❏   45

A Interactive Game to Enhance Student Understanding of Materials Management

William E. Mueller and Gholam H. Massiha
Departement of Industrial Technology, University of Louisiana at Lafayette, USA

Article Info	ABSTRACT
	It is difficult for students to grasp essential concepts of materials management because there is a considerable amount of new terminology as well as the need to develop a "feel" for what appears to be a static, but in actuality, a very dynamic process. In an attempt to overcome the language barrier as well as help the student develop a "feel" for the process, an old case study from the 70s has been revised and updated it for today's student. The method of presentation has also been changed from an out-of class activity to an in-class group activity. Initial results, based on 3 classes of 35-40 students each, have been positive with absenteeism reduced from a historical average of 10-15% down to 2%. Student attitude appears to be better and test results appear to be better although comparisons in this area are more difficult to measure. A copy of the game is provided and maybe be freely used in your classroom. Any suggestions for improvement would be greatly appreciated.

Corresponding Author:

G.H. Massiha,
Departement of Industrial Technolgy,
University of Louisiana at Lafayette,
241 E. Lewis St. Lafayette, Louisiana, 70504, USA.
Email: Massiha@louisiana.edu

1.   INTRODUCTION

In recent years supply chain management and lean concepts have been the focus of many publications. In particular, single source vendors and just-in-time deliveries have gained a great deal of notoriety, particularly for large firms with continuous processes or flow manufacturing. But the question has always remained as to whether these concepts were transferrable to mid size firms or smaller job shop firms [1].

The advantages of single source vendors are great: a closer partnership, shared technical advances, a fine tuned delivery system and tight cost controls. However, unless a firm has the economic clout and volume of demand that commands vendors' attention; the firm's results will not approach those of larger organizations.

The Achilles heel of a single source supply chain was dramatically exposed in the spring of 2011 with the Japanese earthquake. A single source supply chain is not immune to earthquakes, floods, tornados and other natural disasters as well as strikes, wars and equipment breakdowns. Perhaps Henry Ford was right with his multiple supplier concept with a primary supplier and one or more secondary suppliers for every major component [2].

While supply chain management particularly with single sources may be more difficult than originally thought, the management of in-house activities should be more easily controlled because a company should know their own capabilities. Indeed a company must have a handle on their in-house activities in order to establish realistic target dates for vendors and customers [3].

However, there are few college courses or training seminars which actually cause students to develop a feel for the master scheduling process and the economic consequences that each decision may cause. In a textbook entitled Production-Inventory Systems by Elwood S. Buffa and Jeffrey G. Miller, 1979 [4], contained a case study master scheduling game to help students develop a feel for the scheduling process. The authors have been unable to determine the authors of the original case to insure they receive proper credit. The game used in our materials management course is a modification and update to reflect today's economic conditions.

2. INTERACTIVE GAME

In the game the student plays the role of a master scheduler for a single work center operation (similar perhaps to a plastics injection molder) with 5 product lines with different margins and different demand patterns. Orders not made incur late charges whereas excess inventory incurs carrying charges.

In a course on production and inventory control or materials management, this exercise should be attempted over the first 5 or 6 class sessions to give the students an understanding of the why and some of the trade-offs that occur even in a simple single work center operation. For students who develop an understanding of the master scheduling process, a spreadsheet can be created to do much of the simple number crunching and cash flow analysis shown on the Profit and Loss (P & L) statements computed for each month.

For each segment of the game (a planning month) students are given sales numbers for the previous period to compute a profit and loss (cash flow) statement and new orders for products. Students then post these potential production schedule quantities on their individual master schedule and decide which to accept and which to decline. Students scratch out orders declined and draw a line through accepted orders when completed. They can draw a line through an order if partially complete and enter a new number for the remaining open order.

Students' decisions will yield a variety of consequences including costs for excess inventory, missed orders, idle production time, and excessive set-up costs. These results will become apparent when the results of their decisions are posted in the P&L statements. As students take different actions the materials management terminology can be introduced to describe what they have just done. Terms such as planning horizon, rough-cut capacity planning and setup time are more easily understood.

The game does not have to cover a whole year but should be done for at least 6 or 7 months. Besides going through the calculations for period "0", it will be beneficial to schedule period '1' as a class together along with computing the profit & loss statement for period '1'.

Once students have a "feel" for the scheduling process and its economic consequences, they should be receptive to discussions of lean concepts to improve the productivity of a system.

One of the more easily determined places for production improvements that can be implemented quickly with immediate payback will be bottleneck areas where work-in-process is backing up and schedules are being delayed. Reducing setup times and implementing "theory of constraints" methodology can be discussed as well as other concepts. Some of discussion topics could include planned and predictive maintenance as well as purchase of new equipment and plant layout revisions.

3. The Master Scheduling Game Case Study

You are the president of the Screw-Ball Shot Company, a small firm which produces balls for use in ball bearings and other industrial products. Since your company is small, you personally make out the firm's master schedule each month, and from it, derive a detailed production schedule.

3.1. Company background

Screw-Ball has a single shot shooter (a machine for making balls) which is run by one operator on each of three shifts. Company policy is to run the machine three shifts a day, for five days a week. If there is insufficient business to keep the machine busy, the worker(s) are idle since Screw-Ball had made a definite commitment to never fire or lay off a worker. By the same token, the firm has a policy of never working on weekends. Thus the capacity of the machine (assuming four week month) is 4 weeks x 5 days x 24 hours = 480 hours per month. Since the hourly wage is $15 per hour, this commits the firm to a fixed labor cost of $15 x 480 = $7200 per month. Once the machine is set up to make a particular kind of ball, it can produce

them at the rate of 5 per hour, regardless of ball type. The process is quite stable. The material content of each ball type is the same, since the balls vary only in shape (spherical balls, square balls, elliptical balls, and so on). The cost of material in each ball, regardless of type, is $5. Raw materials are never a problem, and can be obtained overnight. Screw-Ball has divided its product line into three categories: A-Balls, B-Balls, and Odd-Balls.

A-Balls: There is only one type of ball in this category. The company has decided to produce this A-Ball to stock, because it is sold to a large number of distributors who require immediate shipment at the end of each month. A-Balls sell for $13 each. If A-Balls are not in stock when demanded, the distributors buy from other sources, and Screw-Ball's penalty is a lost sale. Historically, the demand for A-Balls has averaged 700 per month. However, sales are usually somewhat seasonal. The following demand for these items has been forecasted:

Table 1. Sales Forcast

Month	Demand	Month	Demand
1	500	7	900
2	500	8	900
3	600	9	800
4	700	10	700
5	800	11	600
6	900	12	500

It takes 40 hours to set up the short shooter to make A-Balls. Screw-Ball has found that its forecasts are accurate to within ±200 units per month.

B-balls: As with A-balls, there is only one product type in the B-ball category, these are called Bean-Balls because of their elliptical shape. Bean-Balls are manufactured to order for a large original equipment manufacturer (OEM); Screw-Ball's price to this company is $11 per ball. The customer usually places "blanket" orders three times a year. When it places these orders, it specifies the delivery of certain quantities in each of the next four periods. The customer has already ordered 2,400 units with delivery of 600 at the end of periods 1, 2, 3, and 4. The company is expected to specify the quantities it requires for a period of 5, 6, 7, and 8 at the beginning of period 4. The delivery schedule containing the order for months 9, 10, 11, and 12 is expected to arrive at the beginning of period 8. The customer has estimated its average monthly needs over the year to be 600 per month, although their estimates are often considerably in error.

Because of the importance of this large customer to Screw-Ball, they always try to satisfy their needs. The company feels that if they ever refuse to accept an order from this company, they will lose their business. Under the terms of their sales contract, Screw-Ball has agreed to pay their customers $1 for every unit not shipped on time for each month that a unit's shipment is delinquent. Delinquent shipments must be made up. It takes 30 hours to set up the shot shooter to make Bean-Balls.

Table 2. **Exhibit 1**:Screw-Ball Open Order File (end of period 0)

Month	Product type	Quantity
1	Bean Balls	600
	Ski Balls	1,000
	Ner-Balls	200
	(*past due from previous period)	
2	Bean Balls	600
	Snow Balls	400
	Ner-Balls	200
3	Bean-Balls	600
4	Bean-Balls	600

Odd-Balls: Odd-Balls are made only to customer order because of their low volume and specialized nature. The company has found that there are three kinds of Odd-Balls that are ordered: Ski-Balls, Ner-Balls, and Snow-Balls. All types of Odd-Balls are sold to distributors at $15 per ball. When a distributor places an order for one, they specify the quantity and the period during which they want them delivered. Screw-Ball looks to see if they can fit these orders into their schedule, and either accepts or rejects the order. If Screw-Ball accepts an order for delivery at the end of a certain period, and fail to meet this commitment, they pay a penalty of $2 per unit for each period delivery is delayed. This penalty is incurred in each period until the

delinquent order is delivered. It takes 40 hours to set up the shooter to make one of the various types of Odd-Balls. Exhibit 1, Screw-Ball's open order file, shows the orders they already have promised to deliver in future periods. The company has tried to forecast the demand for the different types of Odd-Balls, but has given up in disgust.

3.2.   Master Scheduling

Master scheduling at Screw-Ball is done once a month, after production for the month is completed and shipped and new orders from customers arrive, and before production in the next month starts. The master scheduling efforts result in two documents. The first is a P&L statement for the month. Exhibit 2 shows that this document factors in sales and production cost, including penalty charges and inventory carrying costs. The inventory carrying cost for any type of product is $0.25 per unit per month left in inventory after shipments for the month have taken place.

The second document the company produces is a master schedule as shown in exhibit 3. This shows what Screw-Ball wants its factory to produce in each month in the future. Since the master schedule loses validity (because of uncertainty) the further into the future that is projected, it is reformulated each month. Note that the master schedule specifies two things that are important in the "action" bucket (the next period for which definite, irrevocable commitments must be made). The first is the number of hours (setup + run) that are allocated to each product to be produced. These can be calculated by adding the setup time to the number of units to be produced divided by 5. The total of all of these times in a month cannot exceed 480 hours. The second important piece of data is a circled number indicating the sequence in which products are to be produced on the machines. This is important because at the end of a month, the machine will be setup for the last product produced. If a continuation of this product run in the next month is desired, no new setup will be required as indicated by this number sequence.

3.3.   The game

You will be asked to play the role of materials manager of Screw-Ball in class. You should arrive in class with a master schedule for the company (use Exhibit 3). It is up to you to decide how far into the future to plan, but you must be sure to at least have the next action bucket filled in as specified. (Don't forget that you are already 200 units past due on Ner-Balls and the machine is currently set up to run them). In class the game will proceed as follows:

Table3. Exhibit 2, P & L statement (period 0)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Beginning Inventory (Past Due)					Ending Inventory (past due)	Inventory Cost (past due)
Product	Price		Production	Available	Demand	Sales		
A-Balls	$13	750	950	1,700	500	$6,500	1,200	$300
Bean-Balls	11	-	600	600	600	6,600	0	0
Ski-Balls	15	-	-	-	-	-	0	0
Ner-Balls	15	-	200	200	400	3,000	(200)	400
Snow-Balls	15	-	-	-	-		0	0
Totals			1,750			$16,100		$700

Sales (total of column 7)………………………… $16,100
Costs:
Labor……………………………………………… $7,200
Materials (total of column 4/$5)…………………8,750
Inventory/past due (total of column 9)……………700
Total Cost………………………………… $16,650
Contribution to profit………………………………(550)
Cumulative contribution…………………………...(550) (add to next period   contribution)

1. You will be supplied with a form specifying (a) actual demand in month one, and (b) any new order requests for Odd-Balls or Bean-Balls.
2. You will then drive a P&L statement for month one, assuming you made what you specified in your master schedule, and that demands are as given.
3. You should then look at your order requests, and accept those you want and reject the rest. Those you accept for delivery in future periods should be added to your open order file (you may use exhibit 1). You are then irrevocably committed to them or their consequences.

4. You should then make out a new master schedule, specifying at least what you want your factory to do in the next "action bucket" (it will be for month 2 at that time). You will find it helpful to have thought out a strategy for your master scheduling activities in advance of class. Extra master scheduling forms will be provided.
5. We will then cycle back through the game.

The Master scheduling Game Tables

Table 4. Period 0 master schedule

Product\Month	0	1	2	3	4	5	6	7	8	9	10
A-Balls	500	500	600	600	700	800	900	900	900	800	700
hours											
Bean-Balls	600	600	600	600	600						
hours											
Ski-Balls	0	1000	400								
hours											
Nerf-Balls	400	(200)	200								
hours	500	500	600	600	700	800	900	900	900	800	700
Snow-Balls											
hours											
Total											
Hours Schedule											

Table 5. Student worksheet

1 Product	2 Price	3 Beg. Inv. (Past Due)	4 Production	5 Available	6 Demand	7 Sales	8 End. Inv. (Past Due)	9 Inv. Cost (Past Due Cost)
A-Balls				☐				
Bean-Balls				☐				
Ski-Balls				☐				
Nerf-Balls				☐				
Snow-Balls				☐				

Sales = total of column 7 _____

Labor Cost _____

Materials Cost (Total of Column 4 x $5) = _____

Inv/Past Due Cost column 8 + 9 = _____

A Interactive Game to Enhance Student Understanding of Materials Management (William E. Mueller)

Total Cost (labor + materials + Inv/Past Due) = _____

Profit = Sales - Total Cost = _____

Table 6. Production orders for master scheduling simulation

PERIOD 3	ACTUAL DEMAND	NEW ORDERS
A-Balls	500	
Bean Balls	600	
Ski-Balls[*]	1000	200 due at end of period 2
Nerf-Balls[*]	200	400 due at end of period 3
		1200 due at end of period 4

[*]Assuming you accepted these orders in previous periods.

PERIOD 2	ACTUAL DEMAND	NEW ORDERS
A-Balls	400	
Bean Balls	600	
Ski-Balls[*]	200	600 due at end of period 3
Nerf-Balls[*]	200	400 due at end of period 4
Snow-Balls[*]	400	

[*]Assuming you accepted these orders in previous periods.

PERIOD 3	ACTUAL DEMAND	NEW ORDERS
A-Balls	800	
Bean Balls	600	Extra 600 (expedited order) by End of period 4[**] (see note), 900 per period due at end of Periods 5,6,7,8
Ski-Balls[*]	600	
Nerf-Balls[*]	400	
Snow-Balls[*]		200 at end of period 5

[*]Assuming you accepted these orders in previous periods
[**]Marketing has been told that if the company does not take this expedited order (for a total of 1200) units in Period 4 they will lose this company completely.

4.   CONCLUSION

The most obvious weakness in the game as well as many organizations is excessive setup time.   In the past, long production runs (hundreds to thousands) were common and even a long setup time was rendered nominally significant since it was spread over many units of production. Today, production runs are much smaller (as few as 1 and often not more than 100). A comprehensive study of setup time reduction will quickly increase productivity without increasing machine speed or significant production modifications. In the future a firm may want to buy new or replacement equipment that is more flexible to changeover even at the expense of some reduction to operating speed..

Instructors may let students work individually or in groups, but in-class and each must submit his/her game result/work. If work is completed outside of class, there is excessive copying and cheating. However, students showed enthusiasm and better solutions when this game was played in the class as students often discuss alternate ideas as to how to handle customer orders. Students were rewarded with a "100" test grade (20% of the course grade) for the successful completion of this exercise. Class absences which historically were 10-15% were reduced to approximately 2%. Students who miss class are given different numbers and have to complete work on their own.

REFERENCES

[1]   Hopp, William, and Spearman, "*Factory Physics, Foundations of Manufacturing Management*", 2nd ed., 2001.
[2]   William E. Hoover, "*Managing the Demand Chain*", New York: Wiley, 2001.
[3]   Marshall Fisher, "*What is the Right Supply for Product?*," Howard Business Review, 1997.
[4]   Elwood S.Buffa and Jeffery G. Miller, "*Production-Inventory Systems, Planning and Control*", 3rd ed., Richard D. Irwin, Inc., 1979.