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To Buy or To Make

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A number of variables go into a manufacturer's decision whether it is cheaper to buy or make a component of his finished product. The authors describe two methods of finding the right answer.

TO BUY OR TO MAKE?

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THE TERM "make or buy analysis" is commonly used to describe special studies designed for the evaluation of alternatives involving the manufacture or purchase of products and parts. The alternatives available to a firm within this framework can be classified as follows:[1]

1. Make or buy a product (or a component) the firm is not currently making.
2. Continue to make or begin purchasing a product the firm is currently making.
3. Make more or less (or buy more or less) of a product the firm is currently making.

The first class of make or buy alternatives will usually involve the commitment of long-term funds; thus, it is essentially a capital budgeting problem. The second class of alternatives may or may not require long-term commitments. If no capital outlays are required and the make or buy decision involves only one product, an incremental cost analysis will usually provide sufficient quantitative data for both the second and third class of alternatives.[2] We are not suggesting that qualitative factors such as quality of the product, reliability of the vendor, etc., are not important considerations. But we shall assume that these factors do not affect the

[1] See H. Bierman, Jr., *Topics in Cost Accounting and Decisions,* McGraw-Hill Book Company, Inc., New York, 1963, p. 163.

[2] Gordon Shillinglaw, *Cost Accounting Analysis and Control,* Revised Edition, Richard D. Irwin, Inc., Homewood, Illinois, 1967, p. 639.

choice between external supply and internal manufacture.[3]

In this article we consider a short-run case which might be classified under both the second and third classes of alternatives. We are considering a firm which has the capabilities and the capacity to manufacture all products internally but also has the opportunity to purchase the same products from an outside vendor. We will not consider any possibility of changing plant and equipment; thus the capital budgeting aspects of the make or buy alternatives can be disregarded. The question is whether the firm should buy the products from a vendor, make them internally, or use some combination of make and buy.

The analysis suggested in this article is quite general and may be extended to more complex situations;[4] we use a special example, however, to carry the argument and make the link between the suggested approach and the more familiar cost accounting approach. We begin by presenting the problem, then consider the cost accounting approach, and finally make the link to a linear programing model.

The problem

Consider a small firm with two departments. In each department the normal operating time is 40 hours per week. Department 1 has fifteen machines with a normal operating time of 600 (15×40) machine hours per week. Department 2 has eight machines, or 320 (8×40) available machine hours per week.

The firm has a certain demand for its two products, each of which it can make or buy. For the present planning period there is a certain weekly demand for 5,000 units of the first product and 4,000 units of the second product. For the firm's own facilities, the required usage co-efficients (machine hours required for each unit of output) are given as follows:

Product	*Machine Hours Per Unit* Dept. 1	Dept. 2
1	.1	.2
2	.3	.2

The firm would like to produce and purchase in a manner enabling it to meet the demand for the products at the least cost. It is assumed that the capital requirements for the alternatives to be considered do not differ significantly and can be ignored.

The cost accounting section of the firm has made available the following cost estimates:

Variable Cost Per Machine Hour	*Regular Time*	*Over-Time*
Department 1	$10.00	$15.00
Department 2	$12.00	$18.00

The raw materials costs for Products 1 and 2 are $10 per unit and $5 per unit, respectively. An outside vendor has offered to supply the firm with any quantity of Products 1 and 2 at $18.00 per unit and $12.00 per unit, respectively.

Before considering the cost accounting approach to the problem, let us indicate the decision alternatives of the problem. The firm can manufacture varying quantities of Products 1 and 2; hence there are two decision variables. Varying hours of overtime can be used in the two departments, which gives us two additional decision variables. Finally, the firm can purchase varying quantities of Products 1 and 2 from the outside vendor. Thus, there are six decision variables in the problem as given; any solution to the problem must specify these six quantities. We begin by indicating how a cost accountant may obtain a solution of the problem.

Cost accounting approach

The cost accounting approach to this problem would require a careful comparative analysis of incremental costs relevant to all available alternatives. Such an analysis may well follow the format shown in Table 1 above.

Making the products is clearly the better alternative if output during regular operating time were sufficient to meet demand. A brief investigation will reveal that the capacity available during normal operating hours is not sufficient. (See Table 2 below.)

Thus, if no outside purchases are made, overtime is required in both departments to meet the given demand. Since overtime use of the firm's facilities is an available alternative, variable costs per unit produced on overtime must be established, as shown in Table 3 on page 28.

Table 3 would indicate that it is advantageous to buy all units of Product 2 that must be produced on overtime in both departments. To obtain the cost data for all the possible alternatives we still have to consider the combination of units

TABLE 1

Variable Manufacturing Costs Per Unit During Regular Operating Time

	Product 1		Product 2	
Dept. 1	.1 x $10.00 =	$1.00	.3 x $10.00 =	$3.00
Dept. 2	.2 x $12.00 =	$ 2.40	.2 x $12.00 =	$ 2.40
Raw Material		$10.00		$ 5.00
Total Per Unit		$13.40		$10.40

Product 1		Product 2	
Purchase Price	$18.00	Purchase Price	$12.00

TABLE 2

Analysis of Machine Hour Requirements

	Dept. 1	Dept. 2
Product 1	500	1,000
Product 2	1,200	800
Total	1,700	1,800
Normal operating capacity	600	320
Required overtime hours	1,100	1,480

[3] For a good listing of relevant qualitative considerations see: R. I. Dickey, Editor, *Accountant's Cost Handbook*, Ronald Press Company, New York, 1960, pp. 19/14-15 or Harry Gross, *Make or Buy*, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1966.

[4] We comment on generalizations later.

TABLE 3

Variable Manufacturing Costs Per Unit During Overtime

	Product 1		Product 2	
Dept. 1	.1 x \$15.00 =	\$ 1.50	.3 x \$15.00 =	\$ 4.50
Dept. 2	.2 x \$18.00 =	\$ 3.60	.2 x \$18.00 =	\$ 3.60
Raw Material		\$10.00		\$ 5.00
		\$15.10		\$13.10

TABLE 4

Variable Manufacturing Costs Per Unit Regular Time in Dept. 1, Overtime in Dept. 2

	Product 1		Product 2	
Dept. 1	.1 x \$10.00 =	\$ 1.00	.3 x \$10.00 =	\$ 3.00
Dept. 2	.2 x \$18.00 =	\$ 3.60	.2 x \$18.00 =	\$ 3.60
Raw Material		\$10.00		\$ 5.00
		\$14.60		\$11.60

TABLE 5

Variable Manufacturing Costs Per Unit Overtime in Dept. 1, Regular Time in Dept. 2

	Product 1		Product 2	
Dept. 1	.1 x \$15.00 =	\$ 1.50	.3 x \$15.00 =	\$ 4.50
Dept. 2	.2 x \$12.00 =	\$ 2.40	.2 x \$12.00 =	\$ 2.40
Raw Material		\$10.00		\$ 5.00
		\$13.90		\$11.90

TABLE 6

	Dept. 1	Dept. 2
Overtime Used	1,100	1,480
Per Unit Requirements of Product 2	.3	.2
Corresponding Units of Product 2	3,667	7,600

produced on overtime in one department and regular time in the other. (See Tables 4 and 5 above.)

Thus, any combination of overtime in one and regular time in the other department yields production costs which are lower than the purchase price.

Having obtained the relevant cost data, a cost accountant would now proceed to search for the least cost combination of making and buying.

As a first step we consider the alternative of making all the demanded products with the firm's facilities. Table 3 shows, however, that all units of Product 2 produced on overtime have a unit cost (\$13.10) that exceeds the purchase price (\$12.00). Obviously we could reduce costs by buying some units of Product 2. As a first step we would probably buy enough units of Product 2 to eliminate its production on overtime in one department. (See Table 6 above.)

By buying 3,667 units of Product 2 we would eliminate all overtime in Department 1; the remaining 333 units of Product 2 would be made during regular operating hours. The results of this decision can now be summarized as follows:

Make:	5,000 units of Product 1
	333 units of Product 2
Buy:	3,667 units of Product 2
Overtime:	
Dept. 1	zero
Dept. 2	$.2 \times 5{,}000 + .2 \times 333 - 320 = 747$ hours

Now we should find out whether this solution could be improved by buying additional quantities of Product 1 or Product 2. In our simple example we refer to Tables 3, 4, and 5. Here we find that

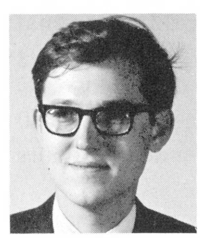
1. The total cost of Product 1 cannot be reduced by buying, since all combinations of manufacturing costs are less than the purchase price.
2. Buying additional quantities of Product 2 would mean cutting down its production at a unit cost which is less than the purchase price. We have therefore arrived at a minimum cost solution.[5]

We have shown that the intuitive yet systematic approach of what one might call traditional incremental cost analysis leads to an optimal solution of our relatively simple problem. It should be apparent, however, that the approach is rather laborious even under our simple assumptions of only two departments and two products. The number of alternatives to be analyzed would, of course, be vastly greater if we assume a more complex situation, and practical limitations would soon make the traditional approach impractical.

Linear programing

The simple illustrative problem permits us to make an interesting observation. Our cost accounting approach is actually an intuitive application of the simplex algorithm for linear programs. Carefully consider each step in our analysis:

[5] We have only shown here that the solution is a local minimum and not necessarily a global minimum. However, for the linear programing formulation, this minimum solution can be shown to be global also.



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A single formula cannot keep all elements in proper perspective at all times...

1. We assumed internal production of total demand requirements for both products. This required overtime in both departments. That is, of our six decision variables four are positive, i.e., production of both products and overtime in both departments, and two are zero, i.e., the purchase levels for both products. Refer to Tables 1 and 2. In the terminology of linear programing, this is a basic solution.[6]
2. We asked if it is less costly to change from this basic solution. In our case the alternatives were to buy one (or more) unit(s) of either Product 1 or Product 2. In either case, this permitted the firm to make one unit less of either Product 1 or Product 2, respectively. The evaluation was to consider the manufacturing cost of each product (at the current basis) and compare it with the purchase cost. For Product 2, the internal manufacturing cost was $13.10 (refer to Table 3), and the purchase price was $12.00 per unit. Thus, it was less costly to buy one unit of Product 2 and make one unit less. Our procedure is equivalent to the optimality test of the simplex method.[7]
3. Now we want to know how many units of Product 2 should be purchased. So long as overtime is required in both departments (i.e., the basic solution above), it would be less costly to buy an additional unit of Product 2 and manufacture one unit less. We must, therefore, determine the number of units to be bought in order to eliminate overtime in both departments. In Table 6, we found that it was necessary to buy 3,667 units of Product 2 before overtime was eliminated in the first department. (Overtime is still required in Department 2.) We have now found another basic solution. (Note that we still have four positive variable values for our six variables.) In linear programing terminology, we found an adjacent basic feasible solution to the problem. This new basic solution called for:

Make:	Product 1	5,000 units
	Product 2	333 units
Buy:	Product 2	3,667 units
Overtime:		
	Department 2	747 hours

4. With this basic solution, we try to find a less costly solution. No simplex evaluation indicates a decrease in costs. E.g., to buy Product 1 costs $18 per unit, and the internal manufacture cost is $14.60 per unit. (Refer to Table 4.) Thus, it is not profitable to buy any of Product 1. We have found the optimal solution of our problem.

Formalized linear program

Previously, we indicated that there are six decision variables for this illustrative problem and four constraints. The variables are as follows:

X_1 The amount of internal production of Product 1
X_2 The amount of internal production of Product 2
O_1 The amount of overtime in Department 1
O_2 The amount of overtime in Department 2
Y_1 The amount of Product 1 bought externally.
Y_2 The amount of Product 2 bought externally.

The four constraints (stated in terms of the variables) are:

Demand Requirement Constraint:

$$X_1 + Y_1 \geq 5{,}000$$
$$X_2 + Y_2 \geq 4{,}000$$

The first constraint says that the amount made of Product 1 plus the amount bought must be at least equal to the amount required. A similar statement is appropriate for the second constraint for Product 2.

Production Constraints:

$$.1\,X_1 + .3\,X_2 \leq 600 + O_1$$
$$.2\,X_1 + .2\,X_2 \leq 320 + O_2$$

The first production constraint says that for Department 1 the production of X_1 and X_2 made must not require more than the time available on regular time (600 machine hours) plus the amount on overtime (O_1 machine hours).

Specifically, each unit of Product 1 uses .1 machine hours in Department 1, and Product 2 uses .3 machine hours per unit. A similar statement is appropriate for the second production constraint for Department 2. The above statements constitute a complete statement of the constraints for the problem. Now we consider an objective function.

Our goal is to minimize total cost. Each of the six decision variables has an associated variable cost per unit of measure. Namely,

6 A basic solution is defined as one which contains as many nonzero variable values as there are constraints. See for example: W. J. Baumol, *Economic Theory & Operations Analysis,* Prentice-Hall, Inc., Englewood Cliffs, N. J., 1963, pp. 73 and 77. In this problem, there are four constraints: two production constraints, i.e., one for each department, and two demand requirements, i.e., one for each four variables with a positive level.

7 *Ibid.*, p. 78.

the variable costs for X_1 and X_2 are the raw material cost of $10.00 and $5.00 per unit, respectively; the variable overtime costs for O_1 of $15.00 and O_2 of $18.00; and finally, the purchase costs for Y_1 and Y_2 at $18.00 and $12.00 per unit, respectively. Thus the objective function becomes:

Minimize $10X_1 + 3X_2 + 18Y_1 + 12Y_2 + 15O_1 + 18O_2$, the cost equation for our problem.[8]

Of course, we require:

$X_1 \geq 0, X_2 \geq 0, O_1 \geq 0, O_2 \geq 0, Y_1 \geq 0, Y_2 \geq 0.$

One advantage in formulating the problem as a linear program is that we can simply state what is feasible (i.e., what is possible in terms of our production constraints in algebraic terms). Also, we can state in algebraic terms our demand requirements. These two sets of algebraic statements together state what is possible and what is required. Then, we state our objective, here to minimize the total cost of overtime, purchases, and materials. Once the linear program is stated, it is a mechanical process to find a solution for the linear program. This solution process is referred to as the simplex method (or simplex algorithm).

Once the linear program is started, it is a mechanical process to find a solution . . . this method could just as easily handle the problem with twenty products and thirty departments.

Although it is beyond the scope of this article to describe the simplex method in detail, it should be mentioned that the simplex method is discussed in very lucid terms by Baumol in his *Economic Theory and Operations Analysis.*[9] Also, there are numerous other introductory texts in operations research, mathematics for business applications, and modern accounting which develop the technique in straightforward terms. For purposes of this article, it is sufficient to indicate that the simplex method is a general technique for solving a linear objective function with an arbitrary number of variables subject to an arbitrary number of linear constraints. That is, the simplex method is not dependent upon the size of the problem. For example, the simplex method could just as easily handle the problem with twenty products and thirty departments as the problem discussed in this paper. However, this is not true of the cost accounting approach.

Consider again the cost accounting approach to the problem. For two departments and two products, there were only a few possible solutions to the problem, namely, (1) make all of both products and incur overtime in both departments; (2) buy some of one product (both products were considered in turn) and make the rest of this product and all of the other product internally, thus incurring overtime in only one department; and, (3) buy some of both products and make the remaining amount required of both products internally, incurring no overtime.

We carefully (and laboriously) considered, one by one, all of these possibilities and chose the best alternative.

All solutions unnecessary

For the linear programing formulation, we do not have to enumerate all the possible solutions, the simplex method selects the best solution without requiring us to think about all the possible solutions. That is, once we have the formulation as a linear program, the simplex method is a systematic method to select the best solution of all the feasible solutions. In our cost accounting approach we could easily overlook one of the possibilities, and it might be the best one. The possibility of overlooking a possible solution for our small problem is not serious, but consider the problem with twenty products and thirty departments.

To enumerate all of them would

[8] The objective function stated here does not include the cost of operating both departments on regular time, which is considered fixed in our formulation of the problem. When using the objective function for calculating the total cost of the firm one would have to add $9,840, the cost of operating the two departments during regular time.

[9] *Ibid.*

be an impossible task. But with the linear programing formulation, we can find a solution in a few minutes with the aid of a digital computer. For the small problem here, the solution was obtained on a relatively slow computer[10] in less than thirty seconds, and this reason is a primary reason for using the linear programing formulation. The optimal solution to the linear program as we formulated the problem is:

$X_1 = 5{,}000$
$X_2 = 333.33$
$Y_1 = 0$
$Y_2 = 3{,}666.67$
$O_1 = 0$
$O_2 = 746.67$

Computer programs for the simplex method are readily available on the market today. Practically all computer manufacturers who will sell you a computer will also sell you a computer program for the simplex method for the particular computer.[11]

The significance of the above discussion is that 1) the cost accounting approach is correct but unworkable for large problems, and, 2) computer programs are readily available to solve linear programing problems. The advantage of the linear programing approach is not that the simplex method is more easily explained than the cost accounting approach but that we can reasonably consider larger problems and solve them by using the digital computer in a reasonable amount of time.

Conclusions

Although not stated explicitly, it is implicit in the foregoing analysis that the linear programing approach to make or buy analysis can be extended to more than two products and more than two departments. Also, if this extension is made, the simplex algorithm can readily provide the optimal solution.

Traditional approach laborious

However, the more complex situation just suggested would create a rather laborious task if the traditional cost accounting approach is undertaken. The multiperiod solution adds a considerable number of variables which can be handled by linear programing but would increase considerably the computational burdens of the cost accounting approach. Likewise, variables in workforce level could be considered where there are trade-offs between hiring workers for many periods and employing these workers on regular time rather than requiring overtime for the present workforce.

In comparing the two approaches to the problem, we should keep in mind that the assumptions for both approaches are the same. Although it is more obvious for the linear programing formulation, both models assume linearity in the production processes and linearity of the cost terms.

In comparing the two approaches to the problem, we should keep in mind that the assumptions for both approaches are the same.

Furthermore, both models assume that fixed costs and variable costs are segregated in like manner—namely, the fixed costs involve operations on regular time and the variable costs involve purchasing costs and overtime costs. One advantage of the linear programing formulation is that it is more obvious that we are making these assumptions than it is with the more traditional cost accounting approach.

Throughout this paper we have referred to the firm as the basic organizational unit. However, this type of model is equally applicable (and, perhaps more useful) for a division within a larger decentralized firm.

Not infrequently, a division is given the task of supplying the firm with a given amount (i.e., a demand requirement) of parts or subassemblies which may be made or bought at a minimum total cost.

[10] The IBM 1620

[11] One example is the MPS program for the IBM 360 computer series.