A Cross-Functional View of Inventory Management, Why Collaboration among Marketing, Finance/Accounting and Operations Management is Necessary

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ABSTRACT

Inventory is a critical asset for most companies, especially those that sell or move finished goods, such as retail stores and distribution centers. Even pure service companies, such as law firms or consulting companies, have inventories of information (data bases) and supplies. Good inventory planning requires a cross-functional approach, involving especially marketing, operations and finance/accounting, the three primary functions of most businesses. Although inventory appears as a single gross dollar amount in a company's Balance Sheet, it has a number of components, as we hope to demonstrate through a series of examples.

INTRODUCTION

This paper will illustrate some of the techniques that production planners and inventory mangers use to determine their inventory requirements. The critical link in a company's total planning and budgeting is that marketing provide accurate demand forecasts and accounting incorporate the inventory plan into their cash flow planning. All of the exhibits in this paper are drawn from active spreadsheet models. If this paper is accepted, all of the models will be demonstrated in the presentation at the conference

TYPES OF INVENTORY

To illustrate the variety in inventory, several classifications are needed. Inventory can be classified as raw materials (RM), work-in-process (WIP), and finished goods (FG). Raw materials are the purchased items or extracted materials that are converted via the manufacturing process into components and products. Work in process is a good or goods in various stages of completion throughout the manufacturing, or assembly, process. Finished goods are those items on which all manufacturing operations have been completed, and are available for shipment to the customer (APICS Dictionary)

Inventory is sometimes classified as independent items or dependent items. Independent items are usually finished goods and composed of multiple parts, such as an automobile or a computer. Dependent items are those component parts that are used to assemble into a finished unit, or independent item. This classification is used in Material Requirements Planning (MRP) systems, and will be described more fully later.

Another distinction can be purchased items vs. manufactured items. While this distinction may not be obvious in the final product, it involves different handling for both the production and accounting functions in their planning and costing.

INVENTORY MODELS

As a general objective, organizations would like to carry enough inventory to meet the demand for their products, but no more than needed because of the cost of carrying inventory. Consequently, there are two basic decisions in managing inventory – how much to order (purchase or manufacturing order quantity) and when to order. We will illustrate some of the more common methods used to make these decisions.

Order Quantity

One of the most widely publicized methods of determining order quantity is the Economic Order Quantity (EOQ) developed by F. W. Harris in 1913 as a means of applying a mathematical approach to the question. The EOQ formula considers two kinds of cost – the cost of placing an order and the cost of carrying, or holding, inventory. As the order quantity increases, the average inventory carried increases, but the cost of placing orders decreases. Conversely, as order quantity decreases, the average inventory carried decreases, but the cost of placing more orders increases. The EOQ is used to find the order quantity that minimizes the sum of ordering and holding costs.

Table 1 shows how the EOQ works. The information needed is shown in cells I1:L3. It includes the annual demand for the item (D), the cost for placing an individual order (S) and the cost for holding a unit of inventory for a year (must be the same period as the demand period). The EOQ is calculated using the formula shown in cells I6:J7, and displayed in cell L4. Formulas for additional calculations are shown in cells I8:L16. The figures on the left-hand side of the table (cells A1:H20) illustrate a systematic search for the EOQ. The order quantity, shown in Column A, is incrementally increased. For each order quantity, average inventory (Column B), holding costs (Column C), number of orders (Column D), ordering costs (Column E), and total costs (Column F) are calculated. In the example, the total costs decrease until the order quantity reaches 160 and then begin to increase. The order quantity of 160 found in the search corresponds to the calculated EOQ. Column H is used to illustrate that the total cost amount is relatively flat near the EOQ. This robustness provides some flexibility in choosing the actual order quantity. For example, if the standard order quantity is in dozens, or a gross of 144, the added cost would be less than 4% more, probably considerably less than trying to get the supplier to send a non-standard quantity.

There is continuing pressure to reduce inventories. The level of cycle inventory is a function of the order quantity. The EOQ equation can be used to focus attention on ways to reduce the EOQ quantity, while retaining the integrity of the model. The equation shows a reduction in demand or ordering costs will reduce the EOQ. Reducing demand is not a realistic option, unless some of the demand is unprofitable. Reducing ordering cost is a more logical objective. Many companies are doing this through computerization of ordering, using blanket orders for ongoing purchases and other forms of simplification. The EOQ equation also shows that an increase in holding costs would also reduce EOQ. While this also may appear illogical, there is one cost element in holding costs that may be reconsidered – that of the cost of obsolescence. If inventory becomes obsolete or unusable quickly, this is a cost to be avoided.

Table 1. Economic Order Quantity

	Economic Order Quantity Example											
		Average	**Holding**	**No. of**	**Ordering**	**Total**	**Minimum**	**% of**				
	Q	**Inventory**	**Costs**	**Orders**	**Costs**	**Costs**	**Cost**	**Minimum**				
	A	B	C	D	E	F	G	H	I	J	K	L
1	20	10	250	200	16000	16250		406%	**Demand**		D =	4000
2	40	20	500	100	8000	8500		213%	**Ordering costs**		S =	80
3	60	30	750	67	5333	6083		152%	**Holding costs**		H =	25
4	80	40	1000	50	4000	5000		125%			EOQ =	160
5	100	50	1250	40	3200	4450		111%			Total cost:	$4,000
6	120	60	1500	33	2667	4167		104%	$EOQ = \sqrt{\frac{2DS}{H}}$			
7	140	70	1750	29	2286	4036		101%				
8	160	80	2000	25	2000	4000	**Minimum**	100%	**Average Inventory**		Q/2	Col. B
9	180	90	2250	22	1778	4028		101%				
10	200	100	2500	20	1600	4100		103%	**No. of Orders =**		D/Q	Col. D
11	220	110	2750	18	1455	4205		105%				
12	240	120	3000	17	1333	4333		108%	**Holding Costs =**		Q/2*H	Col. C
13	260	130	3250	15	1231	4481		112%				
14	280	140	3500	14	1143	4643		116%	**Ordering cost =**		D/Q*S	Col. E
15	300	150	3750	13	1067	4817		120%				
16	320	160	4000	13	1000	5000		125%	**Total costs = Q/2*H + D/Q*S**			Col. F
17	340	170	4250	12	941	5191		130%				
18	360	180	4500	11	889	5389		135%				
19	380	190	4750	11	842	5592		140%				
20	400	200	5000	10	800	5800		145%				

The EOQ calculation does make some assumptions that may preclude its use:

- Only one product is involved
- Annual demand requirements are known
- Demand is spread evenly throughout the year
- Lean time is known and constant
- Each order is received in a single delivery
- There are no quantity discounts (Stevenson 2012, p. 566)

While these assumptions may initially appear restrictive, they apply to a number of products, especially those fitting the JIT, or lean production, environment. In addition, the EOQ can be easily adapted to computerized monitoring and automatic reordering for a large number of items.

Order Replenishment

Table 2 shows another way of arriving at an order quantity and, at the same time, deciding when to reorder. This is a simulation that uses random demand numbers to trigger reorders of a given quantity. For a given order quantity, it is possible to see the number of stock outs that could result. The simulation model makes it possible to vary order quantities and reorder points to minimize stock outs. This simulation model also makes it possible to examine alternatives in order quantity, reorder point, and order lead time. The value of this model is more apparent when demonstrated, which the authors will do at the conference.

Table 2. Ordering Simulation

GIVEN DATA					Order Period			3
					Beginning Inventory			100
Demand/Period			50		Average Daily Demand			51
Periods/Year			365		Average Ending Inventory			88
Order Quantity (Q)			200	40	Number of Orders		ORDER	7
Lead Time (L)			1	60	Number of Stockouts		STKOUT	2
Reorder Point (ROP)			100		Type of System			REORDER
	BEGIN	ORDERS	DAILY	ENDING	INVEN	ORDER	ORDER	
DAY	INVEN	REC'D	DEMAND	INVEN	POSITION	R SYS	P SYS	COMM
1	100		56	44	44	200		ORDER
2	44		47	-3	197			STKOUT
3	-3	200	50	147	147			
4	147		41	107	107			
5	107		53	54	54	200		ORDER
6	54		42	12	212			
7	12	200	56	156	156			
8	156		50	106	106			
9	106		52	54	54	200		ORDER
10	54		58	-4	196			STKOUT
11	-4	200	58	138	138			
12	138		52	86	86	200		ORDER
13	86		50	37	237			
14	37	200	49	188	188			
15	188		55	132	132			
16	132		55	77	77	200		ORDER
17	77		49	28	228			
18	28	200	52	175	175			
19	175		43	133	133			
20	133		51	82	82	200		ORDER
21	82		48	34	234			
22	34	200	52	182	182			
23	182		43	138	138			
24	138		59	79	79	200		ORDER
25	79		55	24	224			
Total		1200	1276	2206	3606	1400		
Average			51	88	144			
Number of orders								7
Number of stockouts				2				2

Materials Requirements Planning (MRP)

One of the most widely used planning methodologies is Materials Requirements Planning (MRP). Developed in the 1960s, it is a method of determining when component parts (the dependent items mentioned above) need to be ordered, and how many are needed, in order to complete the final product (the independent item) on time. Table 3 shows an MRP schedule for a simple product (a stool) with six component parts. The demand is irregular – 80 units in Period 7 and 120 units in Period 10. The bottom part of the table shows when the orders would have to be placed for each component item in order to be able to complete the orders for the stools in the periods desired. Table 3 illustrates an irregular demand pattern. Table 4 shows the result when the demand is regular, 20 units each period, a more desirable situation for the production department.

Table 3. MRP Plan (Irregular Demand)

		PERIOD NUMBER										
		1	2	3	4	5	6	7	8	9	10	TOTAL
Item No.	**Stool**				On Hand				Size Rule:		L4L	
Parents:					Lead time		2		Lot Size:			
					Safety Stock				Action:			
Gross Requirements								80			120	200
Scheduled Receipts												
On hand - No action								-80	-80	-80	-200	
Net Requirements								80			120	
Plan Order Receipt								80			120	200
Plan Order Release						80			120			200
Projected on Hand												
Demand												
Planned Order Rel. (units)		1	2	3	4	5	6	7	8	9	10	Total
L4L	Stool					80			120			200
L4L	Frame				80			120				200
L4L	Seat				80			120				200
FOQ	Legs			600			600					1200
FOQ	Cushion			400								400
L4L	Raw Frame		80			120						200
FOQ	Material	1000										1000
	Total	1000	80	1000	160	200	600	240	120			1800
Total Hours Required												
Hours/unit	Item	1	2	3	4	5	6	7	8	9	10	Total
10	Stool					800			1200			2000
7	Frame				560			840				1400
5	Seat				400			600				1000
1	Legs			600			600					1200
2	Cushion			800								800
2	Raw Frame		160			240						400
1	Material	1000										1000
	Total	1000	160	1400	960	1040	600	1440	1200			5600

Table 4. MRP Demand (Regular Demand)

		PERIOD NUMBER										
		1	2	3	4	5	6	7	8	9	10	TOTAL
Item No.	**Stool**				On Hand				Size Rule:		L4L	
Parents:					Lead time		2		Lot Size:			
					Safety Stock				Action:			
Gross Requirements		20	20	20	20	20	20	20	20	20	20	200
Scheduled Receipts		20	20									40
On hand - No action				-20	-40	-60	-80	-100	-120	-140	-160	
Net Requirements				20	20	20	20	20	20	20	20	
Plan Order Receipt				20	20	20	20	20	20	20	20	160
Plan Order Release		20	20	20	20	20	20	20	20			160
Projected on Hand												
Demand												
Planned Order Rel. (units)		1	2	3	4	5	6	7	8	9	10	Total
L4L	Stool	20	20	20	20	20	20	20	20			160
L4L	Frame	20	20	20	20	20	20	20				140
L4L	Seat	20	20	20	20	20	20	20				140
L4L	Legs	80	80	80	80	80	80					480
L4L	Cushion	20	20	20	20	20	20					120
L4L	Raw Frame	20	20	20	20	20						100
L4L	Material	20	20	20	20							80
	Total	200	200	200	200	180	160	60	20			920
Total Hours Required												
Hours/unit	Item	1	2	3	4	5	6	7	8	9	10	Total
10	Stool	200	200	200	200	200	200	200	200			1600
7	Frame	140	140	140	140	140	140	140				980
5	Seat	100	100	100	100	100	100	100				700
1	Legs	80	80	80	80	80	80					480
2	Cushion	40	40	40	40	40	40					240
2	Raw Frame	40	40	40	40	40						200
1	Material	20	20	20	20							80
	Total	620	620	620	620	600	560	440	200			3760

As with the simulation model described in Table 2, the MRP model has more meaning when it can be demonstrated.

PRODUCTION PLAN

Another approach that is used to determine how much to produce each period is called production planning. Often this would be used for finished assemblies, such as an automobile. This is illustrated in Table 5. The upper part of the table shows a variety of variables to be considered in putting a production plan together.

Starting with a forecast, the production plan is determined and the resultant beginning and ending inventories for each period. Table 5 shows a level production plan (constant amount each period), which results in both backorders (Period 1), a buildup of inventory in Period 3 through 8, and a sell-off of inventory during the remainder of the year.

The Production Plan offers another opportunity of using a “What-If” analysis by varying the production amounts each period to search for the best combination of costs, which include hiring and layoff costs when production varies, as well as inventory carrying and backorder costs. As with previous models, this has more meaning when demonstrated.

Table 5. Production Plan

Input Data					
Beginning inventory		Target ending inventory		Hiring costs per w orker	$400
Beginning no. of w orkers	20	Target ending w orkers	20	Firing costs per w orker	$500
Hours/w orker/month	160			Regular w ages per hour	$10
Overtime hrs/w orker/mo.	20	Machine capacity - units	200	Overtime w ages per hour	$15
Labor hours/unit	80	Storage capacity - units	200	Inventory carrying/unit/month	$20
				Backorder cost/unit	$60

Trial Solution										Total Costs					$14,300
		1	2	3	4	5	6	7	8	9	10	11	12	1	Total
Beginning inventory	1		-35		10	30	50	85	105	125	115	65	25		
Production	1	50	50	50	50	50	50	50	50	50	50	50	50		600
Demand		85	15	40	30	30	15	30	30	60	100	90	75		600
Ending inventory		-35		10	30	50	85	105	125	115	65	25			
Inventory carrying costs				200	600	1000	1700	2100	2500	2300	1300	500			12200
Backorder costs		2100													2100
Total costs		2100		200	600	1000	1700	2100	2500	2300	1300	500			14300

Production plans, of the type shown in Table 5, can be designed to search for the optimum solution, using tools such as linear programming. This makes it possible to quickly evaluate the negative effects of imposing constraints on the plan, such as no stock outs, maximum inventory level because of storage capacity, tolerable variation in production to avoid layoffs and rehiring, and the like. This type of plan requires the convergence of marketing, finance/accounting and operations if it is to truly reflect the corporate plan.

Safety stock

The models described above all assume that demand is known; however, as most companies find out, demand varies and sometimes exceeds the demand forecast. Consequently, most organizations carry some extra inventory, referred to as safety stock. Table 6 shows the effect of demand variability on the quantity of safety stock needed to satisfy different service levels. The left-hand side of the table shows the amount of safety stock increases as the variability of demand increases (from left to right in the table). The right-hand side of the table shows the effect of a single catastrophic demand period (Day 20) in which the demand increases by a multiple of 5, 10, 15, and 20 times the normal demand. In this case, there is no amount of safety stock that will cover the catastrophic demand. An example could be the emergency room of a hospital is faced with a train wreck that requires large amounts of blood. They cannot carry much extra blood in anticipation of a train wreck because of limited shelf life of the blood; therefore, they must arrange for access to quick replenishment of blood from neighboring hospitals or blood banks. Normally, however, companies can rely on the situation on the left-hand side of Table 6 as being representative of their demand patterns. Obviously, if they can reduce demand variability, they can reduce the need for extra safety stock inventory.

Table 6. Safety Stock Analysis

	Demand Range (Units per day)			
Days	15-25	10-30	5-35	0-40
1	20	26	26	4
2	23	20	13	3
3	24	27	13	20
4	22	23	26	26
5	16	14	25	18
6	19	19	20	37
7	18	22	11	31
8	16	20	18	15
9	18	15	27	4
10	24	11	20	13
11	16	13	7	34
12	16	28	30	36
13	19	19	16	18
14	24	19	18	2
15	20	27	32	40
16	17	11	24	2
17	17	18	28	0
18	19	26	31	35
19	18	11	17	28
20	16	25	7	20
Average	19	20	20	19
Std Dev.	3	6	8	14
Safety Stock Required				
85% SL	3	6	8	14
97% SL	6	11	16	27
99+%SL	9	17	23	41

	Demand Range (Units per day)			
Days	15-25	10-30	5-35	0-40
1	22	16	25	14
2	19	25	21	19
3	19	22	29	38
4	20	28	8	7
5	19	27	16	1
6	18	13	6	1
7	19	18	10	27
8	16	20	31	31
9	17	12	12	33
10	23	30	28	28
11	18	22	24	27
12	18	15	21	37
13	21	14	20	13
14	24	28	34	23
15	16	11	10	21
16	24	19	17	0
17	18	12	19	36
18	21	20	29	16
19	20	26	10	33
20	100	200	300	400
Average	24	29	34	40
Std Dev.	18	41	63	86
Safety Stock Required				
85% SL	18	41	63	86
97% SL	36	81	127	171
99+%SL	54	122	190	257

MICRO-MACTO INVENTORY PLAN

The approaches described above can be used by production planners and inventory managers. At some point, they must develop a plan that can be integrated into a total company plan. Table 7 illustrates a way they could plan, at least for the normal replenishment and safety stock levels of inventory. Table 8 shows a way that Accounting, or Finance, could determine the gross amount of inventory allowable under the total company cash flow plan.

Differences between the two approaches have to be reconciled, if the groups are to proceed with a meaningful plan. This is critical if the plans are to have meaning. This plan provides for cycle inventory and safety stock; other special demands have to be handled separately, as shown in Table 8.

Table 7. Inventory Plan from Operations

		Product 1	Product 2	Product 3	Total	
		TV	Circuit board	Fuse	All Products	
Build-up of Inventory from Individual Items						
Sales per Year (units)		500	1,600	6,400	8,500	
Purchase price per unit		$200.00	$40.00	$1.60	$20.50	Average
Total cost of purchases/year		$100,000	$64,000	$10,240	$174,240	
Carrying cost/unit/year	25%	$50.00	$10.00	$0.40	$5.12	Average
Ordering cost per order	20	20.0	20.0	20.0	$20.00	
Sales per Week (units)	50	10	32	128		
Economic order quantity	EOQ	20	80	800		
Weeks of supply per order		2.0	2.5	6.3		
Safety Stock (weeks)	1	1.0	2.0	4.0		
Safety Stock (units)		10	64	512		
Average Cycle Inventory	2	10	40	400		
Total Average Inventory (units)		20	104	912		
Average Turns		25	15	7	18	
Total Inventory ($)		$4,000	$4,160	$1,459	$9,619	**By operations**

Table 8. Inventory Plan from Accounting

	Total Target				
Mark-up on Cost	50%	100%	150%	74%	
Selling Price	$300.00	$80.00	$4.00	$35.72	Average
Total Sales per Year	$150,000	$128,000	$25,600	$303,600	
Cost of Sales	$100,000	$64,000	$10,240	$174,240	
Gross Margin	$50,000	$64,000	$15,360	$129,360	
% Gross Margin	33%	50%	60%	43%	Average
Target Inventory Turns				25.0	
Target Inventory Dollars				$6,970	**By accounting**
Calculated minus Target Inventory				$2,650	

Inventory turns (units) = annual sales in units / total average inventory in units
Inventory turns (dollars) = annual cost of sales / total average inventory in dollars

If the amount of inventory requested by Operations exceeds that considered available by Finance/Accounting (as shown in Table 8, the two possibilities to reduce the amount requested are to reduce the order quantity or to reduce the safety stock.

OTHER TYPES OF INVENTORY REQUIREMENTS

In addition to the need to plan for normal inventory replenishment, there are at least three additional types of inventory requirements to be considered – seasonal, promotional and hedging. Seasonal inventory is the amount required to satisfy seasonal demand requirements. Promotional inventory is required for new product introductions or major sales promotions. Examples of hedging inventory are the amount required to buy ahead of price increases or phase out of a product.

Table 9 summarizes the inventory categories discussed so far. The Transit inventory is the amount on order but not yet received. Figure 1 shows the information in Table 9 as a graph. The graph displays the fluctuations in inventory level, as different drivers of inventory rise and fall during the year.

Table 9. Summary of Inventory Requirements

	1	2	3	4	5	6	7	8	9	10	11	12
Cycle	20	10	0	20	10	0	20	10	0	20	10	0
Safety	10	10	10	10	10	10	10	10	10	10	10	10
Transit			20			20			20			20
Seasonal					10	20	30	20	10			
Promotion	20	20	0									
Hedging										10	20	30
	50	40	30	30	30	50	60	40	40	40	40	60

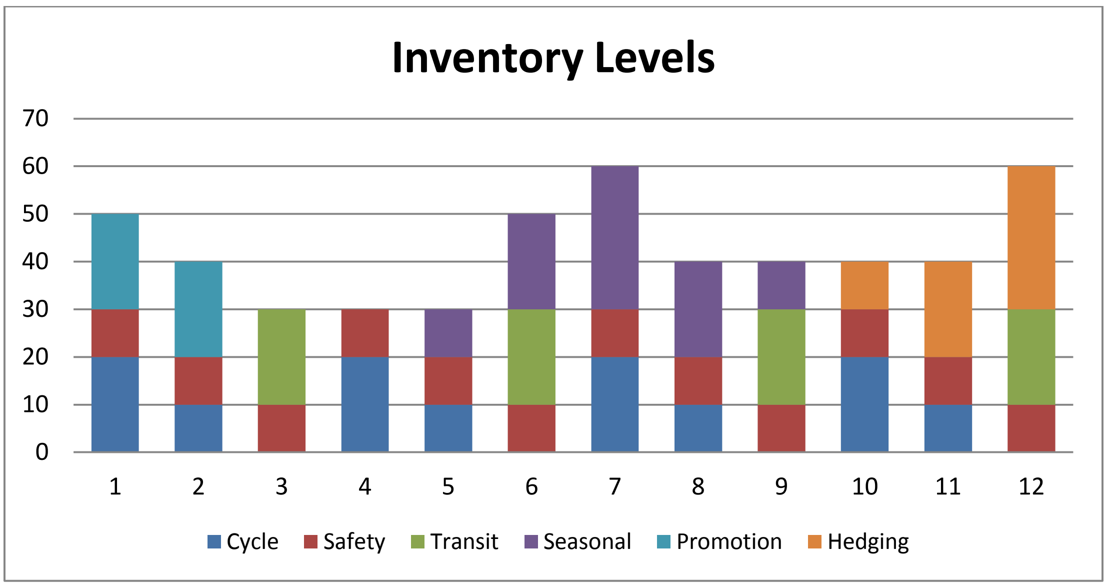

Figure 1. Inventory Levels throughout the Year (data in Table 9)

Figure 1 shows fluctuations in inventory levels throughout the year. Marketing should carefully review the amounts available for promotions, seasonal and safety stock to form their own opinion as to the adequacy of the amounts. Accounting should also review the projections to see that an increase in inventory does not signal a problem, but a preparation for seasonal sales. AT the end of the year, the increase in inventory may mean reduced costs resulting from an "early buy" or protection against a potential shortage at a supplier who will be shifting production to a new facility.

CONCLUSIONS

Inventory is an important asset for most companies. Good inventory planning is critical for retail and wholesale businesses in order to maximize their sales revenue. It is equally important for manufacturing businesses in order to be able to produce the specific products their customers need. Inventory planning should be the result of a systematic and logical approach and not just an arbitrary estimate of the overall needs.

We have shown a number of techniques that operations managers use to plan the amount of inventory they consider necessary. Marketing must provide meaningful forecasts and collaborate with operations management to update and adapt the forecasts with the capability to supply. Finance/accounting must also participate so they recognize the changes in inventory level as necessary for the operations managers to meet the demand forecasts from Marketing. Finance/accounting also must incorporate the inventory plans in their cash flow forecasts.

As previously noted, the examples used in this paper will become more meaningful when they can be demonstrated with live spreadsheets.

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