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Inventory Ordering Decisions Over the Product Life Cycle

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by

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INTRODUCTION

This report will link two key business concepts together. It will first examine the characteristics of different inventory replenishment systems used by purchasing managers. Second, it will bring the marketing phenomenon of the product life cycle into the picture. The varying demand patterns found in a typical product life cycle curve will become test data for a simulation exercise to determine which of four ordering models yield the lowest combination of holding and ordering costs. The costs related to holding finished good inventories account for a large portion of a firm's total cost structure (Adam and Ebert, 1989). To stay competitive, a firm cannot allow its inventory to become greater than the demand for that good, nor can it afford to sacrifice customer service simply to save some dollars in inventory holding. The savings from reduced inventory are small when compared to the cost of lost sales and dissatisfied customers (Plossl, 1985).

So how can a firm be competitive in both cost and customer service? What is the best ordering method to use to ensure both low inventory levels and high customer service? Four frequently used models for probablistic demand are described in the second section of this paper. Probablistic demand is examined rather than deterministic since demand varies over the life cycle of a product. The appropriate inventory model for a company is dependent upon many factors, including replenishment lead times, the inventory related costs for the item and certain management policies (Vollmann, 1988).

Another factor that can effect the ordering decision is the demand pattern for a good. Even though independent demand items tend to have a fairly smooth demand pattern (Vollmann, 1988), a finished good does have varying demand trends along its life cycle. These trends range from rapid decline all the way to exponential growth. The inventory model selected for replenishment of an item must consider these different demand patterns. The third section of this paper will address this issue by examining the product life cycle phenomenon, and the changes in demand that occur as the product is introduced, grows, matures and declines.

The fourth section of this paper presents a brief review of articles that deal with the effects of probablistic demand on optimal ordering policies. While much has been written on both the ordering methods and the product life cycle, very little research has been reported that combines these two fields. The final section of this project presents a mathematical analysis that links various ordering strategies with the demand pattern found over a typical product life cycle curve. Inventory holding and ordering costs are used as a measure of effectiveness for the inventory policies.

MODELS FOR INVENTORY DECISIONS

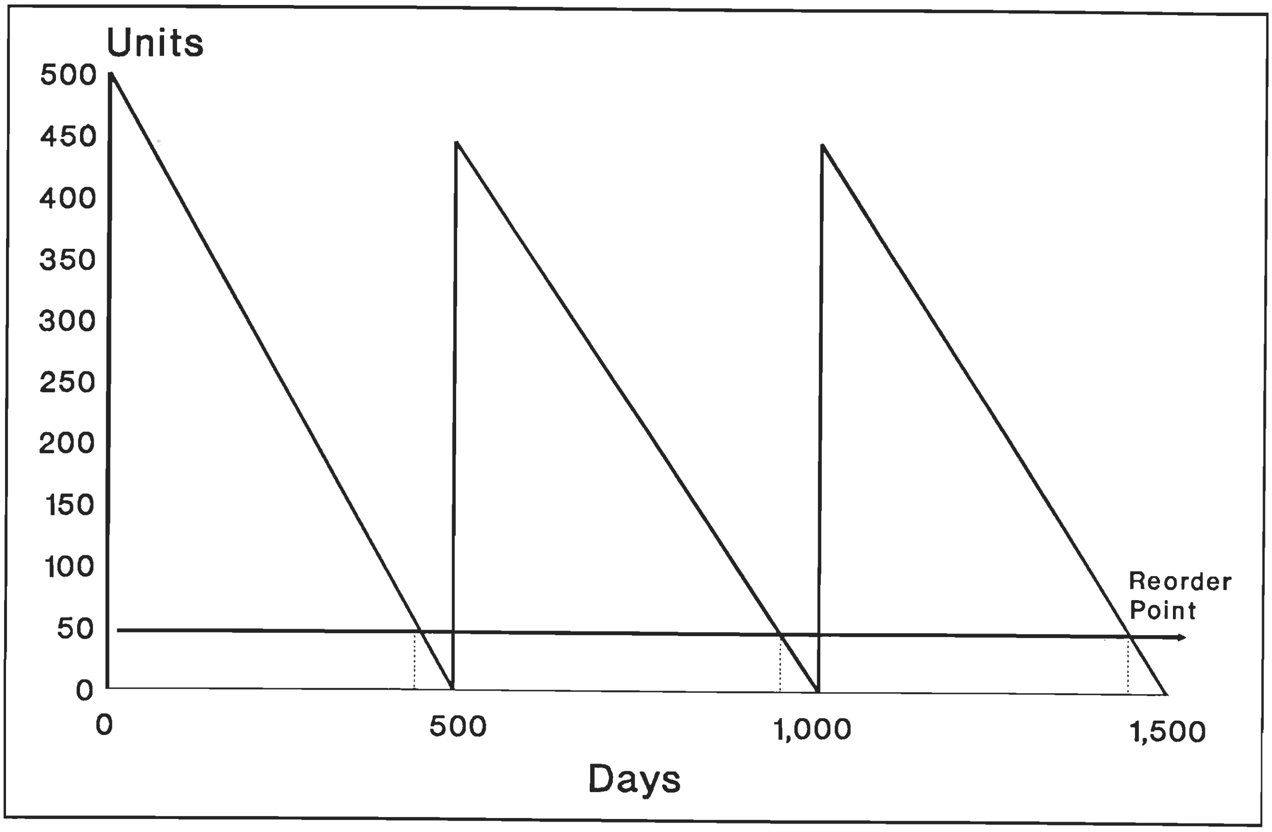
Many different inventory models and variations of these models are available. Basically all of these models answer two questions. First, how much should be ordered, and second, when should these orders be placed (Vollmann, 1988). This paper considers four of the most useful probablistic models. Since inventories of finished goods are rarely deterministic or known, only probablistic models are considered in this analysis. These models allow the demand for an item to vary through time. The four major models for probablistic demand are considered in this research. The models include: fixed quantity - variable time, variable quantity - variable time, variable quantity - fixed time, and fixed quantity - fixed time. Most other probablistic ordering systems are simply variations of these models with varying assumptions, such as unlimited capacity for storage and predictable demand.

To better illustrate the models, an example is used. Consider an office where a worker fills out a daily report form. At some point this worker will need to reorder the blank forms to continue performing this job. Since these are daily reports, demand is obviously 1 form per day. Assume that it takes 50 days for an order to be processed and filled. An economic order quantity analysis shows that to achieve the lowest possible combination of inventory holding and carrying cost, the worker should order the forms in quantities of 500. Assume further that the maximum desired inventory for the form is set by the company at 500. No stockouts are allowed.

FIXED QUANTITY - VARIABLE TIME (Q,R): In this model, the worker uses 500 as the order quantity and 50 as the reorder point. Some system is put in place to determine when the supply of the form has reached 50 (the reorder point). The worker then places an order for the economic order quantity (500 forms). This model is often referred to as a two-bin system. Exhibit 1 shows the inventory pattern of forms over time. The dotted line represents the placing of an order for more forms.

VARIABLE QUANTITY - VARIABLE TIME (S,R): This model is identical to the (Q,R) model except for the amount of the order. Rather than ordering the "Q" amount (500), the worker would place an order for 450 forms to bring the total inventory up to the maximum inventory level (S or 500). If the replenishment lead time is equal to zero, these two systems are identical. Of course, the maximum inventory level is not always set equal to the economic order quantity.

Exhibit 1: Inventory levels using the (Q,R) model.



VARIABLE QUANTITY - FIXED TIME (S,T): In this model, a schedule is set up so that the worker checks the inventory level once in a given period (T). For example, if the time period is once a quarter, the worker will check the supply of the form once and place an order at that time to bring the inventory up to 500 forms (maximum inventory level or S). The size of the order will depend on the stock level when the check is made.

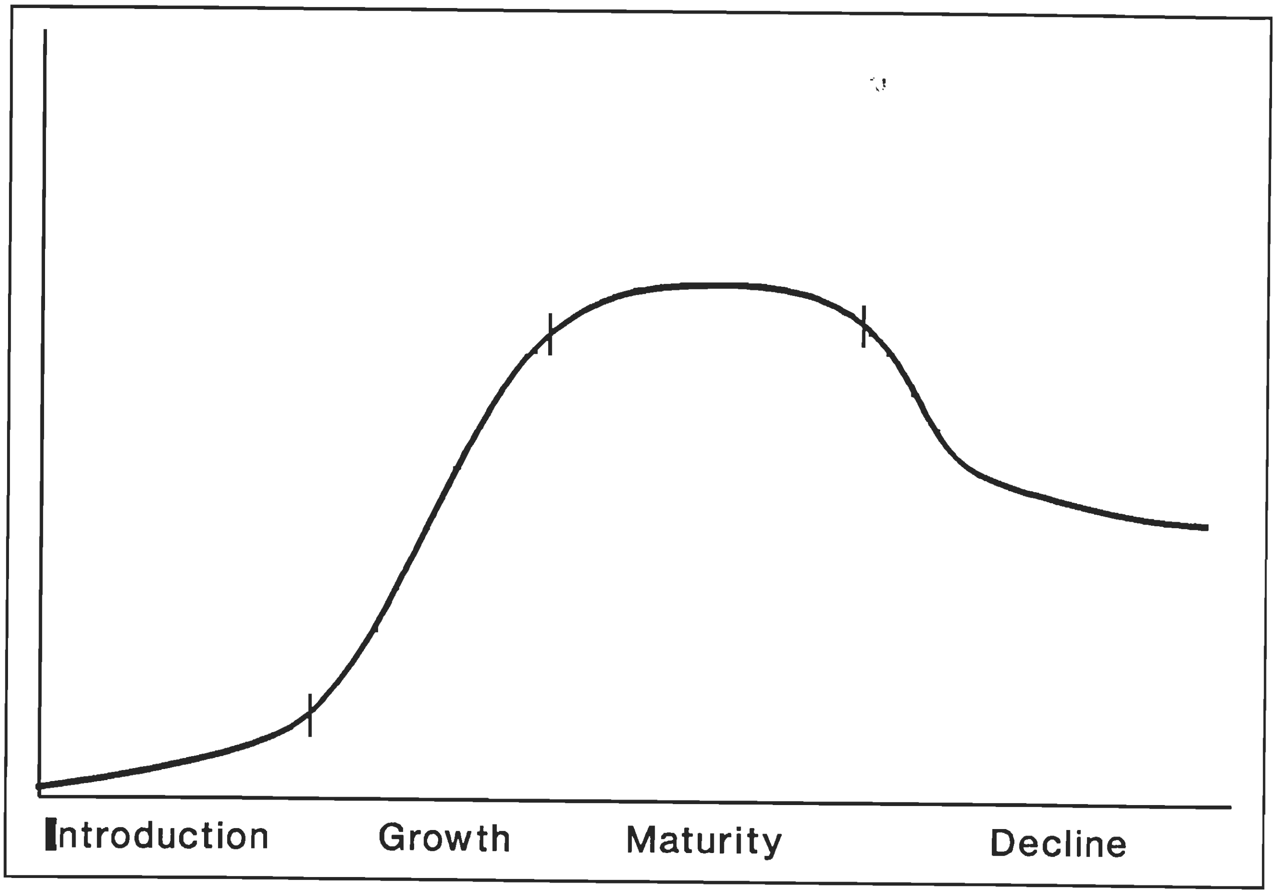
FIXED QUANTITY - FIXED TIME (Q,T,R): This model is slightly more complicated than those previously discussed. Here, the worker checks the inventory periodically (T). If the stock level is below the reorder point (R), an order for the economic order quantity (Q) is placed. If the inventory is not below the reorder point, no order can be placed until the next inventory check.

While these four techniques seem very similar in this simple example, there are important differences between the models. Methods using a maximum inventory level higher than the EOQ will produce higher inventory holding costs. Models using a reorder point would normally require continuous monitoring either by the worker or by computer.

The results of this simulation indicate that the (S,R) model yields the lowest cost and still ensures that there were no stockouts. The (Q,R) model also worked but would entail a slightly higher holding cost. It's inventory level at times reached 500 forms while the (S,R) model never held more than 450 forms at any time. The (S,T) model also worked but only because the time period between checks was less than 450 days. The total cost of the (S,T) model is higher than the first two because of the higher average inventory level. The final model (Q,T,R) has a high probability of stocking out at some point. Fifty forms is not a large enough buffer if the inventory level is only checked every quarter or 83 days (250/4). In other words, when the number of forms is checked to be between 50 and 83 forms, no order can be placed but shortages will occur before the next check period.

Demand in the example was assumed to be constant (1 form per day). In the real world, however, few items have such a deterministic demand. In this paper demand will fluctuate and follow the trends of the product life cycle. With different patterns of demand, the optimal decision (S,R) may change. The product life cycle is described further in the next section.

Exhibit 2: Product life cycle.



THE PRODUCT LIFE CYCLE

No marketing textbook would be complete without a discussion of the product life cycle. The Product life cycle (PLC) refers to the change in demand for a good over the period that the good is on the market. Just as humans go through different stages of development, products follow certain demand patterns over their lifetime (Berkowitz, 1989). The four stages of the PLC are: Introduction, growth, maturity and decline. Each of these stages are shown in Exhibit 2 and described in the next paragraphs.

INTRODUCTION: The introduction stage begins as soon as a product becomes available to the consumer. Sales during this period are generally low but upward sloping.

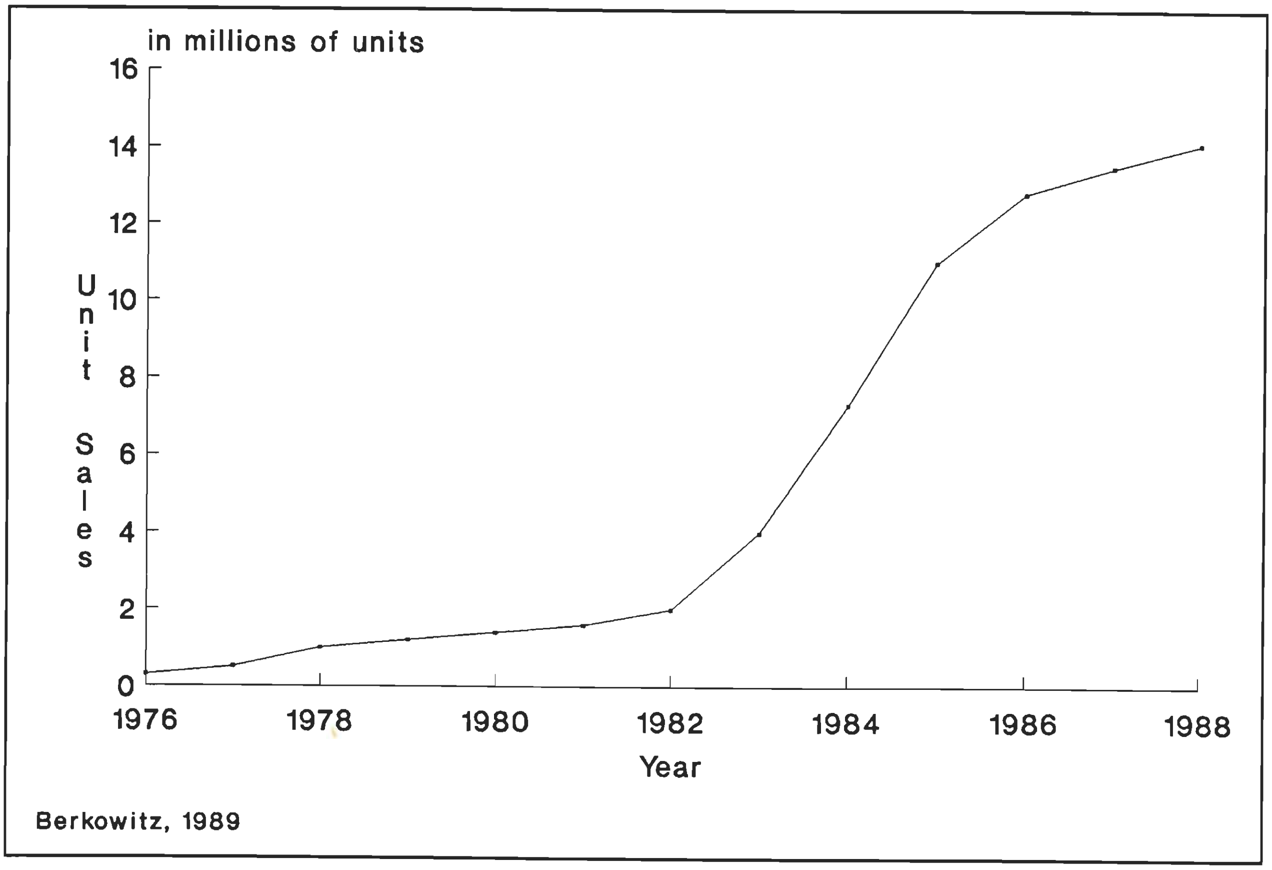
These low sales are due mainly to the unfamiliarity of the product and reluctance of retailers to carry a new product (Berkowitz, 1989). The length of this stage depends entirely on the product. If it is complex and expensive, the introductory stage may last a long time (Husted, 1989). The introduction stage ends when sales and demand begin to climb rapidly.

GROWTH: Such a rapid increase in sales marks the beginning of the growth stage. Word of mouth advertising and improved access convince more and more consumers to purchase the good. In this stage, demand for the product may be low or moderate, but it is rapidly increasing. This stage ends when sales and demand begin to taper off (Boone, 1989)

MATURITY: In the third stage, demand for the product grows at a slower pace than in the growth stage. Sales then peak and begin to decline. The majority of products on the market are in the mature stage (Husted, 1989). It is here that survival depends on cost cutting and careful management. Products can stay in this stage indefinitely but are usually pushed out due to technological innovations. The stage ends when the downward sloping demand becomes increasingly negative.

DECLINE: The decline stage of the product life cycle continues the downward sloping demand pattern of the mature stage. Major reasons for a decline would include: advances in technology, social trends and foreign competition. The steepness of the slope depends on the reason for the decline and the product itself. Sales in the decline stage may taper off slowly or they may drop off suddenly and completely. The decline stage, along with the PLC, ends with the removal of the product from the market.

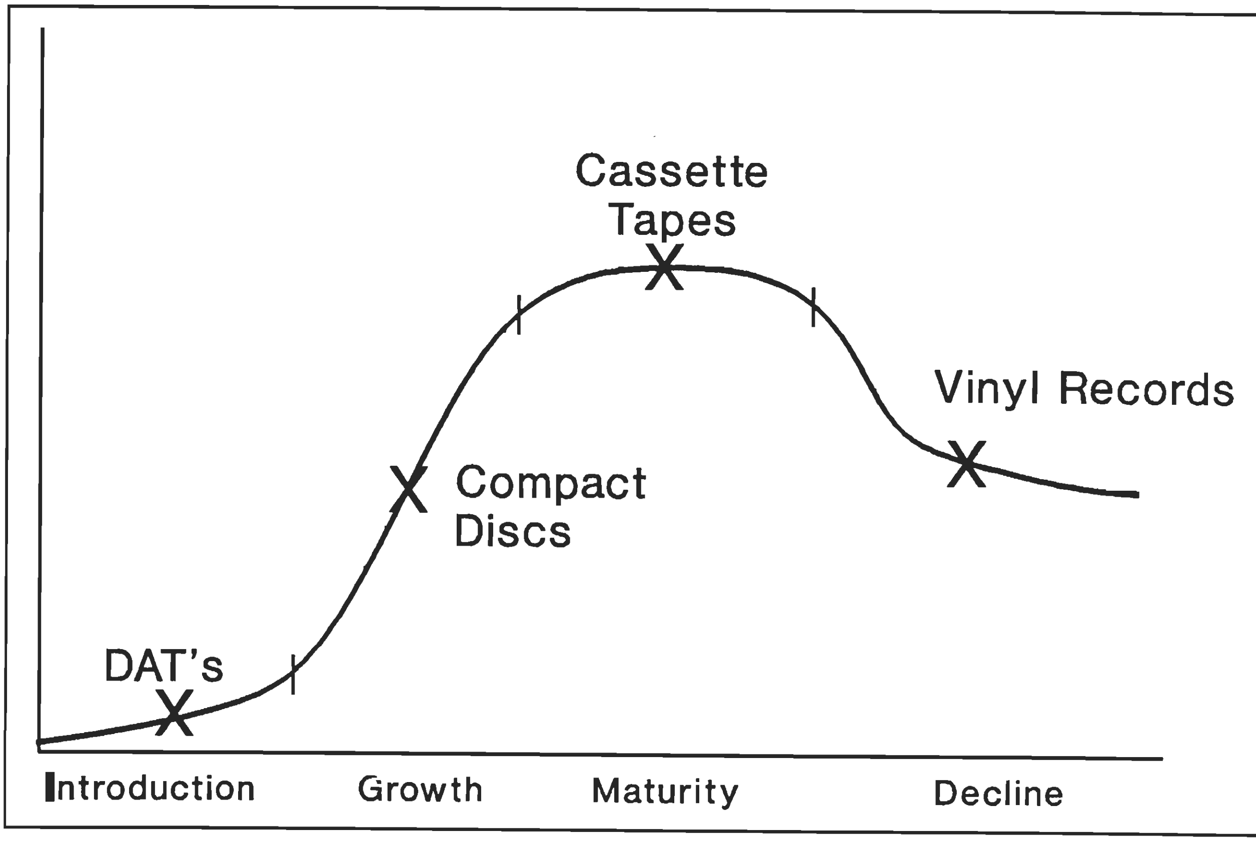
Exhibit 3: VCR sales from 1976 to 1988.



To further illustrate the effect of the product life cycle, consider the video cassette recorder. After introduction in the mid 1970's, VCR sales experienced slow increases. Then VCR's went through a period of exponential growth as they became common in most American households. Finally, recent sales figures show that the VCR market is slowing down. In Exhibit 3, VCR sales are plotted against time. The graph clearly follows the pattern of a traditional product life cycle. The length of time the VCR stays in this mature stage depends mainly on new technological advancement. If a superior system comes out, the VCR may become obsolete overnight. Or if Americans gradually watch less and less TV, the sales may just taper off slowly.

Products in a particular industry often follow each other along a PLC. A good example is the music industry. Shown in Exhibit 4 is the traditional product life cycle for

Exhibit 4: Product life cycle for recording media.



different mediums of recorded music. A old favorite, the long playing vinyl record, is quickly giving ground to the explosive compact disk market (shown in the growth stage). Currently in the mature stage, standard cassette tapes are just beginning to feel an impact from DAT's or digital audio tapes (shown now in the introduction stage) (Boone, 1989).

It should be noted, however, that not all products follow a classical product life cycle. Fad products such as the "Rubik's Cube" have a very compressed PLC. They became incredibly popular but quickly faded from the shelves. Other products, such as Nabisco's animal crackers have been strong sellers for decades and decades. Some products, especially in the fashion industry, follow a completely different PLC. Demand for items such as wide ties or short skirts can grow, decline and then grow again (Husted, 1989). In a study conducted in 1982, 80% of the items investigated were found to have reasonably normal product life cycle curves (Onkvisit, 1989).

REVIEW OF LITERATURE

An extensive search of books and periodicals revealed only two articles dealing with the inventory implications of the product life cycle. Neither of the articles dealt with the entire curve. The first one, written in October of 1989, examines the growth stage of the demand pattern. The second, published in May of 1989, concentrates on the decline portion of the curve. Both articles were published in the netherlands.

Haiping Xu land Hsu-Pin Wang wrote, "An Economic Ordering Policy Model for Deteriorating Items with Time Proportional Demand" (Xu and Wang, 1989). In this article, they present a demand pattern that is deteriorating at a constant rate similar to a product in the decline stage of its life cycle. The article utilizes the Wagner-Whiten approach to determine optimal order size. No attention is given to the logic behind choosing the Wagner-Whiten dynamic program or to the variability of the demand data. The conclusion of the article stated that the research was useful to industries whose products are subject to deterioration of demand. No recommendations are made with the exception of the implied recommendation of the Wagner-Whiten dynamic program to determine optimal order quantities.

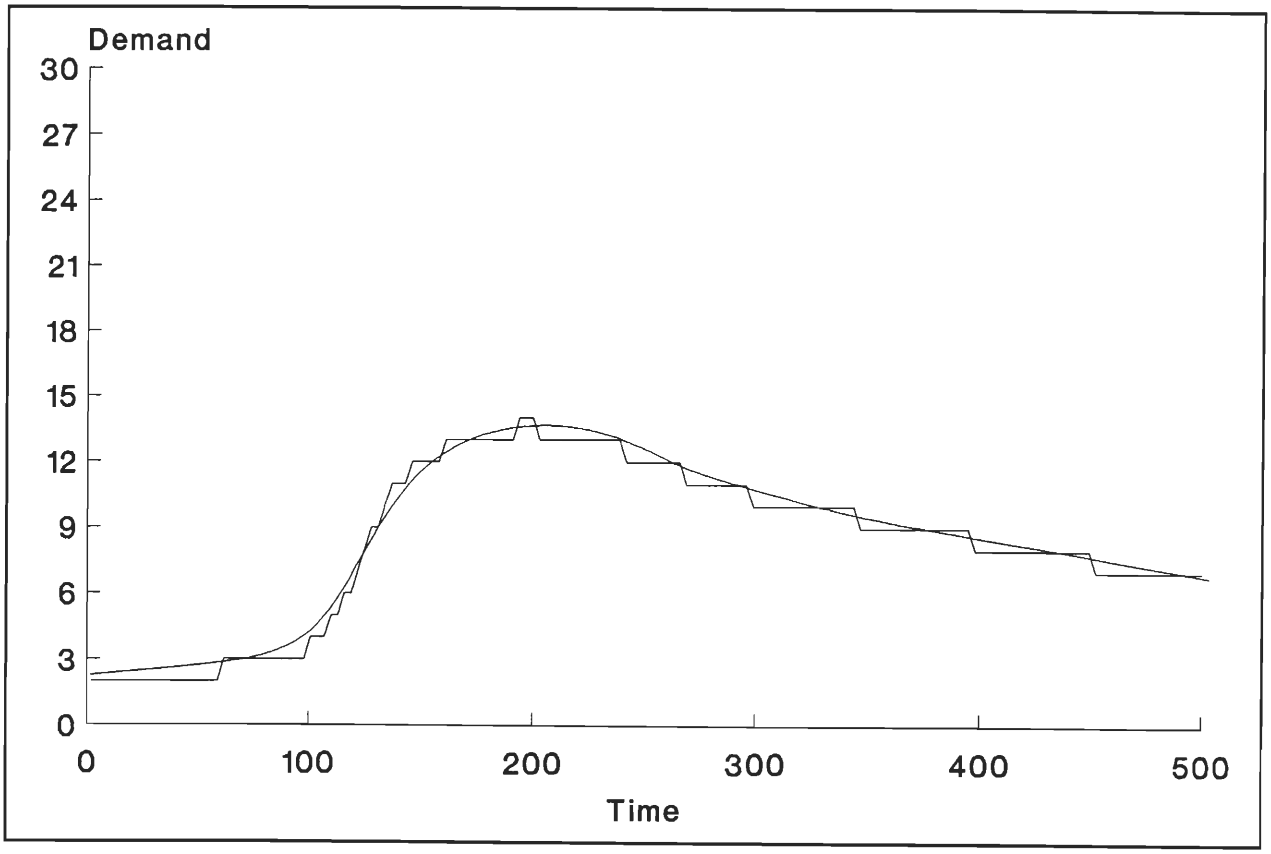
G. E. Martin wrote the second article entitled "Discount Pricing Policies for New Products" (Martin, 1989). His paper focuses primarily on negotiating ordering discounts with suppliers during the growth stage of the product life cycle. Martin attempts to optimize the discount price and replenishment schedule for one or more buyers. One very limiting assumption is that the firm must not keep any inventory and operate on a Just-In-Time basis. The model does not consider any inventory holding costs.

Both of these studies differ significantly from this project. First, both of the articles utilize only a portion of the product life cycle. Second, and most important, neither article acknowledges that firms have a choice in the ordering model they use. The main purpose of this research is to determine which model works the best and delivers the lowest cost.

SETTING UP THE DATA

In order to determine which model will yield the lowest holding and ordering cost over the product life cycle, fictional demand data is used. Exhibit 5 illustrates the demand for a fictional product called a "tut." The demand for tuts ranges from 2 to 14 tuts during its life cycle. The stepped nature of the graph is caused by rounding to the nearest whole unit. The general shape of the graph is taken from the typical product life cycle curve discussed in previous sections.

Exhibit 5: Sample demand data.



Since the demand changes over time, the problem of calculating the economic order quantity is complicated. With a deterministic demand pattern we can simply calculate "Q" by using the following equation:

$$Q = \sqrt{\frac{2DC_o}{C_h}}$$

where,

D = Annual demand

C_o = Cost to order

C_h = Cost to hold 1 unit for 1 year)

The three choices when dealing with probablistic demand are:

1) Use the average demand or about 8.36 tuts per period.

2) Use Wagner-Whiten - a dynamic programming application.

3) Use a heuristic model such as part period balancing (Vollmann, 1989) or the Silver-Meal heuristic (Silver & Peterson, 1985).

In their textbook, Edward Silver and Rein Peterson give a mathematical rule of thumb for this decision process (Silver & Peterson, 1985). Using a ratio called the variability coefficient, a demand estimate can be determined. This is done by taking the variance of demand for each period and dividing it by the square of average demand per period. If the resulting ratio is less than .25, then an average demand should be used to determine Q. If it is greater or equal to .25, a heuristic would be better suited.

In our example, the variability coefficient is .19. Therefore, the average demand, or 8.36 tuts, is used in the economic order quantity equation. Other variables in the EOQ formula will be estimated as follows:

Cost to order	C_o	$100

Value of item	v	$300
Rate of holding cost	r	25% per tut/per year
Cost to hold (v * r)	C_h	$75
Time horizon		2 years
Annual demand (8.36 * 250)		2,090 tuts

These variable relationships obviously would not be constant for every product. Sensitivity analysis for the EOQ equation, illustrates that these values need not be exact for the EOQ formula to be useful in ordering decisions (Silver & Peterson, 1985). In other words, the ordering and holding cost estimates can vary considerably from the true cost and Q stays roughly the same.

The information presented above is used to calculate Q or the optimal order quantity that will be used for two of the ordering models. As shown below, Q equals approximately 75 tuts.

$$Q = \sqrt{\frac{(2)(2090)(100)}{(300)(.25)}} = 75 \text{ Tuts}$$

Before comparing the four ordering systems, we must make the following assumptions:

1) The lead time for ordering tuts is zero
2) The time period between inventory checks will be once a week or every 5 working days
3) The reorder point will be set at 70 tuts for models with periodic review and at 15 for continuous review models
4) The maximum inventory level will be set at 150 tuts

RESULTS

The data set up in the previous section was tested for total cost for each of the ordering models. This was done using four short computer subroutines in BASIC language. The results of the test are shown in Exhibit 6:

Exhibit 6: Results of each ordering model

	Q,R	S,R	S,T	Q,T,R
Orders placed	57	30	100	57
Average inventory	44	77	105	82

Each order placed cost the company $100. Each unit of average inventory is equal to $150 in holding cost over the 2 year period. Exhibit 7 shows the same results in dollar costs.

Exhibit 7: Results of each ordering model in dollars

	Q,R	S,R	S,T	Q,T,R
Ordering cost ($)	5,700	3,000	10,000	5,700
Holding cost ($)	6,600	11,000	22,500	12,300
TOTAL COST ($)	12,200	14,550	32,500	18,000

CONCLUSIONS

The results of this experiment suggest that the "Variable Time - Fixed Quantity," or (Q,R), model is the most cost efficient to use with a demand pattern similar to a typical product life cycle. The other model that incorporates variable times between orders also performed well. This is due primarily to the lower reorder points used with these two models. One of the main advantages of continuous review of inventory is the ability to set the reorder point relatively low. In the fixed interval models, it was necessary to increase the reorder point to avoid stockouts during heavy demand periods.

Many factors other than cost are part of the ordering model decision. Continuous review of inventory levels may not be possible in all cases. The amount of money saved on ordering and holding cost could easily be eaten up by the cost of monitoring inventory levels. Purchasing managers and operational managers must decide which is truly cheaper. The difference over a two year period between the best continuous review model and the best periodic review model is about $5,800. This amount may not cover the cost of computer and labor time involved in continuously reviewing the inventory level.

Another issue that could alter the optimal inventory model choice is the desired customer service level. The reorder points in this experiment are based on 100% customer service. If it is possible to give less than 100% service, then the periodic review model users could lower their reorder point which would lower their inventory levels and in turn lower their holding cost.

The company must also decide how much attention should be given to this problem. In our example, a total of 4,180 tuts were demanded over 2 years. Each of these cost the company $300. That is an expenditure of $1,254,000. The difference between the best and worst model is about $20,300. This is approximately 1.6% of the total cost associated with selling tuts. The company may decide that the monetary difference in the models is not significant.

DIRECTIONS FOR FURTHER STUDIES

This experiment has important applications in the business community. If a products had a constant demands, there would be no need for ordering models. It is only when fluctuations in demand occur that the ordering process becomes complicated. A somewhat predictable demand change such as a product life cycle can be anticipated. A shrewd company can recognize the beginnings of this trend and alter its ordering philosophy accordingly. As was mentioned before, about 80% of all products follow a PLC curve. Thus, further study in determining the best way to order each product is important.

Some would argue that this one example cannot be generalized over all products following the product life cycle. One example is probably not enough, but this demand pattern can serve as an average demand pattern for all such products. Since each product has different ordering costs and holding costs, that would make it impossible for one model to work with all the different combinations. One should remember, however, that the numbers used to estimate ordering and holding cost have a relatively small effect on the economic order quantity. The main difference between one product and another should instead be measured in terms of the variability of demand. Our demand variability coefficient came fairly close to the .25 cutoff set by Silver and Peterson. As the variability rises in a demand pattern, the models we studied may not have been adequate to fulfill our needs.

The Q,R model resulted in the lowest cost over the entire product life cycle curve for the example examined. This topic needs further investigation. The next stage should be to break the curve down into its four basic sections. When this is done, the different models should be applied to the separate portions of the PLC. Even though the Q,R model gave the lowest total cost, another model may have produced lower costs over one specific section of the curve. while the articles in the review of literature did break down the product life cycle into its different parts, they did not consider the same four ordering models.

When this research is complete, managers can adjust their ordering systems to fit the exact requirements. For example if the product is entering the growth phase, a particular model can be used. When the stage began to change to maturity, the system could be altered again. Additional research in this area could lead to a better cost structure which for firms which would make the firm more efficient and more competitive.

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