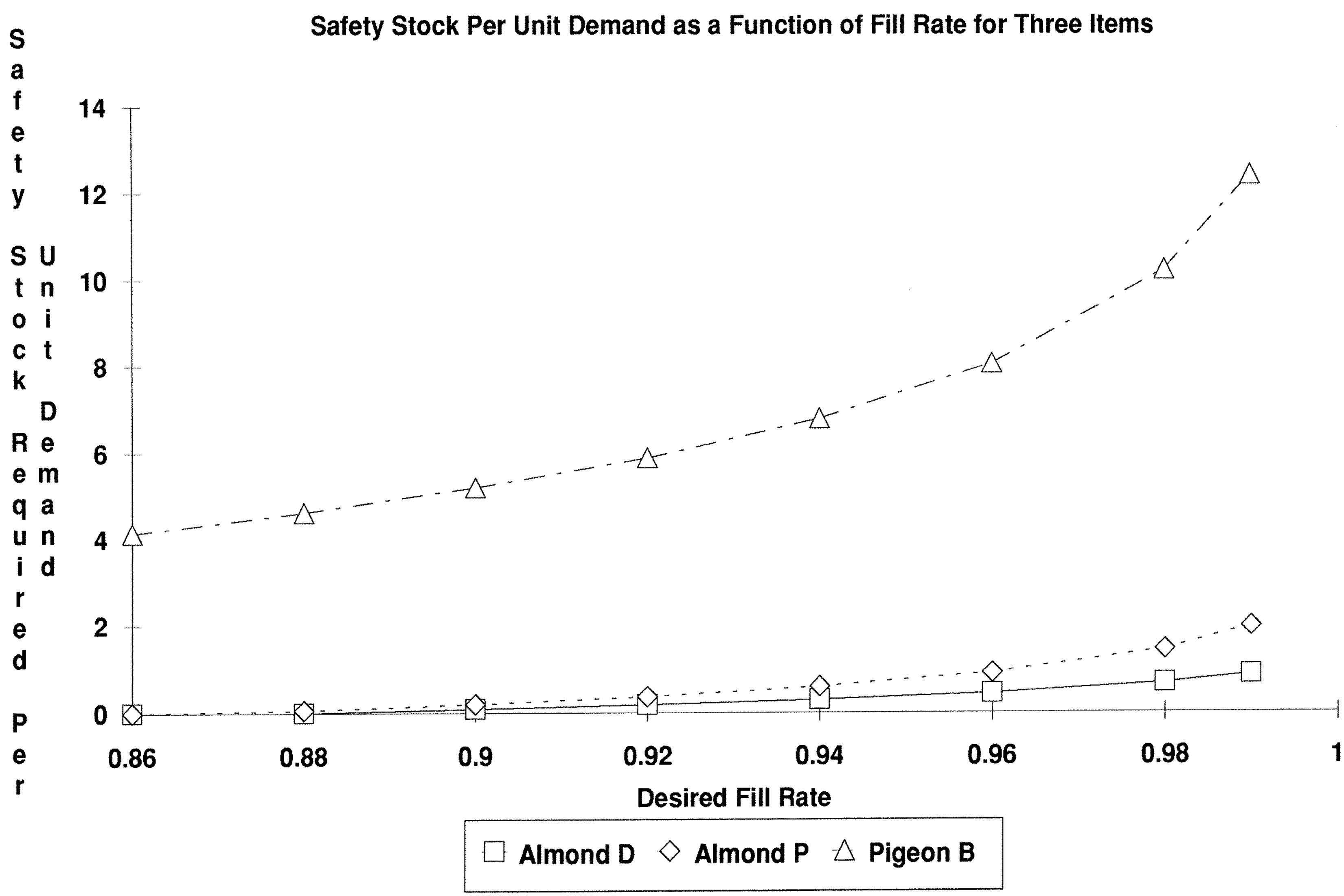
C2A3ASOL.XLC is the solution to Assignment 3a. It illustrates that an A item requires more safety stock in absolute terms than a C item to achieve a high fill rate. C2A3BSOL.XLC is the solution to Assignment 3b. It illustrates that a C item requires relatively more safety stock than an A or B item to achieve any reasonable fill rate. This coupled with the fact that there are many C items explains why the class of C items requires a safety stock investment that is disproportionate with its share of demand volume.

C2A4ASOL.XLC is a solution to assignment 4a. It illustrates that lead time variability increases the safety stock requirement.

We usually close the meeting by pointing out that Case 2 is an excellent preparation for Case 3. For case 3, the software and case description are sufficient for them to conduct the analysis. We sometimes omit mandatory oral progress reports for Case 3 (this case occurs near a mid-term break on our calendar) but we post office hours to discuss the case with any team that wishes it.

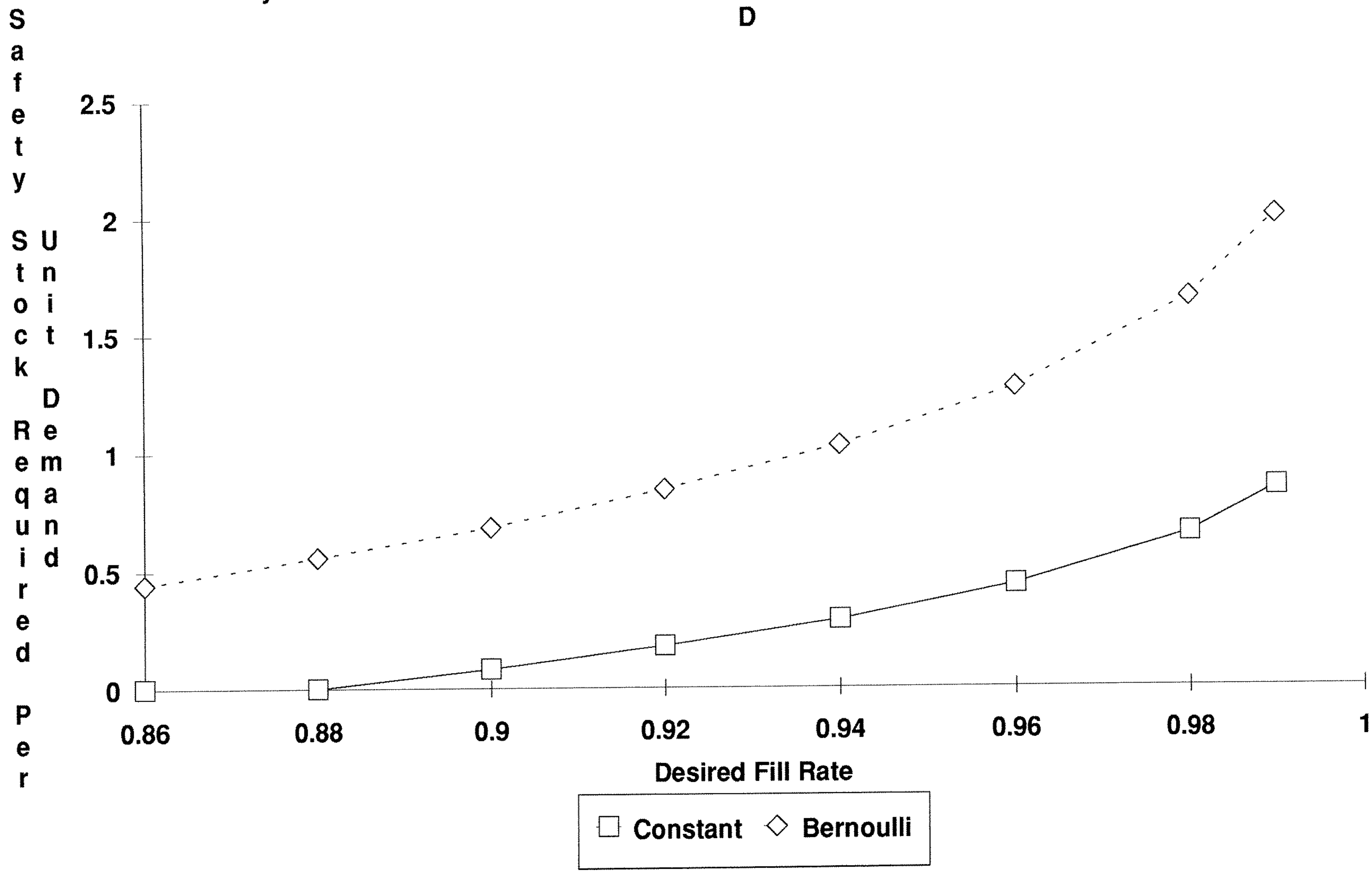
Safety Stock as a Function of Fill Rate for Three Items





Safety Stock Per Unit Demand as a Function of Fill Rate for Three Items
Safety Stock Required Per Unit Demand
14
12
10
8
6
4
2
0
0.86
0.88
0.9
0.92
0.94
0.96
0.98
1
Desired Fill Rate
Almond D
Almond P
Pigeon B

Safety Stock Per Unit Demand as a Function of Fill Rate for Two Lead Time Models: Almond-D



	A	B	C	D	E	F	G	H	I
1									
2									
3									
4									
5									
6		This spreadsheet is designed to explore solutions to assignments							
7	3 and 4 of Case 2 in Llenroc Plastics.								
8		For a detailed explanation of the model behind these							
9	calculations, see Appendix D to Case 2.								
10									
11									
12									
13									
14		To begin, PageDown and enter the numbers you have chosen.							
15									
16									
17									
18									
19									
20									
21				USER SPECIFIED DATA					
22									
23	Lead time for ordering laminates from the								
24		the central warehouse in weeks (L), by item:							
25							**Mean**	**Std.Dev.**	
26				Almond D		60x144	2	0	
27				Almond P		36x120	2	0	
28				Pigeon Blue PF		48x96	2	0	
29									
30	Weekly demand data by item:								
31							**Mean**	**Std. Dev.**	
32				Almond D		60x144	66.2	27.81	
33				Almond P		36x120	11.3	8.73	
34				Pigeon Blue PF		48x96	1	3.14	
35									
36									
37	Weeks of Supply Order Quantity by item:								
38							**WOS**		
39				Almond D		60x144	2		
40				Almond P		36x120	3		
41				Pigeon Blue PF		48x96	3		
42									
43									

	A	B	C	D	E	F	G	H	I
44			SPREADSHEET COMPUTED CONSTANTS						
45									
46	Lead Time Demand by item:								
47									
48					Mean	Std. Dev.	Coeff. of Var.		
49		Almond D		60x144	132.4	39.33	0.30		
50		Almond P		36x120	22.6	12.35	0.55		
51		Pigeon Blue PF		48x96	2	4.44	2.22		
52									
53									
54	Order Quantity by Item:								
55					Q				
56		Almond D		60x144	132.4				
57		Almond P		36x120	33.9				
58		Pigeon Blue PF		48x96	3				
59									
60									
61									
62									

	A	B	C	D	E	F	G	H	I
63	CALCULATE:								
64		G(s) = Q/Stdev * (1-f) by item for a range of fill rates:							
65									
66		f:			0.5	0.52	0.54	0.56	0.58
67		Almond D		60x144	1.683224	1.615895	1.548566	1.481237	1.413908
68		Almond P		36x120	1.372905	1.317989	1.263073	1.208156	1.15324
69		Pigeon Blue PF		48x96	0.33779	0.324278	0.310767	0.297255	0.283743
70									
71	Solve for s:								
72	s:								
73		f:			0.5	0.52	0.54	0.56	0.58
74		Almond D		60x144	0	0	0	0	0
75		Almond P		36x120	0	0	0	0	0
76		Pigeon Blue PF		48x96	0.032252	0.061117	0.091211	0.122643	0.155538
77									
78	By table look up for A items								
79	By algebraic solution for Laplace demand (B and C items):								
80		s = ln(Q/Stdev * (1-f) * 2*sqrt(2))/-sqrt(2)							
81									
82									
83	Compute safety stock required (s*std. dev. of lead time demand):								
84									
85		f:			0.5	0.52	0.54	0.56	0.58
86		Almond D		60x144	0	0	0	0	0
87		Almond P		36x120	0	0	0	0	0
88		Pigeon Blue PF		48x96	0.143217	0.271398	0.405035	0.544614	0.690687
89									
90	Compute safety stock per unit of weekly demand:								
91									
92		f:			0.5	0.52	0.54	0.56	0.58
93		Almond D		60x144	0	0	0	0	0
94		Almond P		36x120	0	0	0	0	0
95		Pigeon Blue PF		48x96	0.143217	0.271398	0.405035	0.544614	0.690687
96									
97	Safety stock per unit of weekly demand for Almond D under different lead time variability:								
98									
99					0.5	0.52	0.54	0.56	0.58
100				Constant	0	0	0	0	0
101				Bernoulli	0	0	0	0	0

	A	B	C	D	E	F	G	H	I
102									
103	Unit Normal Loss Function as Tabulated in Silver and Peterson, Table B.1								
104	s	G(s)	G-1(x)						
105	--------------	--------------	--------------						
106	9999	0	9999						
107	9999.01	7.145E-06	4						
108	9999.02	7.469E-06	3.99						
109	9999.03	7.806E-06	3.98						
110	9999.04	8.158E-06	3.97						
111	9999.05	8.525E-06	3.96						
112	9999.06	8.908E-06	3.95						
113	9999.07	9.307E-06	3.94						
114	9999.08	9.723E-06	3.93						
115	9999.09	1.016E-05	3.92						
116	9999.10	1.061E-05	3.91						
117	9999.11	1.108E-05	3.9						
118	9999.12	1.157E-05	3.89						
119	9999.13	1.208E-05	3.88						
120	9999.14	1.262E-05	3.87						
121	9999.15	1.317E-05	3.86						
122	9999.16	1.375E-05	3.85						
123	9999.17	1.435E-05	3.84						
124	9999.18	1.498E-05	3.83						
125	9999.19	1.563E-05	3.82						
126	9999.20	1.632E-05	3.81						
127	9999.21	1.702E-05	3.8						
128	9999.22	1.776E-05	3.79						
129	9999.23	1.853E-05	3.78						
130	9999.24	1.933E-05	3.77						
131	9999.25	2.016E-05	3.76						
132	9999.26	2.103E-05	3.75						
133	9999.27	2.193E-05	3.74						
134	9999.28	2.287E-05	3.73						
135	9999.29	2.385E-05	3.72						
136	9999.30	2.486E-05	3.71						
137	9999.31	2.592E-05	3.7						
138	9999.32	2.702E-05	3.69						
139	9999.33	2.816E-05	3.68						
140	9999.34	2.935E-05	3.67						
141	9999.35	3.059E-05	3.66						
142	9999.36	3.188E-05	3.65						
143	9999.37	3.321E-05	3.64						
144	9999.38	3.460E-05	3.63						
145	9999.39	3.605E-05	3.62						

Llenroc Plastics

Instructor's Notes

Case 3 Oral Progress Reports

Many students are initially overwhelmed with the apparent demands of Case3. There are so many possible ways to locate warehouses that they are at a loss as to where to begin. We reassure them that we do not intend to have them investigate all possibilities. We tell them that if they think about the relationships there are only a small number of combinations that make sense. They need to understand the following relationships.

Begin with a focus on the impact of the number of warehouses on cost.

Does the number of warehouses affect warehousing costs? The answer is yes because the warehouse operating costs are related to volume. The more warehouses there are, the smaller will be the volume per warehouse. Does the warehouse cost function exhibit increasing or decreasing returns to scale? The students must look into the spreadsheet to find the answer to this. If it is decreasing returns to scale then warehousing costs will decline as we reduce the number of warehouses. If it is increasing returns to scale, then the reverse is true. Attached is a printout of WCOST.XLC that shows the warehousing cost function. We hand out a copy of this page to each team during the meeting. The function exhibits decreasing returns to scale. Therefore, reducing the number of warehouses will decrease warehousing costs.

Does the number of warehouses affect transportation costs? The answer is yes but since the product must travel from Nashville to the customer anyway, the choice of regional warehouse location just adds some detours to that trip. It is not a major factor in total transportation cost.

How does the number of warehouses affect inventory investment? We need to answer this question for each category of inventory. Does it affect the amount of pipeline stock? As with transportation costs, the answer is yes but for the reason expressed in the previous paragraph, the location of warehouses is not going to greatly affect the amount of pipeline stock in the system. That is more a function of where we locate our manufacturing site(s) relative to where the customers are.

Does the number of warehouses affect the investment in cycle stock? We remind students that in the Distribution Game they had to determine economic order quantities for regional warehouses. Why, in the Distribution Game, did we only charge \$0.04 per dollar-year of inventory at the regional warehouses when computing regional economic order quantities? After all, the full inventory holding cost was \$0.24 per dollar-year. The reason is that given the order quantity at the central warehouse, if the cycle stock is not held at the regional warehouse it must be held at the central warehouse. The regional order quantity only affected where the cycle stock was held, not how much was held. Therefore, the appropriate holding cost was the incremental holding cost (the central warehouse holding cost rate is \$0.20 per dollar-year.) Similarly, for Llenroc Plastics, the total amount of cycle stock in the system is determined by the order quantities placed by the central warehouse. The number of warehouses and the order quantities of the regional warehouses only affects the geographical distribution of cycle stock, not its total. (The differential holding cost in Llenroc Plastics is zero because we are modelling transportation and warehousing costs explicitly.) Consequently, cycle stock is unaffected by the number of warehouses.

How does the number of warehouses affect safety stock? Students generally recognize that safety stock must decrease if we reduce the number of warehouses. This is a good opportunity to discuss risk pooling with them. Table 3.7 clearly shows how the coefficient of variation decreases when we aggregate demand across regions. From Case 2, students recognize that this means a reduction in safety stock requirements. To make the discussion more analytical, we sometimes observe that if A and B are independent random variables then because $\sqrt{\sigma_A^2 + \sigma_B^2} \le \sigma_A + \sigma_B$ we will have a smaller amount of safety stock to support demand A+B then we would need to support demand A and demand B separately. Table 3.7 shows dramatic reductions in coefficient of variation as we aggregate demand. Consequently, reducing safety stock requirements is a powerful incentive to reduce the number of warehouses. If the students keep a large number of regional warehouses and set the fill rate for B and C items to be very high at the regional warehouses, then the cost spreadsheet will show that Llenroc will lose money with this strategy ("we can provide great service until we run out of business").

We note to students that another way to reduce safety stock requirements without reducing the number of warehouses is to centralize the stocking of some items. For example, a possible strategy is to keep a large number of warehouses but only use them to stock A items. Under this strategy, stock the B and C items only at the central warehouse. The A items require very little safety stock (Case 2 illustrated this.) If customers ask a regional warehouse for a B or C item, then the order is simply transmitted immediately to the central warehouse. This can be modelled in the spreadsheet SAFETY.WK1 by setting a high fill rate for A items at the regional warehouses and a low fill rate for B and for C items at the regional warehouses.

While we are on the subject of fill rates, we tell the students that we will check their solutions to see that the lead times they specify between the central warehouse and the regional warehouses are consistent with the fill rates they have chosen. That is, if for C items, they set a very high fill rate at the central warehouse then the lead time at the regional warehouse will be close to the transportation time. However, if they set a low fill rate at the central warehouse, then the lead time from when a regional warehouse places an order to when they receive it will on average be greater than the transportation time because there is a good chance the item will not be in stock at the central warehouse and the regional warehouse will have to wait until that product is produced, a time that is measured in weeks. We don't expect a detailed analysis of this point but students should not ignore it. Students note that the variability of lead time will be high in this case with a consequent higher coefficient of variability of regional warehouse lead time demand. We agree but observe that the spreadsheet implements a very simple model of safety stock as a piece of a larger cost model.

As a result of the discussion so far, students will realize that the cost arguments will probably drive them to have as few warehouses as possible. The only argument in favor of many warehouses is customer service. Students will naturally think that to get good customer service we need warehouses close to the customers. To counter that bias, we ask them to think about what is meant by customer service. We are not in a retail business. That is, customers do not walk into our store and walk out if we don't have the product on the shelf. We sell to distributors and OEM's in most cases. These organizations place orders to replenish their inventories of our product. They are generally willing to wait some amount of time. Wilson Plastics promises delivery within 10 days. Llenroc promises 20 days but can't make that even with all the warehouses they have now. Customer service will be determined by how long the customer is willing to wait, how long it takes to move the product from where we stock it to where the customer is , how frequently we make shipments to the area in which the customer is located, how high our fill rate is at the location where we stock the product, and, if this fill rate is less than 100%, how long it takes to fill a backorder at the location where we stock the product. Emphasize that frequency of shipment is an important factor in customer service and they should address it.

Ask the students how long it takes to drive a truck from Nashville to Maine, or from Nashville to Los Angeles. Long haul carriers put two drivers in a truck so that an 18 hour trip can be accomplished in a single day. Tell the students to look at a road map of the United States to see how many major highways pass through Tennessee.

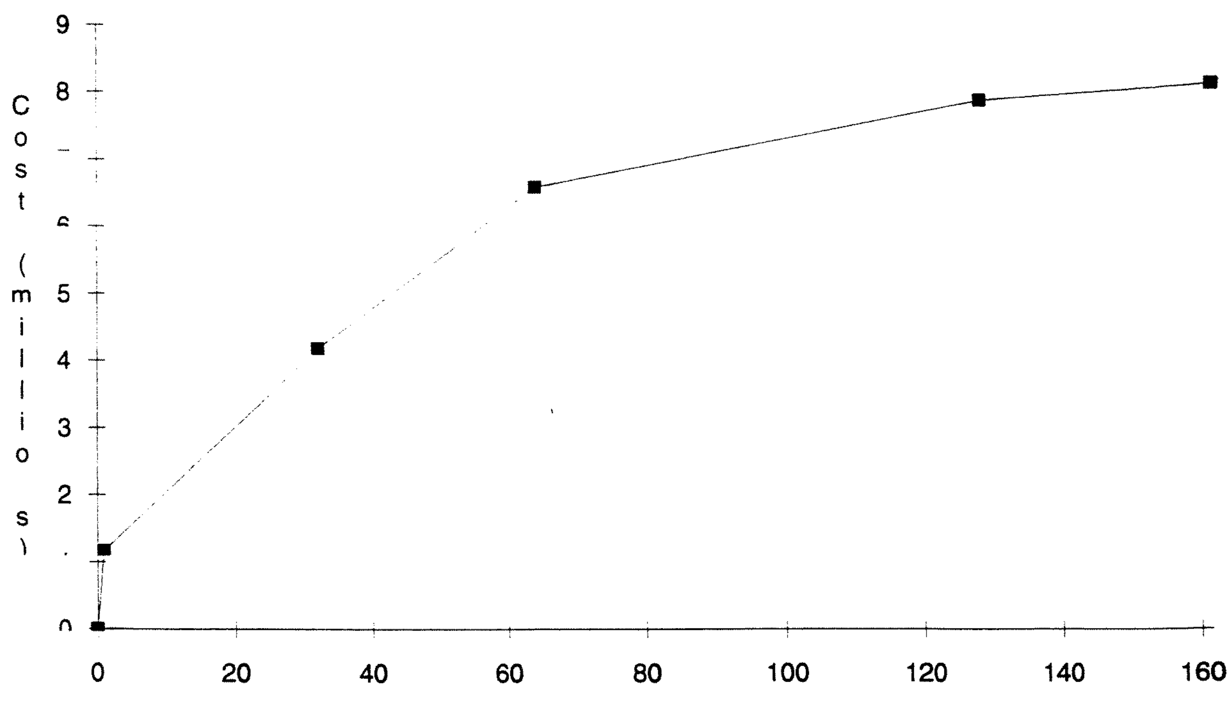
The last thing to observe is that customer service doesn't have to be measured uniformly. Customers in Montana do not expect the same level of service as customers in Illinois and it is not cost-effective to try to provide equivalent service. Although the case doesn't raise the issue, different sized customers expect different levels of service as well.

These observations are to balance the bias towards locating warehouses close to the customer. We note that that is typically what the marketing department wants to do and that is why Llenroc has so many warehouses.

There is no one right answer to how many warehouses Llenroc should have. It depends on how you measure customer service and what cost you are willing to incur to provide that service. It is clear however, that Llenroc could provide good customer service with significantly fewer warehouses than the number currently in place. If the students limit themselves to a small number of warehouses, there are only a few combinations of locations that they will need to investigate before they can make an intelligent recommendation.

Since the last time this case was taught (Fall 1993), we have developed a new model of safety stock that illustrates the risk pooling principle. The model is found in the spreadsheet NEWSAFTY.XLS. It is not documented yet, but the adventurous instructor is welcome to study it and put it to use. We will rewrite Appendix F at a later date to explain this approach.

	A	B	C	D	E	F	G
143	Warehouse costs are determined by adding a fixed base cost to						
144	a volume dependent variable cost that represents labor and lease costs.						
145	The variable cost is derived from a piecewise linear function given by						
146	these cut-off points:						
147							
148	If the annual Volume (V) is:				Then the Cost is:		
149							
150	Cut 0: 0				==> 0		
151	Cut 1: >0 & <=32,000,000				==> V * 0.0975+ 1.065		
152	Cut 2: >32,000,000 & <=64,000,000				==> (V - 32) * 0.075 + 4.185		
153	Cut 3: >64,000,000 & <=128,000,000				==> (V - 64) * 0.02 + 6.585		
154	Cut 4: >128,000,000 & <=161,464,121				==> (V - 128) * 0.00762432 + 7.865		
155							
156	For a graphical representation of these costs. look at WCOST.XLC						



Llenroc Plastics

Instructor's Notes

Case 3 Final Reports

The components to the report should include a warehousing plan, with regions assigned to warehouses, a transportation plan with routes and frequency of use, an inventory plan with fill rates and lead times for both regional and national warehouses, and a discussion of the customer service implications of the revised distribution system. We also ask for an executive summary.

There were serious errors in the original spreadsheet model. The spreadsheet errors were that the warehousing cost model was not implemented correctly (it picked up the current cost slope to apply based on volume but it does not add in cost from the last cost breakpoint; also the cycle stock and safety stock inventory investments are overstated by a factor of 12 since it multiplies months of supply figures by annual volume instead of monthly volume; also it is shorter to travel from Nashville to Atlanta to Tampa than from Nashville to Tampa). The corrected WCOST.WK1 spreadsheet is dated 9/10/92 or later. There is also an EXCEL spreadsheet version of the WCOST model that does not use any macros. It is labelled WCOST.XLS. At some point, we will need to recalibrate the safety stock calculations somehow to get the total inventory investment into the right ballpark. We have begun working on that. NEWSAFTY.XLS is an undocumented model that computes safety stock requirements and exploits risk pooling.

Students generally do a good job in exercising the spreadsheets: experimenting with warehouse locations, forming routes, trying different fill rates, and computing costs. Some teams put much more effort into this than others. One team, for example, picked 4 warehouses, did what appears to be a cursory analysis of this one scenario and stopped. Other teams conducted extensive sensitivity analyses of their solution. Three strategies are common: the single warehouse in Nashville, a two warehouse system (Nashville and a facility in the west, either San Francisco or Salt Lake City), and a four warehouse system (Nashville, Chicago, San Francisco, and New York). There are reasonable arguments in defence of each one of these strategies but the students need to make these arguments.

The effort spent in optimizing transportation routes also varied between groups. It is particularly easy to see this effort in the plans for multiple warehouses. A common flaw when there is more than one warehouse is to have material backtrack across the country. For example, if the students plan to serve Texas out of a facility in Salt Lake City, we point out how they are shipping material from Nashville across the Rockies and then from Salt Lake City back across the Rockies to Dallas. This is not efficient.

Students also develop some tunnel vision in dealing with the spreadsheet formulation of the problem. For example, if the weekly demand in a city is greater than one truckload they will talk about shipping the difference to that city on a different truck on another route. They do not seem to recognize that this is an aggregate view of a planning problem and that the demand data is a weekly average of an annual total. They treat the routing problem as a deterministic scheduling problem. All that is really important is to get a good estimate of the transportation costs and to understand what the average frequency of shipments to a particular location will be. The average frequency does not need to be an integer.

As a result of the Case 2 analysis and the Case 3 progress report meeting, most students realize that safety stock requirements decrease as warehouses are eliminated and demand is consolidated in the Nashville warehouse. Some students talked about the reduction in variance as demand is consolidated when they should have said the standard deviation is reduced. Some students tried different ABC classifications but often got confused in this. For example, reclassifying all the B items as A items and all the C items as B items got one team into trouble. Students did do experimentation with the fill rates. A typical shortcoming here is to guarantee very high fill rates for A items (which is easy to do) and only 90% fill rate for B and C items. We point out to students that distributors are likely to be well protected with inventory for the A items as well but poorly protected for B and C items. This results in everyone being out of stock of B and C items on a regular basis. Other teams discover that it really does not cost very much to have 99% fill rate in all items, relative to the other costs that are being considered.

There was some confusion between models and reality. Although the economics of the spreadsheet model drive the solution towards closing many warehouses, it is not wise to recommend that warehouses be shut down immediately. The company must embark upon a process of transition which most students ignored. Ask the students to identify which warehouses should be closed in the first year. Atlanta is an obvious choice.

Nearly all the reports were a disappointment with regard to the customer service dimension. The most common flaw here is to assume that customer service will be great even for a one-warehouse system because the transportation time from Nashville to any other part of the country is only a couple of days. It is true that Nashville is ideally located; but, what is missing from this is the fact that the frequency of shipment also affects the time a customer must wait for product. See the oral progress report notes for Case 3 for this discussion. Even students who understood this expended very little effort in documenting how well a single warehouse can service the country.

We point out to students that the real company did, in fact, close warehouses and centralize their stock. It had many of the benefits that they predict in their reports. However, the company did lose business on the west coast as a result of the consolidation because their customers on the west coast perceived this change as one of abandonment: they thought that Llenroc Plastics was leaving the west coast market. Since population growth in the U.S. is concentrated in the southwest, the decision to close a west coast warehouse does have strategic implications.

With some exceptions, what we don't see in the student reports are in-depth discussions of customer service and innovative ways of serving the customer. Students make no distinction between OEM customers and distributors or between large and small customers. For example, who really needs next-day service? By and large, distributors should be placing replenishment orders and should not require immediate delivery. OEM's should be ordering against a production plan. The only time they would need next day service would be as a result of bad planning. The solution that the company actually adopted was to arrange with nearby distributors to provide emergency shipments to OEM's. The students tend to focus simply on fill rate as the measure of customer service. They don't translate the cost reductions of centralization into price reductions. They don't compare their performance against Wilson Plastics. They don't discuss the impact EDI might have. (Recall in Case 2 there was a hint that EDI could be quite important for this company.) They don't look at the market analysis that was covered during the introduction to Llenroc Plastics (overhead transparencies).

We note in the student evaluations from Fall 1993 that they didn't quite see the point of Case 3. They felt they were missing something. This suggests that we need to extend the case write-up to force them to consider the issues we think are relevant here.

This is also a good opportunity to discuss how to write an effective executive summary with the students. Here is a case of students presenting a radical proposal (eliminating warehouses) to the CEO of a company. The CEO is going to face considerable opposition to implementing such a proposal. What, in a nutshell, are the students providing the CEO to get his attention and anticipate his objections? The executive summary should state the recommendation. Students tend to say things like "we analysed the warehouse costs and the transportation plan, etc." but they never say what the result of this analysis is. Perhaps they are afraid of spoiling the surprise. Then the executive summary should very concisely state the argument in favor of that recommendation. Then the summary should state the estimated impact of the recommendation as concretely as possible: for example, x million dollars profit combined with a reduction in customer wait time to within 10 days. It should do all of this together with a few background statements to position the problem area in a single page.

LLENROC PLASTICS

INSTRUCTOR'S NOTES

CASE 4 ORAL PROGRESS REPORTS

(OLD NOTES: 1992)

One of the main things to convey to students is the overall lesson of this case, which is that relatively small investments and changes in operating procedures can have a significant impact on capacity. The company upon which this case is based actually purchased another small company in order to acquire that company's pressing capacity. The acquisition cost millions of dollars and was a serious drain on the company's finances. After the fact, the analysis suggested in this case revealed that this acquisition was unnecessary. The existing presses had adequate capacity provided certain improvements were made.

The technical details of the case require a combination of a simulation study and an economic analysis to find the best set of options to recommend. Qualitative recommendations in terms of work force organization and the handling of press shutdowns are also required.

For the simulation studies, the students may use any simulation package with which they are familiar. Our students use either SIGMA or XCELL+. I help a little with the modelling assumptions that are possible. For example, I first explain the difference between carrier plates and separator plates. There is one carrier plate per carrier and five laminate separator plates. The separator plates get moved by overhead cranes with suction cups from the teardown station (31 in figure 4.1) to a table with rollers (80). From there, the plate rolls to another table (180), then through a cleaner (81) to a final roller table (82). From there, the separator plates are moved by overhead cranes with suction cups to the buildup station (32). Note that there are three tables on which separator plates can sit (80, 180, and 82). The carrier plate is moved directly from the teardown station (31) to a roller table (131) and then to the buildup station (32). Thus, there is only one table for a carrier plate to sit on (they do not stack). I tell the students to ignore simulating the separator plates. The buildup station hardly ever waits for a separator plate. There are times however, when the buildup station waits for a carrier plate. Consequently, the whole simulation can be written in terms of simulating the circulating flow of carrier plates. In XCELL+, table 131 can be modelled as a buffer of 1 unit.

It is tricky in a factory simulation language such as XCELL+ to model a press, which operates on multiple units (carriers) at once. Here is how I explain it: Model the press (10) as a workstation with a single process that draws inventory from an input buffer (capacity 22, the number of carriers in a press load) and deposits it in an output buffer (also with capacity 22). The process is triggered "high" (an XCELL phrase) when inventory in the input buffer hits 22. Once triggered, the process works on carriers *one at a time* until all 22 units have been processed. Set the time per unit to be the average length of a press cycle divided by 22. Similarly, the next downstream workstation (12) has a single process that is triggered "high" when inventory in the output buffer hits 22. This is the basic idea of how to mimic the press cycle but it could be more complicated to implement. For example, how do you model the steady accumulation of carriers in the input accumulator while the press cycle is in progress? Model the input accumulator (11) as a buffer with capacity 22. Then we need a dummy workcenter between that buffer and the press input buffer that is triggered "high" when the inventory in the press output buffer hits 22 and rapidly processes all the carriers in the input accumulator buffer and puts them into the press input buffer. Table 4.2 suggests that it should take about 7 minutes to move all 22 carriers from the input accumulator into the press. Similarly, model the output accumulator (22) as a workstation that rapidly unloads the press output buffer (using trigger "high") and puts the carriers into a output accumulator buffer. The unload process should take about 7 minutes. Note that both the load and the unload process trigger high on the contents of the press output buffer. A problem could arise if the unload process triggered before the load process so that the number of carriers in the press output buffer immediately dropped below 22. The load process would never again get triggered. Which process gets triggered first may depend on which workstation was entered into the model first. If you suspect that is the case, make sure the load workstation is entered into the model first (deleting workstations and re-entering them, if necessary).

Some student groups report that this approach doesn't work. They introduced an additional buffer with a zero-time workstation and more complicated trigger rules to make it work. Other groups reported that it did work.

More XCELL+ modelling hints: the movement time from the output accumulator to the teardown station can be modelled by introducing a dummy workstation that represents the material transport step. Also, keep the same process name in all the workstations.

Students ask how long they should run their simulations. I leave this to their judgment, realizing that with only a week to perform the analysis of this case, they will be hard pressed to develop and test a model and make extensive simulation runs of many scenarios.

Students wonder about the option of replacing the press operator. It doesn't seem to affect the performance of the equipment to replace the operator. They are right. Physically, the press operator sits in front of a control panel by station (11) that controls the loading and unloading of the press. The control panel is largely automated. The operator does next to nothing but watch the panel and throw a switch when it is time to begin the next unload/load cycle. That operation can be entirely automated for $45,000. It is obvious that this automation is a money-saver. The point is that some recommendations for improvements come easily. Others need more extensive justification.

The main purpose of the simulations is to estimate the average number of days required to produce the weekly demand of 100 press loads. This is what is needed in the economic justification of the investments. However, we do ask them to look at variability in the output as well. The reason is that in Case 5 students will be trying to eliminate inventory and turn the fabrication room into a just-in-time shop. That will be difficult to accomplish if the output of the presses is highly variable. If the improvements they are making to the presses result in a significant reduction in variability, the benefits to the fabrication room are a qualitative justification for the improvement.

Llenroc Plastics

Instructor's Notes

Case 4 Oral Progress Report

(New: 1993)

We introduce Case 4 in a laboratory session to demonstrate the simulation software available. Students are required to have read the case prior to coming to lab.

We begin with a review of the issues of the case. There is the clearly stated problem of capacity: the press is only yielding fourteen press loads per day. The company must work weekends to keep up with demand. This causes preventive maintenance schedules to slide. This results in deteriorating equipment. The problems compound. The case mentions that the company is considering acquiring more presses to keep up with demand. In fact, the company purchased another factory in order to acquire this pressing capacity. This created serious financial difficulties for the firm. Analysis such as conducted in case 4 revealed that this investment in pressing capacity was unwarranted.

The problem of the leaky platens is more than just a cost inefficiency. Raise the point that a press load is not a homogeneous collection of laminates. Any given press load will contain A, B, and C type items (part numbers). What happens if the spoiled laminate is an A item? It is no big deal, because inventories of these items are high. What happens if the spoiled laminate is a C item? There is a good chance that there is a customer (probably a distributor) waiting for this item. That item will have to be rescheduled for production. This will likely take several days. Suppose there is no more treated printed paper for that pattern. Then the treater will have to be rescheduled to produce that paper. This could add several days. Furthermore, it can be a day or more before the MRP system (case 6) is notified that the laminate is spoiled. There are all sorts of delays that can happen. This should make clear how a little variability in the production process can create significant variability in the manufacturing lead time and how customer service in the distribution system is affected by that variability.

Before introducing any simulation model, create a "sanity check" using the following simple calculations. The underlined numbers are numbers we ask students to provide. The basic question is "how many press loads could we expect to see produced in a day?"

Time per pressload:

Breakdown station:
Avg. time per carrier * # carriers per press load
= 2.65 min. / carrier * 22 carriers / press load
= 58.3 min. / press load

Buildup stations:
Avg. time per carrier * # carriers per press load
+ avg. delay between press loads
= 3.00 min. / carrier * 22 carriers / press load + 7 min./ press load
= 66 min. / press load + 7 min. / press load
= 73 min. / press load

Press:
MTTF = "mean time to fail"
= 8 shifts * 480 min./shift assuming continuous processing
= 3840 min.
MTTR = "mean time to repair"
= 1 shift * 480 min. / shift
= 480 min.
Avg. availability = MTTF / (MTTF + MTTR)
= 3840 / (3840 + 480)
= 0.89
Avg. processing time per press load
= probability of PB,VD,V4 * 56 min./load
+ probability of OH,O5,O8 * 58 min. / load
= 57 min. / load assuming equally likely construction type
Avg. time per press load
= avg. processing time / load / avg. availability
= 57 min. / 0.89

= 64 min. / load

Maximum processing time per press load
= 73 min. / press load (build-up)
We should see that the press is idle on occasion, waiting for the input accumulator to fill.

Productive time available per shift at build-up station
= time / shift - contracted break time / shift
= 480 min. / shift - 50 minutes / shift
= 430 min. / shift

Avg. number of press loads / shift
= Productive time available / 73 min. / press load
= 430 min. / shift / (73 min. / press load)
= 5.89 press loads per shift.

Avg. number of press loads / day
= 5.89 press loads per shift * 3 shifts per day
= 17.67 press loads / day

Note that this is higher than the 14 press loads per day quoted in the case. There are two reasons for this. The first is that the third shift is not a full eight hours. (It is actually ?? hours). The second is that the above analysis ignores the impact of variability. A simulation model should do better job of capturing that effect. For simulation purposes, we told the students to assume that all shifts are 480 min. in duration.

One student asked how the workers would respond to be asked to work through the breaks. In the ensuing discussion, students quickly rejected that idea and generated the idea that extra workers could act as "floaters", relieving other workers to take breaks but keeping the process going.

Yield loss has no essential place in the simulation. We asked the students to compute whether the material cost savings alone would justify the replacement of the platens. The reduction in variability could be presented in their reports in a qualitative discussion.

We explain the nature of the synchronization improvements. The current system has the buildup operators wait for an overhead crane to bring the stainless steel plate from #82 to #32. The synchronization option is simply some automation that brings the steel plate to the halfway point between #82 and #32 where it waits until the operators are ready to position it. This cuts the time per carrier load by almost 30 seconds. The same idea can be applied at the teardown station as well. Is it worth it?

The press control operator sits in a little booth near #15. His task really is very simple and can be replaced with process control equipment. He spends much of his time doing paperwork.

This case can be used as a challenge to students to develop an appropriate simulation model. It is a nontrivial modelling task. Given the time pressure to complete all the cases in one semester, we have now opted to give students a working simulation model of the press. With that, they should have no difficulty in completing the case in one week. The educational objective becomes simply to show students the role that simulation models can play in industrial engineering. The model used at Cornell in Fall 1993 is PRESS7N.XL4, a model constructed using XCELL+. Students can easily vary the processing times at the build-up and teardown stations and the breakdown characteristics of the press. Under development is a Windows 3.1 animation of Press 7 that can be used to conduct the required experiments.

Whatever model is used, part of the lab session is devoted to showing students how to change parameters and how to record daily variation in the number of press loads processed.

The only guidelines offered on the case 4 written report are that it should not exceed 7 pages in length, including a one page executive summary.

Llenroc Plastics

Instructor's Notes

Case 4 Final Reports

The students should be able to verify using simulation that Press 7 is currently having difficulty meeting a production target of 100 press loads in 5 days. It needs about 6 days to complete this production. When viewed on a daily basis, the current capacity seems to be about 16 press loads per day and there is considerable variability about that average. Most groups simulate the system for one full week; some groups simulated as many as 30 days. Bar charts of daily output illustrate the variability nicely: the press breakdowns create a serious problem.

[1992: Reports differ in the assumptions used within the simulation. For example, some groups assumed 44 carriers while others assumed 47 carriers in the system. Some groups modelled worker breaks in detail using SIGMA, others approximated the breaks using the breakdown feature of XCELL+.] In Fall 1993 at Cornell all students used PRESS7N.XL4.

The investment in new platens is easily justified. The annual material savings is between $210,000 and $220,000 per year, depending on assumptions. The material savings alone are sufficient to justify the investment. The reduction in output variability, and the increase in throughput by eliminating breakdowns are additional benefits. Labor savings varied between student teams due to differing assumptions.

Many students included the cost of downtime to install the equipment as part of the economic analysis. This is fine, but they generally overestimated the cost of downtime by assuming that it represented a period of lost revenue. The point is that if they built up inventory in advance of the shutdown, there would be little, if any, lost revenue. The appropriate cost is the holding cost of the inventory, which is small compared to other costs and benefits of the case.

By including an overestimate of the cost of downtime, some students missed the economic advantages of synchronization and process control equipment.

In evaluating the process control equipment to replace the press operator, many students failed to note that a press operator is required three shifts per day. Therefore, the annual savings are on the order of $75,000 per year, rather than $25,000. Students were generally reluctant to implement the process control equipment. They are unwilling to reduce the work force even when it is clear that an individual is not contributing to the economic well-being of the firm. I point out to them that that individual need not be laid off since many of the teams recommended hiring additional workers in order to keep the presses running during worker breaks.

The students should discover that all the suggested changes in the case should be implemented.

Most students recognized that material would have to be built up in advance of equipment installation. I wrote on each of reports asking them to consider what type of inventory should be built in anticipation of the shutdown (A, B, or C items). During the oral presentations of Case 7, I returned to this question. All the students recognized that it makes most sense to build A items in that situation. They would not have been able to answer this question at the beginning of the course, but they have seen this idea enough times during Llenroc Plastics that it comes very easily to them.

LLENROC PLASTICS

INSTRUCTOR'S NOTES

CASE 5 ORAL PROGRESS REPORTS

(OLD NOTES: 1992)

The machine locations on the shop floor are permanent.

The simulation should not be the center of case or discussion. Use simulation as support for recommendations. The use of a computer for the simulation is optional.

[The data in Table 5.4 seen inconsistent with the data in Table 5.1 For example, the time per run batch in practice is 18 min. on average but that doesn't agree with Table 5.4 (7 sec. per process batch, avg. of 3 laminates per process batch [table 5.2], and 140-220 laminates per run). Also, given sanding speeds, the number of sheets per minute at the sanders seems unrealistically high. Also, how many inspection teams are there per shift? Also, if 20% of all inspections are class A, how is it that the average inspection time is 21 minutes. That is mathematically too high given the data of Table 5.4. We will work on these problems this summer.]

The main problem is that the presses, the MJ's, the sanders, and the inspectors are all working independently with the result that there is a lot of work in process inventory. The central problem to attack is the lack of coordination between these areas. It is possible to solve these problems with low-tech, low budget solutions.

Students want guidelines on how much they can spend on this problem. Can they build shelves, conveyer belts, computer-vision systems, etc.?

Advise them not to unbrick the wall to the inspection room unless they can solve the problem of fork lift truck drivers hitting their masts. They may recommend unbricking the wall if they plan to use conveyors through the opening.

The students should consider the frequency, and variability, at which press jobs finish and get delivered to the fabrication room.

LLENROC PLASTICS

INSTRUCTOR'S NOTES

CASE 5 ORAL PROGRESS REPORTS

(NEW NOTES: 1993)

In the team meetings for this case, I did most of the talking but left some time for questions at the end. I drew the student's attention to the contrast between table 5.1 and Table 5.4. Table 5.4 could be called engineering data. That is data that specifies what level of productivity the individual operations could achieve. Table 5.1 measures actual performance. The productivity is much lower (times per press load are much higher than what Table 5.4 would suggest). The queue times are high. This year, I explained that the queue numbers were not actual performance. They were estimated using a simulation model but they fell far short of what the actual queue times were. Actual queue times had to be 5 and 6 times as big to explain the inventory levels we know existed. The fabrication room was full of inventory. We have video clips that pan across the room and show that, except for aisles, every square foot of space is used for WIP storage. I describe the tremendous activity of fork lift trucks wheeling in and out moving this inventory. We have video of the sanding operators standing around waiting for a fork lift truck to arrive. The point to emphasize is that from the engineering data it should be clear that there is no excuse for such high inventory levels in this portion of the plant. This area is ripe for conversion to just-in-time / continuous flow manufacturing. The goal of the case is to design and describe such a system.

Next, I tried to offer a plausible explanation for why the system performance could be so poor. Certainly, there will be a buildup of inventory between fabrication and inspection because inspection is only a two shift operation, but that will be at most one shift's worth. The inspection is fast and can work down the bulge very quickly. The problem is in front of trimming and between trimming and sanding. If you stood and watched the sanding operation, you would notice that the operator at the input side can waste as much as half an hour per skid of laminates, checking the paperwork and counting laminates. Some detective work is in order. The problem can be traced back to the teardown stations of the presses. Imagine the teardown operation: operators are removing laminates and stacking them on a skid. At the end of a press load, how much does the skid weigh? The students figure out that it is between 560 and 880 pounds. The skid cannot be moved out of the way except by fork lift truck. If there is no truck available, what should they do? Well, if the next press load has the same dimensions, they will continue stacking laminates on top of the same skid. At some point, a fork lift truck comes and moves the skid and replaces it with an empty skid. So, the skid may consist of 21/2 press loads of material. At that point, you have lost "press load integrity." Press load integrity means that all the laminates for a press load move through the remaining operations together. Press loads are now split between multiple skids and each skid has a life of its own.

What problems does this create? Well, at the sanding operation, there is an adjustment to make depending on the desired thickness of the laminates. All laminates in the same press load have the same desired thickness, but a skid consists of laminates from several different press loads. This explains why the sanding operator is counting laminates: he needs to know how deep to go in the stack before changing the thickness setting.

The problem is more serious. Not only have you lost press load integrity but you have also lost production order integrity. Each press load consists of several production orders. A production order is series of identical laminates: all with the same part number and destined for the same customer. For example, a production run could be 75 sheets of Cloud Marble 3x8 for Herman Miller. The customer may be simply the national warehouse: that is, it may be an order to replenish stock in the distribution system. On the other hand, there may be a large customer order that cannot be satisfied from inventory and so a production order is scheduled to cover it. If press loads are split between skids, production orders may be split between skids. Imagine an expediter who is asking the sanding operator to work on the Herman Miller order quickly. The operator can locate 25 of the sheets of that production order but cannot find the other 50. It is up to the fork lift truck drivers to track it down. The whole system depends on fork lift truck drivers and they are free to roam around unsupervised.

On the output side of the sanders, the operators are sorting (not inspecting) the laminates onto different skids. For example, the Herman Miller order may be put on a separate skid so that it can be expedited through the remaining process steps. The skids are heavy so once the loading has been completed, the sanding operation must stop until a fork lift truck comes to remove the skids. Once again, material handling problems bring the operation to a standstill.

Because of these inefficiencies at the sanders there is not a continuous flow of material from the trimmers to the sanders. Instead, the fork lift drivers move skids away from the trimmers and find a place to store it. They bring skids out of storage to the sanders as needed. Thus, there is little incentive at the trimmers to work efficiently: their output is simply going to storage and there is no rush for that to happen.

All the student teams accepted this as a plausible explanation for the current behavior of the system. I pointed out that the solution that was implemented had the following features: a continuous flow was established from trimmers to sanders to inspection. Overtime was used to flush the current level of inventory out of the system. A rule of Press Load Integrity was enforced: teardown operators at the presses were not allowed to mix press loads on the same skid: fork lift truck operators were dedicated to the task of removing the skids at the end of each press cycle. Finally, the investment required to implement the changes was very small. The results were dramatic: reduction of inventory, increased productivity at the trimmers and sanders, rapid flow times, and less confusion. I was able to relate these results to the students' experience with Just-In-Time games we had played the week before in lab.

The problem the students face is to design a system that has these characteristics. We ask for a qualitative description of the design. We do not ask for a simulation (in spite of what the text of the case suggests). There was a collective sigh of relief when I announced this.

At this point, I asked the students the difference between a transfer batch and a process batch. Most were unfamiliar with the terminology. I asked them to identify the process batch at the trimmers. They recognized that this was 2, 3, or 4 laminates per process batch, depending on the dimensions. I asked what the process batch size at the sanders was. They answered that the sanders operated on laminates one at a time. I asked what the process batch size at the presses was. Answer: a press load (140 - 220 laminates). Now, in response to the question "what is a transfer batch?" they recognized that it was the number of laminates that transferred at a time from one operation to the next. Currently, the transfer batch size is a skid of material which is several press loads of laminates. If the transfer batch size is changed to a press load, then the number of transfers must increase. Material handling activity must increase. I point out that one of the concerns in switching over to Press Load Integrity was the availability of fork lift truck drivers. So, part of their design should be to estimate the number of material moves that are required, the estimated time requirement for the moves, and the estimated number of people and fork lift trucks required to support this activity. There is little data in the case to support this, but they could measure the distances from the plant layout and rough out some travel time estimates.

Of course, if they choose to use conveyors, then the transfer batch could be as small as one laminate moving between operations. If they choose this idea, then I ask them to pay close attention to the issue of production order integrity. When a laminate comes out of a sander, how will they know to what customer it is destined? How does information flow in this system? Student teams in the past have done a good job of analyzing material flow but a very poor job of analyzing information flow. They wave their hands and say "a computer system" will track it. I encouraged teams to come to grips with this issue and be specific, avoiding computer solutions if possible ("Could you do it with ping pong balls?").

The design should emphasize low-tech low cost solutions. For example, automated guided vehicles, automatic storage and retreival systems, computer vision, and bar coding are not appropriate solutions. Simple roller conveyors or carts are allowed. Photoelectric cells to count laminates are also allowed. Moving equipment is discouraged. It is obvious that you should move one of the sanders to be closer to MJ1 but that is costly (the sanders are connected to a blower system that removes the sawdust up through the roof). The point is, can they achieve 80% of the productivity of the ideal solution with minimal investment and minimal delay? Defer equipment moves to a second phase of their proposal. They do not need to estimate the cost of their solution except in rough terms (less than $10,000, less than $50,000, etc.).

If they propose conveyors then note that the transfer batch size affects what weight the conveyor must support: a conveyor that transports a press load at a time must be very rugged. Ask them to worry about turning angles in the conveyor. If it is gravity fed, then worry about the length and drop rate requirements: you couldn't go all the way from sanding to inspection with gravity feed.

Llenroc Plastics

Instructor's Notes

Case 6 Oral Progress Report

Discussion 1:

Ask the students to describe the problem with database accuracy in their own words. Essentially, there is a mismatch between the information system's view of the world and the actual situation. The inventory of treated printed paper is often less than indicated by the database system due to scrap (the printed paper is brittle and breaks due to excessive handling). There are two possible approaches for improvement. One is to improve the database accuracy. The other is to make the system less sensitive to errors in the database.

How could the software be changed to make the system less sensitive to database errors? One method would be to allow a more dynamic creation of press loads. The software could indicate production orders for different part numbers and sort them into press load groupings, but it should be possible for the build-up operators to cancel or modify production orders when there are shortages of treated printed paper. The composition of the press load should be determined when build-up is completed and the database tracking of press loads should be updated at that point. Under the current system, there is no way to change the composition of a press load once the computer has issued the paperwork.

What is the problem with treating partial rolls of printed paper? The open rolls collect dirt which contaminates the resin. What are possible solutions? One solution would be to treat whole rolls at a time and re-roll them. The disadvantage with this is that the treated paper is stiff and requires a large diameter roll when re-rolled. There is not sufficient storage space to re-roll every pattern of printed paper. Another solution is to cover the partial rolls of untreated paper with plastic. This simple idea was implemented by the company. A significant improvement in product quality (due to cleaner resin) was noticed soon afterwards. The point here is that simple changes in one part of a manufacturing process (eg. raw material storage) can have significant effects on other parts of the process (eg. laminate quality).

What are the benefits of re-rolling treated paper? It should result in less breakage (sheet storage exposes paper to damage more than re-rolling does). It should reduce cycle counting and estimation problems. The re-rolling process could include a precise way to measure the number of feet wound onto the roll. Unrolling and cutting has a very high yield so the number of feet left on the reel after sheets are cut could be estimated accurately. There should be a reduction in safety stock requirements because cutting to specific lengths would only occur as needed. (Review with students the notion of risk pooling from case 3.)

Because of space restrictions, the idea of re-rolling paper can be applied only selectively. How would the students decide where to apply the idea? Study the derived demand data for the printed paper. (These data are not provided in the case. The question is on how they would proceed with the analysis if the data were available.) Look for situations in which the demand for paper of a certain pattern and width is highly variable across more than one length. This drives a safety stock investment in each length of this pattern/width combination. By re-rolling the paper and cutting to length as needed, there will be a reduction in variability and therefore, a reduction in safety stock requirements. In most patterns, demand is concentrated in a particular length, so re-rolling would have only marginal benefit in terms of reducing safety stock.

<u>Discussion 2:</u>

Ask the students to review the analogy of a plane schedule to explain the benefits of a cyclic schedule. In particular, short cycles and frequent runs will reduce cycle stock and improve response times to order placement.

Some ideas for managing the waiting list and lot sizes:

- give priority to backorders over replenishment orders
- item lot sizes may be extremely small from the perspective of press room scheduling; however, some item lotsizing will probably be induced by the cutting operation if the treated, printed paper is stored in rolls.
- the decision of exactly which items will be placed in the next load can be postponed until that load is being built up. Items are chosen from those with available material.

Ask the students to study the demand data in Table 6.1. For any of the items do they notice any trends in the demand data over the four weeks considered? The answer is "no." Now look at Table 6.2. Is the demand highly variable? The answer again is "no." The coefficient of variation is extremely low. This illustrates that when the demand data are aggregated nationally and aggregated by size and thickness classifications the coefficient of variation drops dramatically. This is another illustration of risk pooling. The demand for pressing capacity by size and thickness classification is reasonably stable. If this were not the case, a cyclic schedule probably would not make sense. The students should realize that another aggregation is possible: there are only two thickness/construction types that are relevant for scheduling: the PB, VD, V4 constructions can be grouped together and the OH, O5, and O8 can be grouped together. This will further reduce the apparent variability.

The story we tell of the real company is that there was initially a great deal of skepticism as to the possibility of a cyclic schedule for the press room. However, after the data of Table 6.2 were presented, the chief production scheduler was challenged to develop a cyclic schedule. She did so and was excited by the short cycle length that was possible (it was much less than two weeks). She became an enthusiastic proponent of the idea thereafter. Furthermore, she was fully aware of all the scheduling complications (more than we have presented in this case) and was able to defend her cyclic schedule against the objections of the other schedulers far better than a consultant would have been able to. The purpose of the case is for the students to discover the same sense of possibilities that the chief scheduler did.

There is no software provided for this case. All the necessary calculations can be made using a spreadsheet. Typically, one student in a team will develop the spreadsheet and other students will exercise it.

In Fall 1993, we told the students to concentrate their reports and presentations on Assignment 1 and part 2 of Assignment 2. Discussions 1 and 2 were only to give a flavor of the larger setting for the case. Nothing of these discussions had to appear in the reports.

The students asked whether they could apply ideas from case 4 such as the swing crews to cover presses during breaks. The answer is an emphatic yes. It is not possible to meet the demand otherwise.

April 8, 1992

Llenroc Plastics
Instructor's Notes
Case 6 Written Report

Assignment 1:

1. Production can be scheduled during a normal 5 day week using 3 shifts. There is enough capacity so that at least one press can be idle for one shift on any given day giving us a "free" shift.
2. Swing crews should be used to cover the presses during breaks. The breaks should be staggered so that only a couple of crews are needed. These crews might be responsible for material handling and staging when they're not covering breaks. They can also run extra loads during the "free" shift.
3. The longest cycle is at most 3 days. The majority of demand can be produced on dedicated presses or in 1 day cycles. Can eliminate plate changes on all presses except press 7.
4. The two lowest demand groups, PB-VD-V4 36x120 and 36x144, may be left out of the cyclic schedule. Orders for items in these groups may be filled by cutting larger boards, 48x120 and 48x144, which have much higher demand and may be included in the schedule without much difficulty. Alternatively, these categories may be run on press 7 every couple of weeks. If necessary, the "free" shift may be used to cover part of the workload on press 7. In either case, these items constitute such an insignificant fraction of total demand that they should not be allowed to seriously disrupt the production schedule.

Assignment 2:

1. The MRP system is no longer used to schedule press loads. The cyclic schedule is fixed and the determination of which items are assigned to a particular load can be made on the floor. Kanbans can be used for the items that are produced on dedicated presses.
2. Fabrication/Inspection will benefit from the predictability of its input from the press room.
3. Demand variation is an extremely important consideration. Extra loads may be run during the "free" shift. Press loads should be as full as possible, especially during low demand periods. Loads may be "topped off" with "filler" items that have high demand and low variation. The idea is to store this excess production capacity in material that we can expect to sell during peak periods

so that additional production capacity will be available for the unstable, lower demand items during those same peak periods.

4. The potential effects of variation can be analyzed in at least two ways. First, we can compare the relative magnitude of the excess capacity of a press with the standard deviation of the daily demand assigned to it. Second, we can plot the (cumulative) daily production capacity versus the (cumulative) daily demand for each of the presses using the four weeks of sales data provided in the case.

LLENROC PLASTICS

INSTRUCTOR'S NOTES

CASE 7 ORAL FINAL REPORTS

Jotting down notes:

mostly a review of major recommendations to date. We had no oral reports after cases 4, 5 or 6 so we focussed on these recommendations. Case 3 was well taken care of earlier.

space limitations prevent rolling all sizes. what sizes of paper to roll up: answer: low volume widths (3 foot). Refer to table 6.3

how to bar code? a common solution: usually vague "computer systems"

what performance measures to post in fab room, in press room: average time a press load takes to move through, scrap rate

how to measure customer service: what specific questions would you ask customer? Order timeliness, order completeness, response to emergencies

how to enter specification market: since spec orders have long lead time, it suffices only to have extra capacity and wider variety of printed papers. Case 4 indicates that there is excess capacity. Cyclic scheduling (case 6) reveals further excess capacity

scheduling: if a press load is incomplete, what would you produce? answer:an A item or a bit towards a committed specification order in the future.

press shutdown for equipment installation, what inventory would you build up in advance? answer A items.

This is a log of Email correspondence with Lee Schwarz concerning LlenrocPlastics.

From root Tue Oct 20 13:25:27 1992
From: lee@zeus.mgmt.purdue.edu (Lee Schwarz)
To: jackson@orie.cornell.edu
Subject: LLenroc
Dear Peter:

In case 2 it is stated that LLenroc "currently uses an ABC classification based on item cost." Does this mean the unit cost of an SKU? If so, I would expect that A's would be mostly 5x12' sheets, and most of the C's would be 3x8'. This would be strange. Or, does this mean by total (item) manufacturing cost? This would yield a categorization that was quite similar to that of total square footage, since as the case describes, most items have the same manufacturing cost per square foot.

Also, can you provide copies of the graphs that are requested in Assignment 3 and 4? We are doing case 2 in lecture/discussion mode, and I would like to use these graphs as illustrations. Can you help?

Thanks for your support.

Lee Schwarz phone: (317) 494-4510
Krannert School of Management fax: (317) 494-9658
West Lafayette, IN 47907 internet: lee@midas.mgmt.purdue.edu

From jackson Mon Oct 26 15:20:10 1992
To: lee@zeus.mgmt.purdue.edu
Subject: Re: More help, please

We would argue that ABC by sheets is more relevant for inventory stocking policies than ABC by square footage. ABC by square footage is correlated to ABC by product cost and therefore focusses on the inventory holding cost aspect of the inventory policies. ABC by sheets is focussed on the charac teristics of the demand process. If I were forced to make predictions of stockout probabilities, I would rather have the demand by sheet data. I xxx We want to think of the A items as high volume, consistent demand items that require little safety stock to protect customer service. It is conceivable that an item falls in the A category by virtue of having a large sheet size although its demand may be medium volume and highly variable.

Its hard to shadow box on this issue. Does that make sense or was your question really something different?

Glad to hear case 1 has been going well. There is no question that this approach requires stamina. I am always puffing behind Jack. His metabolism is bionic.
Regards, Peter.

From root Wed Oct 28 15:21:22 1992
From: lee@zeus.mgmt.purdue.edu (Lee Schwarz)
To: jackson@orie.cornell.edu
Sent: Wed Oct 28 15:18:54 1992

Subject: Even more help, please

Thanks for the note about ABC: It turns out that I misunderstood what "orders" meant. I thought it meant number of orders received from customers for some SKU, where one order might be for several sheets. The case is pretty clear about "sheets" but I missed it. And, of course, I agree with your interpretation/justification for using sheets.

Now, more help, please:

In case 3, Appendix F describes describes a procedure for computing the mean and standard deviation of an average (category) A, B, or C item. The weights, alpha(i), for all items in category i are equal weights, 1/n(i). In other words, the average mean demand for category A items would be the simple average of all the item demands in that category. Why isn't a weighted average being used here, where the weight for item j would equal item j's fractional share of total (average) demand of all items in that category?

Ashok and I finished 5 of a planned 8 1-hour sessions to discuss Case 3 today. Things went very well. Three more tomorrow.

Thanks for your continuing help. Best regards to Jack.

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From root Thu Oct 29 11:47:32 1992
From: jackson@cosmos2.orie.cornell.edu
To: lee@zeus.mgmt.purdue.edu
Subject: Re: Even more help, please

Whatever linear combination of items we use we will end up skewing the standard deviation for the category in funny ways. We opted for the simplest linear combination, but without enthusiasm. Go ahead and have your students weight them differently (they have the spreadsheet). Your linear combination does a better job of combining the means than ours does. But remember, the purpose of the exercise is to estimate the safety stock that will be required for each of the categories and it is the lower volume items in each category that drive a disproportionate amount of the safety stock investment. A volume weighted measure will understate the amount of safety stock required. Actually, we also use these numbers to estimate cycle stock and our approach will understate cycle stock requirements. Hmmm. maybe we should weight the means by volume and keep the simple average for the variance.

Your questions are great! Its we who should be thanking you for your critical involvement. I hope you are keeping notes of problems you are experiencing. I will spend time next summer improving the materials.

Best regards, Peter

From root Fri Nov 6 14:12:29 1992
Date: Fri, 6 Nov 92 14:13:10 -0500
From: lee@zeus.mgmt.purdue.edu (Lee Schwarz)
To: jackson@orie.cornell.edu
Sent: Fri Nov 06 14:16:50 1992
Subject: More help, please

With respect to LLenroc #3:

1 If "low" fill rates are specified, the SAFETY worksheet returns negative safety stocks (SSMOS's). We have suggested that students workaround these by setting the correstponding SSMOS's to zero in the WCOST worksheet. Is this the most sensible way to handle this problem?? (If so, would it be sensible to have the SAFETY worksheet return a zero?)

2. What is your thinking about the fact that the SAFETY worksheet ignores riskpooling; i.e., the impact of the number of warehouses on total system safety stock (given fixed fill rates and fixed central-to-regional replenishment times)? Risk-pooling should allow fewer warehouses to operate with lower system safety stocks than more warehouses. Is the cost impact of risk-pooling small?

What are your ideas about how risk-pooling might be incorporated? One possibility that occurs to us is: given a set of regional warehouses, with break bulk points assigned to them, then it is easy to compute the mean demand served by each region (from Table 3.3). Further, the sum of the variances (across all the regions) should(?) equal the variance of national demand. So, one might set the variance of demand at region i equal to (variance at national)*(mean demand at region i)/(mean demand at national. What do you think?

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From root Sat Nov 7 18:13:01 1992
From: lee@zeus.mgmt.purdue.edu (Lee Schwarz)
To: jackson@orie.cornell.edu
Sent: Sat Nov 07 18:16:18 1992
Subject: Case 4 HELP!/ Case 5 help

Case 4:

We are scheduled to discuss on Thursday, 11/12!

We think that we understand the BASICS of the Excel+ model you sent us (for example, we understand how to change processing time distributions, setup times, etc.), but we are very confused about several things.

First, and perhaps most important, our goal for the Case 4 discussion is to introduce the basics of the Excel+ model -- we understand enough to do that now -- and then to present representative output statistics under various scenarios: different buffer sizes between teardown and buildup, the original vs the synchronized processing times, and, if possible, with and without coffee and lunch breaks.

So, if you can provide representative statistics, then that's really all we need. If, however, you can't provide representative statistics then we would like to have enough facility with the model so that we can generate representative statistics ourselves. That leads to the following questions about the Press7 model you sent us:

1. The buffer between teardown and buildup has capacity of 2, not the 1 unit implied by the case writeup and schematic.

2. There is a buffer with capacity of 3 between transport and teardown. We didn't realize that there was a buffer there.

3. There is a major and minor setup of 10 and 5 minutes respectively for transport B. Why?

4. How do we model coffee and lunch breaks?

5. How to model press breakdowns?

6. We think that we understand how the press model works, but the press time is either 56 or 58 minutes. How is the delay between press loads modelled?

Case 5:

Any notes, handwritten or otherwise that you can send us on Case 5 would be very helpful. Or cases 6 and 7, too!

Thanks for your continuing support.

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From root Mon Nov 9 15:35:17 1992
From: lee@zeus.mgmt.purdue.edu (Lee Schwarz)
To: jackson@orie.cornell.edu
Sent: Mon Nov 09 15:33:11 1992
Subject: LLenroc Cases 5&6

Ashok and I would appreciate any general information that you can provide about Cases 5 and 6. In addition, we have the following specific questions:

1. How are work orders handled in the fabrication, press, and buildup workcenters? Cases 4 and 5 mention "paperwork" that identifies, among other things, "customer orders". What is the paperwork: what information does it provide? How is it logically and physically organized? Are workorders for treating paper specific to customer orders? The more you can tell us about this paperwork system, the better.

2.What happens in the "Assembly Room", number 21 in figure 2. I'm sure I read this somewhere, but in my mildly paniced state I can't find where.

3. Case 5 mentions "buildup of inventory at the end of the second shift" in the Inspection room. It also mentions two-shift operation. Does this mean that Inspection works on the first and third shifts?

3. Table 5.4 give actural production time/process batch in trimming as "Unifrom[6 ,8] seconds". Is this a typo?????

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From root Tue Nov 10 10:19:07 1992
From: lee@zeus.mgmt.purdue.edu (Lee Schwarz)
To: jackson@orie.cornell.edu
Sent: Tue Nov 10 10:24:39 1992
Subject: More help, please

Case 4 describes operators at build up and teardown waiting for forklift trucks. I also remember that Jack talked about replacing some material handling equipment with carts. Is this where carts were used, or was it in fabrication?

Case 6 cites "inventory of treated papers" in the build-up room. Please provide more detail. How large was this inventory? Did it include printed paper? Why is this called the "build-up room"? I had been thinking that this is where press loads were staged. Now I'm beginning to think that press loads were staged in the "assembly room".

Thanks for your help. We are having fun, but it would be wonderful to have you or Jack here.

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From root Wed Nov 11 13:05:13 1992
From: jackson@cosmos2.orie.cornell.edu
To: lee@zeus.mgmt.purdue.edu
Subject: Re: More help, please

SAFETY.WK1 was a quick and dirty spreadsheet for this case. I wanted something that was easy to explain to students who had not had an inventory theory course.

We told our students to set negative SSMOS to zero as you did. Yes, it would be a good idea to have the spreadsheet do this automatically. I'll add that to my TO DO list. Thanks.

Your idea on incorporating risk pooling sounds right. It should also be possibleto incorporate it in the spreadsheets with minimal explanation to the students. I'll add that to the TO DO list too. Thanks.

Are you keeping a log of your suggestions? I would really appreciate a copy at the end of the semester. Thanks.

Best regards, Peter.

From root Wed Nov 11 14:19:12 1992
From: jackson@cosmos2.orie.cornell.edu
To: lee@zeus.mgmt.purdue.edu
Subject: Re: Case 4 HELP!/ Case 5 help

Ouch. The press7 model was developed by Jack and he typically is the resource person for that case. He is out of town until Monday. I will fax a student report to you immediately. I hope it is useful. Be prepared for a big fax bill. I don't think I can give

you detailed help in time for your class tomorrow. I've got meetings this afternoon. Sorry. I should have checked my e-mail sooner.
Good luck. Peter.

From root Thu Nov 12 11:19:26 1992
Date: Thu, 12 Nov 92 11:20:36 -0500
From: lee@mgmt.purdue.edu (Lee Schwarz)
To: jackson@orie.cornell.edu
Sent: Thu Nov 12 11:25:38 1992
Subject: LLenroc Cases 5 and 6

Thanks for sending the student report. It helps a bit.

We are still looking forward to receiving answers/information as requested in my message of 11/9 regarding "paperwork", the assembly room, and inventory buildup.

Thanks

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From root Thu Nov 12 11:39:34 1992
Date: Thu, 12 Nov 92 11:40:49 -0500
From: lee@mgmt.purdue.edu (Lee Schwarz)
To: jackson@orie.cornell.edu
Sent: Thu Nov 12 11:45:40 1992
Subject: Llenroc Case 5

1. The top line of p 5-2 describes a "batch of laminates" Is this a press load or some other quantity?

2. In the "Other Issues" section on p 5-2: "checking tickets so they are in order" What does this mean??

Thanks

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From root Thu Nov 12 16:42:59 1992
From: jackson@cosmos2.orie.cornell.edu
To: lee@mgmt.purdue.edu
Subject: Re: Llenroc Case 5

This I can respond to quickly.

"batch of laminates" at top of page is a press load.

"checking tickets" : a press load is a collection of laminates of the same dimension and thickness. The computer program that generates the press load sorts the items by customer (national warehouse/direct shipment to regional/ or direct shipment to OEM) and type (I don't know what type refers to here: let's assume it is part number). However, there are several opportunities for this to get scrambled. The computer program generates a ticket for each customer/part number combination. One ticket could represent several laminates in a particular press load. A batch of these tickets wrapped in an elastic band represents a press load. This is what the assemblers use to tell them how to build the books. All they are concerned with is making sure that they build the right quantities: they are not concerned with the order in which they put the laminates into the press load. for example, if they are short some paper they will build as much of the load as they can and finish building the load later, when they get the paper. So the laminates in the press load are not sorted to match the bundle of tickets. For most press loads, they are. When the press loads are nicely sorted, it is easy to off load the sanders onto skids according to destination. Note that the tickets can also be separated so that a collection of tickets goes with one skid, another collection goes with another skid, etc. The count could be low however, because of scrap. But it is the sander operators who must check the tickets, verify the laminate counts, sort the laminates, inspect the laminates (a quick check), sort the tickets, and manage the skids. The sanders have a fair bit of mental work to do and it is more difficult if the laminates for a particular destination are spread throughout a press load. Suppose they make a sorting mistake and put a laminate on the wrong skid? Then their counts won't tally and they have to find the missing laminate.

Can your students devise a better system?

Regards, Peter.

From root Thu Nov 12 17:21:57 1992

From: jackson@cosmos2.orie.cornell.edu

To: lee@midas.mgmt.purdue.edu

Subject: Case 6

Instead of a fax tomorrow, I'll go ahead and try to describe the information system in more detail.

The MRP system can distinguish between three types of order for finished goods: a replenishment order for the national warehouse (caused because inventory of a part number dropped below a reorder point), a special order for a regional warehouse, and a special order for an OEM. Typically, the lot size for each part number will be more than onsies or twosies. Winnebago, for example, will order a large number of sheets of a single part number. The replenishment orders too will be sized to some "economical" lot size. The special orders may or may not be sized. There may be onesies or twosies here. At this point, the MRP system kicks out a file of authorized orders, listing customer number (national, warehouse, or OEM), part number, and quantity. Oops, No. Before this, the MRP does a simple bill of materials explosion to identify the paper requirements for these orders. It checks these requirements against its record of printed paper inventories. If it believes that the on hand inventory of printed paper is sufficient for the order, it will authorize the order. If not, it will either reduce the quantity of the order or put the order on hold (I'm not sure which). At this point, the MRP system kicks out the file of authorized orders. A separate homegrown program (not part of the commercial MRP package) takes this file and organizes it into press loads of identical size and thickness. This program prints out a list of press loads, and prints the tickets that will accompany the press load through the factory. The production scheduler takes this list of press loads and manually schedules when and on what press the load will go.

Every day, he will release the bundles of tickets for the press loads that are to be assembled that day. These tickets go to build-up room. In the meantime, the MRP program takes the file of authorized orders, performs the bill of materials explosion and nets out of printed paper inventory the requirements for these orders. If the inventory of a certain paper (pattern and size combination) drops below a reorder point, the MRP system generates an order to treat more paper. Here is where it makes a conversion between sheets required and feet of paper to treat, using an average yield figure which may not match the actual yield of the treating run. The treating order is matched against the estimated inventory of untreated paper (in feet) and orders with the paper suppliers are placed when this estimate drops below a reorder point.

I believe the ordering process ofor treating and purchasing Kraft paper is the same.

Note that physically, building books is a two step process: assembling the sheets of printed paper and overlay paper into press loads takes place in the buildup room next to the printed paper inventory. Second step is to assemble the printed and overlay paper together with the Kraft paper (as many as are needed) into the required books. This happens in the assembly room where the stainless steel plate and the release paper are placed on top of each book. The assembly room is right beside the press room, so that the assemblers can continually feed the operators who load the carriers. There is a buffer inventory of press loads of printed and overlay paper between the buildup room and the assembly room. The bundle of tickets with an elastic band chases the press load through the system.

How's that?

Peter.

From root Sun Nov 15 14:17:15 1992

Date: Sun, 15 Nov 92 14:18:29 -0500

From: lee@mgmt.purdue.edu (Lee Schwarz)

To: jackson@orie.cornell.edu

Sent: Nov 15 14:23:53 1992

Subject: Guess?

Thanks for the information about Llenroc's MRP and material-flow system. The pieces are beginning to fall into place.

Here are a few questions that we're still puzzled about wrt Case 5:

1. Which two shifts do the Inspectors work? Why is there a built up at the end of the second shift? Related to this, Table 5.1 displays an average queue time in front of inspection as about 221 min. If one third of the batches wait one shift (8 hours), why isn't this number bigger?

2. What's the story on the stainless steel plates that built into the books in the assembly area? Are these separator plates or are they used in addition to the separator plates. What's confusing here is that in case 4, separator plates are recycled as part of the build-up and tear-down processes in press operations.

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From root Mon Nov 16 08:44:20 1992
From: jackson@cosmos2.orie.cornell.edu
To: lee@mgmt.purdue.edu
Subject: Re: Guess?

Answer to your second question on the separator plates. There are two kinds of plates. Thin stainless steel plates separate the books within a carrier. They have no effect on optimization/simulation of press 7 since the carriers are prepared off line (in the assembly room). Then there are large stainless steel plates that separate one carrier from another within the the press. Of these there are a limited number and they cycle through the press. These are the focus of the simulation in case 4. Sorry for the confusion. I'll come up with different names to distinguish the plates in the next revision.

I'll get back to you on your case 5 questions.

Regards, Peter

From root Mon Nov 16 11:15:31 1992
From: jackson@cosmos2.orie.cornell.edu
To: lee@mgmt.purdue.edu
Subject: Re: Guess?

I just spent some time with Jack and cleared up some of your questions. Turns out I learned a lot from these answers that I hadn't really understood.

The buffer between teardown and buildup has a capacity of 1 carrier plate as in the writeup. This is 131 in the schematic. As described on the bottom of page 4-2. The separator plates (not carrier plates) are removed from the carriers at station 31 and cycle through 80, 180,81,and 82 back to the buildup station (32). We ignore this loop in the simulation and concentrate on carrier plates. Now here is where I had misunderstood the process. I remembered from the slide show that the carriers are built up with separator plates in a different room from the press room. I never resolved the obvious conflict of this idea with the description on page 4-2, which Jack wrote. The fact is that the build up of the carriers with the separator plates is station 32, but it is enclosed in some phony walls to cut down on the noise for these operators. So in the slides it looks like a completely separate room when in fact it is part of the press material handling system. This distinction is not crucial for the students since they focus on the carrier plates.

Jack has a bigger story about what goes on here but I'll save it for the revision.

Note the carrier plates are all the same size and do not need to be changed when changing from one press load size to another. The separator plates do need to be changed, but Jack instituted a zero changeover time system at Press 7 (part of the bigger story I alluded to) so the students can ignore changeovers.

The buffer size of two in the PRESS7 simulation may come from Jack originally focussing on the separator plates. I'm not sure.

The case writeup is insufficient concerning the buffer size between the press output accumulator and the teardown station. Station 16 can hold one carrier and it moves back and forth between the output accumulator and station 30. Station 30 can hold one carrier. It is a fixed position buffer. Not shown in the schematic is a station that moves back and forth between station 30 and the teardown station. It can hold one carrier so there is a total buffer of three between the output accumulator and the teardown station. We will fix the writeup in the next revision.

Xcell has major and minor setups. Since this is a single product system, it will ignore the major setups. What is important, I believe is the 5 minute setup time.

How to model coffee and lunch breaks? Pose that question to the students. What we hope is that the students will come up with some idea such as a swing crew that cycles around the different presses to keep them operating while the other operators take breaks.

How to model press breakdowns? Jack may have forgotten to include that in the XCEll model. It is simple to add that capability.

Press loads are either 56 or 58 minutes. Should use an average time here. There are data in case 6 that permit the computation of the average. (tAble 6.3).

Case 5 mentions the buildup of inventory at the end of the second shift. This was a fact in the real plant because the second shift was only partially staffed However, in writing the case we made it fully staffed so we should change the writeup to say that the build up occurs during the third shift. Thanks for catching this.

There is no typo in saying trimming time is 6 to 8 seconds per process batch. The MJ's are very fast. As fast as you can feed in the laminates, it trims them. The wait for forklifts in case 4 is at the teardown station, since they offload the laminates onto skids and need to have the skids moved. Where Jack was proposing the idea of carts was in the fabrication room between the MJ's and the sanders to speed the flow of material through this step. We let the students come up with this idea (with some prodding if needed).

We have no data on the amount of inventory of treated paper, which is why we don't have a detailed case on this portion of the factory. Jack guesses there was a million dollars worth of inventory there: a considerable number of sheets of every possible size and pattern combination. We can't be any more precise than that.

I hope the description of build up and assembly is reasonably clear now.

Average queue time in front of inspection is listed as 221 min. which is inconsistent with the fact that it is only a two shift operation. You're right. None of those queue times are real. We hired a student to make them up, based on a simulation and didn't check them as thoroughly as we should have. The actual queue times were longer than all of the listed times.
Regards Peter.

LLENROC PLASTICS: MARKET-DRIVEN INTEGRATION OF MANUFACTURING AND DISTRIBUTION SYSTEMS

HANDOUTS TO STUDENTS
JANUARY, 1994

CONTENTS:

8/26/93

ORIE 416/515
Design of Effective Manufacturing Systems
4 credits
Fall, 1993

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Juan Pereira (ORIE 515)

Meeting Times:
Lecture: T,R 1:10-2:25 p.m. HO314
Lab: OR416 (Seniors) R 2:30-4:30 p.m. E&TC 253
ORIE515 (Grads) F 2:30-4:30 p.m. E&TC 253
\+ Weekly team meetings

Prerequisites:
ORIE 410 or graduate standing. ORIE416 enrollment is limited to seniors. ORIE 515 enrollment is limited to graduate students. Course involves the application of operations research methodologies at a basic level but the focus is on issues in manufacturing system design. Familiarity with spreadsheet software and graphical operating systems is assumed.

Purpose:
To give students an experience in the design of an integrated manufacturing and distribution system.

Grading Weights (Tentative; subject to revision based on evolution of course):

Team-Based

15% Case 1 Presentations
3% Case 2 Presentations
10% Case 3 Presentations
10% Case 4 Presentations
15% Case 5 Presentations
15% Case 6 Presentations

Individual

2% Lecture Attendance
2% Homework Assignment
10% Participation in the Manufacturing Operations Game
2% Lab Attendance
3% Meeting Report
3% Grader-blind Assessment Report
10% Intellectual Contribution

Feedback:

Experiential learning is fundamentally different from traditional teaching methods in engineering. In experiential learning, we do not tell you what to learn. Instead, we provide a structured environment for discovery. The techniques for experiential learning are experimental in nature. We are committed to developing and exploring these techniques and we rely on your feedback to guide us. There will be several opportunities for you to provide anonymous critiques of different aspects of the course. Please treat these opportunities seriously and give thought to what you are learning and how you are learning it. The final assessment report will force you to articulate the impact of the course on your own professional development.

LLENROC PLASTICS

CASE 1 WRITTEN REPORT GUIDELINES

Prepare a typewritten report, double spaced using 12 point typeface (like this) that presents your analysis of Case 1. Use sentence form (not point form). The report should consist of an introduction and a series of seven sections that address, in order, the seven assignments of the case. **Begin each section on a new page.**

A written response to the discussion questions is NOT required: their purpose is to stimulate discussion within your team. You may wish to address some of these questions in the introduction or in your response to Assignment 7.

The Introduction should summarize the problems faced by the Atlanta Transportation System of Llenroc Plastics and present an overview of the report.

Use descriptive titles for your section headings. For example, "Transportation Cost Model" is better than "Assignment 1."

The requirements of the first six assignments are quite specific. Assignment 7 is open-ended. You will be graded on how well you have grasped the issues raised by the case and by how satisfactorily your strategy addresses the issues.

The faculty and T.A.'s must read and grade many reports in one evening. For that reason, brevity is a virtue. The following limits apply:

Section	Maximum No. of Pages
Intro	2
1	2
2	3
3	1
4	2
5	2
6	1
7	3

Begin each section on a new page.

We look forward to reviewing your analysis.

LLENROC PLASTICS

CASE 3 REPORT GUIDELINES

Prepare a written report addressing the issues raised in case3. This should be a formal report in the style that you would use at the completion a consulting contract with Llenroc Plastics. In particular, you should include a 1-2 page executive summary at the beginning of the report that presents a synopsis of the problem situation, the scope and structure of the analysis (an outline of the report), a concise statement of your distribution system design recommendations, and a brief summary of the costs and benefits of your recommendations, preferably in a quantitative form. Since the written report for case 2 was not intended to include any strategic discussions, you may repeat or modify in case 3 any recommendations you made in case 2.

The body of the report should be designed to present your distribution system design in more detail and to buttress the arguments for your recommendations. As indicated in the case, your design must be specific with regard to warehouse location, transportation plans, and inventory stocking policies. You may choose to organize sections in the report about each of those topics. In addition, you must evaluate the impact of your design on customer service.

The text of the report should not exceed 10 pages, double-spaced, in a 12-point font, including the executive summary and any tables, maps, and graphs. This forces you to be selective in terms of the summary information you present to the reader. It is more difficult to summarize effectively than it is to provide detail. If you wish to provide detail, you may use appendices. However, like all readers, we will assume that anything that is interesting or important in the appendices is summarized in the body of the report.

Llenroc Plastics
Final Report Requirements and Guidelines

The Final Report must not exceed **15 pages, double spaced** of textual material. It should include an Executive Summary and an Introduction that includes one paragraph of background description of Llenroc Plastics. **You must also hand in copies of all your previous reports (Cases 1-6).**

The content of the report is suggested in the description of Case 7. Your major problem is to organize and summarize your strategy for the company. The structure of the report does not have to follow the series of topics listed in Case 7. You may reorganize these topics into a structure that makes sense to you. All the topics are important, however, and you should address them somewhere in your report.

There are two unacceptable extremes that you should avoid. One extreme is a "pep talk" report that is filled with enthusiastic platitudes ("Llenroc Plastics must cut costs, reduce leadtimes, and improve customer service") without a concrete plan to achieve those objectives. The other extreme is a report that gets bogged down in detail (truck routes, economic calculations, Gantt charts, simulation outputs, and so on). Remember that your earlier reports have already covered most of the details. You are handing in copies of those reports as supplements to the final report. This report should summarize the positive steps that you would take to transform Llenroc Plastics into a world-class manufacturing company.

Your audience for this report is the chief executive officer of the corporation. You must offer specific recommendations, describe or quantify the anticipated benefits, explain why the recommendations will create the benefits, and suggest a program of action to implement the recommendations. Anticipate the objections the CEO is likely to encounter in trying to implement your recommendations and give him or her the basic arguments to overcome these objections.

You are comfortable with the detailed analysis you conducted in the first six cases but you are, no doubt, uncomfortable with the less well-defined issues raised in Case 7 (customer service, performance measurement, quality management). You must use your imagination here. Recall that we have talked about different kinds of customers (OEM's, distributors, large customers, small customers) and different markets (specification, direct, residential) and different geographical regions. Does one manufacturing-distribution strategy serve all of these customers and markets equally well? Imagine, too, the possible conflicts if you emphasize customer fill rate as the single performance measurement. For example, does it make sense to measure the press operators on fill rate? For what decisions are they responsible that affect fill rate? Can you design a performance measure or measures for the fabrication room that guides the individuals in this room to make Llenroc a world-class competitor? Are these measures consistent with the press room performance measures and the dispatcher's objectives? How will you measure overall logistical success?

You are not bound by the solutions you proposed to earlier cases and you may use ideas developed by other teams. Give credit for borrowed ideas. Let's hear the best ideas possible for this company!

ORIE 416/515

Confidential Evaluation of Student Contributions

You must complete one of these forms in order to receive a grade in this course.

Your Name:____

In the table below, score the contribution of each member of your team, excluding yourself, for each of the five categories indicated. (Integrate their value over the entire semester to date, making allowance for a reasonable number of plant trips and other commitments.) Use the following scoring system:

1	2	3	4	5
Unsatisfactory		Adequate		Excellent

Contribution Categories:

A. Overall Contribution: Is this individual a critical reason for your team's success?

B. Level of Effort: Did this individual carry a fair share of the workload?

C. Contribution to Written Reports: Was this individual an important contributor in preparing text and graphics for presentation?

D. Effectiveness as Team Member: Did this individual attend meetings, participate in discussions, cooperate with team strategies, and coordinate their activities with you? Was it pleasant to work with this individual?

E. Leadership: Did this individual initiate discussions, generate enthusiasm, build a consensus, and organize your efforts?

Team Member	**A. Overall**	**B. Effort**	**C. Reports**	**D. Team Play**	**E. Leader-ship**

Other Confidential Comments Related to Team Member Contributions:

1

```
for n=1 to H do
    I_0 = I_0 - d_n
        if I_0 < 0 , then
            ρ_n = -I and I = 0
            else ρ_n = 0
    next n

for n=H down to 1 do
    if ρ_n > R then
        ρ_{n-1} = (ρ_n - R) + ρ_{n-1} and ρ_n = R
    next n
```

✓

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