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ACCOUNTING ESTIMATES AS COST INPUTS TO LOGISTICS MODELS

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HEADNOTE

Models often are taught in undergraduate courses of Logistics, Materials Management, Production/Operation or Transportation, while cost estimation often is taught in undergraduate accounting courses. Since these subjects are seldom integrated or coordinated, the college student and professional accountant may be unable to supply appropriate cost inputs to even the most elementary logistics models. This problem is demonstrated with the Economic Order Quantity model for which undergraduate accounting majors have difficulty understanding and/or estimating order cost per order.

ACCOUNTING ESTIMATES AS COST INPUTS TO LOGISTICS MODELS

Introduction

The Logistics concept revolves around efficiency or effective performance at minimum cost. Cost minimization models are important and relied upon in logistics management. The importance of cost minimization to logistics has not been fully appreciated by undergraduate teaching in the subject areas of logistics and accounting.

Logistics students normally take accounting courses but seldom learn how to measure costs in those courses. The typical undergraduate program includes financial accounting as well as accounting tailored for decision making, managerial accounting. Managerial accounting classes often include financial accounting for inventories (cost accounting) and only a brief segment on cost estimation. This segmented approach to cost estimation leaves students prepared only for algebra involving assumed values for all input variables of a logistics model.

Accounting students often have a course in Logistics or Operations or Materials Management, but rarely integrate this material with their accounting courses. In introductory courses the inputs to cost minimization models are usually "given" with little or no discussion of their source or calculation. Likewise, accounting students tend to deal with problems in relation to the textual material preceding them. A problem requiring methods from chapter five usually is not assigned after chapter eight, nor are problems from sophomore accounting assigned to juniors or seniors. This segmented approach leaves accountants handicapped when non-textbook problems are faced and may lead to severe estimation and definition problems.

Segmented teaching of cost models across the disciplines is likely to leave managers unable to properly communicate needs and accountants unable to meet them. Only by very careful communication can accountants provide useful inputs to logistics models and without coordinated education this care and diligence is extremely rare. It is not sufficient to assume either that accountants understand logistics or that logisticians understand accounting.

The need for coordinated education is demonstrated by the results of a survey in which undergraduate business students were instructed to estimate the order cost in the common economic order quantity model. The students seemed unable to properly distinguish between the concepts of average costs and marginal costs.

The following section of this paper contains a brief review of the proper cost definition for the EOQ model that highlights both cost estimation and cost definition errors. The next section reviews the impact of errors in model inputs following the "garbage in-garbage out" paradigm. Finally, some hope for improvement comes from suggested coordination between accounting and logistics educators.

Cost Definition for EOQ Models

The lot-sizing problem is basically a decision on how much to order rather than how much inventory to hold, where to hold it, or how to supply inventories to production or marketing. The optimal size per order is a function of the costs related to lot size. In the classic model there are only two such costs; the cost of order processing and the holding (carrying) cost. The order cost can be reduced by having few orders of large size. The holding cost, which is proportional to the average inventory on hand, is reduced by having frequent (small) orders. The model is traditionally solved for a year-long planning horizon by assuming that (1) the number of orders (units demanded over units per order) times the cost per order is the total ordering cost and (2) the average inventory held equals one-half of the units per order. In the classical formulation two accounting numbers are required: cost per order processed and cost of holding the average inventory on hand usually expressed per unit per year or as a percent of unit cost.

The optimality of the EOQ model is based on the trade-off between marginal order cost and marginal carrying cost. Any fixed costs of the ordering function or of the carrying function are irrelevant to the lot-sizing question, but would be included as part of an average cost estimate. Fixed costs are expenditures that do not change with the volume of orders placed or with the size of each order. Fixed costs of ordering include all the investment in equipment, staff, and supplies necessary to do any ordering at all. Since the EOQ is computed for each stock-keeping unit (SKU) separately, most of the ordering function costs (typewriters, computers, staff on contracts, etc.) are clearly fixed and hence not affected by placing one more order.

Likewise, if carrying costs for a particular item are calculated for the marginal unit held, then costs related to the warehouse building, equipment, staff, and similar items must be considered fixed. The averaging of fixed costs is required by some financial accounting regulations, but it is often distortive in management accounting applications. Averaging total costs is an easy solution to the cost estimation problem but may provide obviously irrelevant figures, or more dangerously, figures apparently good enough for use. An example follows that demonstrates this pitfall.

Cost Definition Algebra

Under the EOQ model the Total Relevant Inventory Costs are:

TRIC = FO + VO(D/Q) + FH + VH(Q/2)

where: FO = Fixed Cost of Order Processing

VO = Variable Cost of Incremental Orders

FH = Fixed Cost of Holding Inventory

VH = Variable Holding Cost per Unit per Year

D = Annual Demand in Units

Q = Order Lot Size in Units

The Economic Order Quantity is found by $-\frac{VO\ D}{Q^2} + \frac{VH}{2}$, which is the first derivative of the TRIC equation with respect to Q. Notice that FO and FH have no derivative with respect to Q since they are not affected by Q. These are not relevant costs for the decision about Q. The first derivative is then set to zero and solved for Q yielding the familiar EOQ equation:

$$Q = \sqrt{\frac{2 \cdot VO \cdot D}{VH}}$$

If fixed costs are averaged in determining Q,

Averaged Fixed Holding Cost is:

FH Q/2 = 2FH/Q

Averaged Fixed Order Cost is:

FO D/Q = FOQ/D

and

Apparent EOQ becomes:

$$Q = \sqrt{\frac{2(VO + FO \cdot Q/D)D}{VH + 2FHQ}}$$

This expression can be quite reasonable for cases in which fixed costs are inconsequential or variable costs predominate. However, there is no reason to assume that ordering and holding inventory do not have fixed costs such as contracted labor and depreciation on equipment and buildings. Further, since the EOQ is calculated for individual stock keeping units (SKU) the ratio of fixed costs to variable or incremental costs could be very high.

Dividing total cost by the number of orders placed that period yields a rough estimate of average order cost which is not appropriate for the EOQ formula.[1] Instead, the marginal or incremental cost of placing an order should be used. In other words, the correct cost estimate is the amount that the ordering cost would increase if one more order were placed per period, or the amount saved if one less order were placed per period.

Impact of Input Errors

The impact of definition errors can be both substantial and complex. If both order and holding costs are defined as average and both have similar proportions of fixed to total cost, the economic order quantity may be reasonably approximated by the mis-defined model. If fixed order and fixed holding costs are equal, they may balance out in their effect on optimal order size since EOQ occurs when order cost equals holding cost. However, it is likely that definition errors are not counter-balancing in the majority of situations. In fact, there is some reason to believe that errors occur for order cost more frequently and more severely than for holding cost.

Inventory cost definition errors result in suboptimal order quantities. Calculating the additional cost of these errors can be outlined in steps. Two EOQ numbers are solved. The first of these is the "true" EOQ from the common formula and the second is from the previously developed formula for average order and holding costs.

$$EOQ' = \sqrt{\frac{2 \cdot VO \cdot D}{VH}} \qquad \text{"true" EOQ}$$

$$EOQ'' = \sqrt{\frac{2(VO + FOQ/D)D}{VH + 2FH/Q}} \qquad \text{mis-defined EOQ}$$

The difference between the quantities resulting from these two formulas is not obvious since the relationship between formulas involves demand (D) as well as fixed order cost (FO) and fixed holding cost (FH). Simultaneous solution of errors of both variables is beyond the scope of this paper except as demonstrated below.

$$TIC' = FO + VO(D/Q') + FH + VH(Q'/2)$$

is the minimum cost inventory policy given by the economic order quantity, and

$$TIC'' = FO + VO(D/Q'') + FH + VH(Q''/2)$$

is the cost of the inventory policy of using average for variable cost in both ordering and holding costs. Therefore the additional cost of the cost definition error is given by:

$$\begin{aligned} TIC'' &= FO + VO(D/Q'') + FH + VH(Q''/2) \\ -TIC' &= FO + VO(D/Q') + FH + VH(Q'/2) \\ \Delta TIC &= VO(D/Q'')-(D/Q') + VH(Q''/2)-(Q'/2) \end{aligned}$$

Assuming D (demand) remains constant, the number of orders D/Q and order size Q/2 are opposite in direction between the two EOQ formulas. In fact, it is possible for the difference expression to be zero if:

$$[VO(D/Q'')-(D/Q')] = [VH(Q''/2)- Q'/2)]$$

or

$$D\ (VO)\ \left(\frac{1}{Q''} - \frac{1}{Q'}\right) = \frac{VH}{2}\ (Q''-Q')$$

In one case where order costs were 78% fixed and holding costs were correctly defined, total inventory policy costs were 23% above those of the correctly calculated economic order quantity.[2] Calculation of the cost of definition errors is simplified when only one of the two inputs is mis-defined, and there is reason to believe this is frequently the case. Thus while the EOQ model is referred to as "robust," definitional input errors can be costly.

A Priori Dispersion of Definition Errors

There is some justification for the assumption that definition errors are much less likely for holding cost than for order cost. It is common to define holding cost in terms of percentage of unit value, a variable cost definition.[3] It is likewise common to explicitly assume that order costs are entirely variable[4] or to implicitly assume that fixed order costs are zero. At least one textbook prescribes averaging fixed order cost[5] and average order cost is simpler to calculate.[6] Errors in order cost definition are actually more detrimental when holding cost is properly defined.

Propensity of Order Cost Definition Errors

In order to measure the propensity for order cost definition errors a simple problem was tested on senior students of business administration. The problem asks for an order cost estimate and allows for solution either as average[7] or variable cost.[8] The test problem is as follows:

[Insert Figure One]

The problem was solved by students in courses unrelated to cost estimation: Accounting Information Systems, Accounting Theory, International Management, and Business Policy. Responses were sorted by major program (Accounting or non-Accounting) and by solution (Average Cost, Variable Cost, Neither). Hand calculators were permitted and ample time was allowed, but the students had considerable difficulty with this problem.

The propensity for average/variable confusion is demonstrated by the figures in Table One. It should be added that unless "reminded" about the EOQ model's variable definitions faculty members and professionals frequently have similar difficulties. The failure to complete either of these calculations is evidence of the students' difficulty with problem material presented separately from textual examples and discussion. Each of these students had completed a sophomore accounting in which both average cost and variable cost estimation were taught. These were students who previously had been able to solve such a problem when it followed the textbook chapter on fixed and variable costs.

[Insert Table One]

Implications of Error Prevalence

If professionals in logistics and accounting are similar to senior students, cost inputs are more often wrong than right. The result is an industry full of powerful models running on the wrong fuel. Attempts at further sophistication of operations/logistics models may be futile in organizations where accountants and logisticians speak different languages.

It may be observed that calculation of variable cost was independent of major since no students were successful in the sample. Ability to complete the problem with wrong answers was also unrelated to student major as tested by the Chi-Square. This may suggest that accounting majors are neither better nor worse at cost definition/estimation for logistics models.

Another observation is that the order cost definition errors of using average for variable cost invariably leads to higher values of economic order quantity, higher inventory holdings and less frequent ordering. The recent popularity of Just-in-Time inventory systems may be interrelated with order cost redefinition. If order costs are predominately fixed and incremental order costs very low, then (Just-in-Time) frequent order, small order, small holding inventory policies make sense. If order costs are primarily then overestimated and large holdings on inventories are unjustified economically.

Remaining Questions on Definition Error Impact

Two empirical studies are needed to assess the economic cost of accounting/logistics definition errors. The external validity of the student sample may be expanded to professionals in logistics and accounting. Perhaps professionals do recognize situations for which variable cost is appropriate; perhaps they do not. The relative size of fixed and variable cost for ordering is not known and might provide comfort, if ordering costs are mostly variable. These studies may shed light on how much cost the economy as a whole is wasting. However, only individual firms can correct reliance on faulty inputs to their EOQ and other logistics models.

Response for Logistics Education

Logistics educators should make very clear distinctions between variable and averaged fixed costs. The EOQ model is one case in which calculus is applied in undergraduate education, but perhaps the meaning of derivatives deserves further emphasis and review. Vocabulary can also make a difference; since order cost per order can be indistinct, terms such as incremental, marginal, and/or variable might be valuable adjectives.

Determining carrying and order cost inputs for EOQ lot sizing is made more difficult because financial accounting systems do not accumulate these costs. Instead, they must be reconstructed by management accountants if they are to be supplied from past accounting data. This process of reconstructing costs for use in inventory models may be difficult when a communications gap exists between accounting and logistics management.

The lack of communication is not entirely the responsibility of logistics educators. Accounting students should be trained to evaluate problems independently of segmented courses and chapters. The skill of finding out what is needed before "giving them what we have on the shelf," belongs in the accounting curriculum. Coordination between academic faculties, though difficult, is not impossible. "Realistic" accounting problems often are more interesting and memorable than examples unrelated to operations/logistics management.

An additional concern is the limited exposure to decision-oriented (managerial) accounting in many business schools. Non-accounting majors usually take only one semester of managerial accounting and even accounting majors frequently graduate with no more than one course. At many schools, cost accounting (financial accounting for manufactured inventories) is combined with managerial accounting, reducing cost estimation to a short segment or eliminating it altogether. If students do not understand the distinction between fixed and variable costs, then a great deal of sophistication in logistics modeling is being wasted.

ENDNOTES

[1] Ralph St. John, "The Evils of Lot Sizing in MPP," Production and Inventory Management Journal, Vol. 25, No. 4 (1984) pp. 75-85.

[2] Willem J. Selen, and Wallace R. Wood, "Inventory Cost Definition in EOQ Model Application," Production and Inventory Management Journal, Vol. 28, No. 4, (1987), p. 47.

[3] John J. Coyle, Edward J. Bardi, and C. John Langley, The Management of Business Logistics (St. Paul: West, 1988), p. 201.

[4] Coyle, Bardi, and Langley, p. 202.

[5] Donald J. Bowersox, Logistical Management, (New York: McMillan, 1974), p. 193.

[6] Selen and Wood, p. 45.

[7] Average Cost Solution is Total Spending divided by total number of orders, (1021346 ÷ 8236=$124/order).

[8] Variable Cost Solution relies on either simple regression or the high/low method, familiar in high school geometry: (261,440-250,214) ÷ (2259-1845) which is between $26 and $27 per order.

Cost-inp.uts

Figure One
Survey Question

A request has been made to you to provide your best estimate of "order cost" for use in calculation of the "economic order quantity" using the formula:

$$EOQ = \sqrt{\frac{2 \cdot O \cdot D}{H}}$$

where: O = order cost per order
D = annual demand in units
H = holding cost per unit per year

	Relevant Purchasing Expenditures	Number of Purchase Orders Processed
1984	\$253,355	1995
1985	\$250,214	1845
1986	\$256,337	2137
1987	\$261,440	2259

Assuming the above history of purchasing department costs and numbers of orders is correct, what is your estimate (to the nearest dollar) of the order cost?

Table One

ORDER COST ESTIMATE ERRORS BY MAJOR

	Accounting Majors	Non-Accounting Majors
Variable Cost Estimated	0 / 0%	0 / 0%
Average Cost Estimated	26 / 44%	15 / 54%
Neither Estimate Found	33 / 56%	28 / 46%
	$\Sigma = 59$	$\Sigma = 43$

NOTE: X^2 for independence of major and problem completion = .87 which is not statistically significant for α = .05

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