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Aggregate Planning Tools for Make-or-Buy Decisions: An Industrial Engineering Suggestion

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Abstract: A routine managerial accounting problem is the make-or-buy decision: to make a needed industrial subcomponent/material in-house, or to outsource/buy/purchase such items, but too often, the decision is treated as a one-time cost consideration problem without taking into account often the advantages of long-term production capacities of the "making" company. This paper proposes an evaluative tool that utilizes the Aggregate Planning Transportation model problem from the applied mathematics field of Operations research, that will enable production planners or small business managers to take long-term perspectives on cost minimization on the make-or-buy decision. Operations Research (or Management Science) has been a source for applied mathematical tools in the practice of Industrial Engineering. The paper suggests that the transportation problem only takes the variable costs considerations for producing a subcomponent in-house, but does not consider the fixed costs concerns that the Assignment problem can solve. Total costs for a planning horizon of more than one-period would be the objective of this evaluation tool. Numerical examples would be provided as to show the relative combinations of production demand that would best utilize this aggregate planning model. This should provide a human-centric computational tool that only requires a basic business graduate's academic training in management science.

Keywords: Make-or-buy; Long-term decisions; Aggregate Planning Model; Transportation Model; Assignment Model

1. MAKE OR BUY PROBLEM:

1.1 The Static case with Breakeven Analysis

A common decision problem set upon management accounting courses is the make-or-buy problem. The main components of this problem is a set of relevant fixed and variable costs for making the product, either the in-house "make" variable cost or the outsourced "buy" variable cost. A fixed cost for setting up the "make" option—often the production set-up costs associated with one production batch. The "buy" option often has a variable cost per unit which invariably is higher than the make option's.

We will assume that the company has excess capacity that can accommodate almost any quantity needed (i.e. uncapacitated case). Table 1 shows a typical give problem:

Table 1. Sample data for Make or buy problem

Option	Make in-house	Buy from outside supplier
Fixed costs of production run	P 10,000	n/a
Variable Cost	P50/unit	P62.50/unit

The solution often depends on the quantity demanded. The breakeven chart shown on Figure 1 shows the decision for ranges of units demanded.

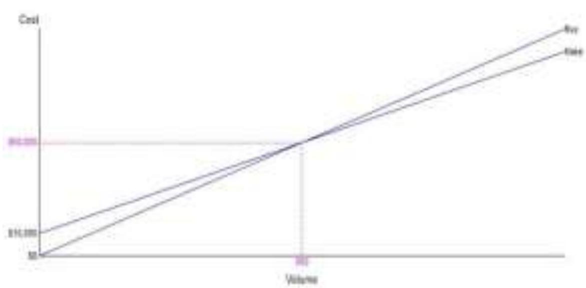

Fig. 1: Breakeven chart for Table 1 data

The concept of breakeven quantity is useful in this decision. Breakeven means the point of which two options become equal in value, making a decision-maker indifferent to choosing one option or the other. When the quantity demanded is less than the breakeven quantity, in the make or buy decision, then it would be economical to "buy" the item; when the demand quantity is enough or more than breakeven, then the fixed costs of production is divided across more units to justify in-house "make". The breakeven quantity to have the option of making the product in-house is given by :

$$Q_{BE} = \frac{F_{make}}{v_{buy} - v_{make}} \quad \text{(Eq. 1)}$$

where :

Q_{BE} = Breakeven units to produce to "make"
F_{make} = Fixed cost to make the product in-house
v_{buy} = Unit variable cost if outsourced/"buy"
v_{make} = Unit variable cost if produced/"make"

(from Krajewski, Ritzman, Malhotra, 2007)

This gives us a breakeven quantity equivalent to:

$$Q_{BE} = \frac{10{,}000}{62.5 - 50.0} = 800 \text{ units}$$

The decision is therefore, buy if units demanded is less than 800, make if quantity is higher than 800 units; and indifferent when equal.

1.2 Disaggregated month-to-month demand

The use of the breakeven formula shown for make-or-buy decisions may be applied to an aggregate demand that can be divided in the immediate term via monthly instalments. It may have happened that the "make" decision was chosen because the whole-year aggregate demand was used to justify. In situations like these, the total demand may be produced in one production lot, but there is the added relevant cost of keeping them in inventory for the next months up to a year. Storage costs become a factor if the volumes to keep are large. Take the example on Table 2, where a quarter's worth of demand is divided into three months' individual forecast demand.

Table 2. Illustrative Sample data for monthly staggered demand

Option	Make in-house	Buy from outside supplier
Fixed costs of production run	P 10,000	n/a
Variable Cost	P50/unit	P62.50/unit
Carrying cost	P 5/unit per month	

Month	1	2	3
Demand	600	0	600

This can now be considered an aggregate

planning problem whose choices each month are to either make the product in-house, and probably store any excess units forward to another month, or to buy the items outright.

1.3. Aggregate Planning using Transportation Problem Formulation

This problem has demand and supply components that have variable costs associated with production, inventory and outsource purchase, and can be cast as a transportation problem in the aggregate planning decision (Stevenson, 2007). Figure 2 gives the template for this uncapacitated aggregate planning problem. Figure 3 shows the solution to the problem in Table 2.

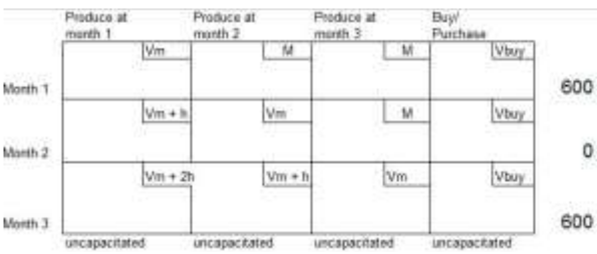

Fig. 2: Transportation Problem formulation

Fig. 3: Transportation problem solution

The solution in Transportation problem format assumes all costs are variable in nature. Therein lies the problem with the transportation problem formulation: Fixed costs are not considered for the contingent event that each month has a production run. In operations research, a binary variable (0-1) should serve as a switch variable for the inclusion of the fixed costs per run.

The total costs assessed, 600x50+600x50 =P60,000, merely corresponds to the variable costs of producing 600 units in month 1 and another 600 units in-house for month 3. The two instances of production runs on both months 1 and 3 were not yet considered. The true total costs inclusive of two production fixed runs would then be P80,000 (i.e. 2 fixed cost runs x P10,000 + P60,000 total variable costs). This is actually more expensive than the outright "buy" option, which is actually P75,000 (600 units x 2 x P62.50 unit purchase price).

A simplifying mindset would see that there is no need to solve 3 different months separately but to simply use the breakeven quantity of 800 unit per run to decide each month whether to make or buy the product. True enough, it is cheaper to buy than to make for each month because the quantity demanded 600 units a month is below the minimum breakeven run size of 800 units. Table 3 shows the total costs breakdown for each month production occurs.

Table 3. Monthly basis (600 units) computations

Option	Make in-house	Buy from outside supplier
Fixed costs of production run	P 10,000	0
Variable Cost	P50/unit x 600 units	P62.50/unit x 600 units
Total costs	P40,000	P37,500

1.4 Combining the Fixed costs of production into its variable costs (Economics' Average Total Cost concept) could get you in trouble

The Theory of Production from introductory economics textbooks (c.f. Mankiw, 2008? Or Samuelson, 2009?) have already combined the fixed costs of production to the variable costs to get average total costs (ATC).

$$ATC = \frac{Total\ Cost}{units} = \frac{Total\ Variable + Total\ Fixed}{units}$$

$$ATC = \frac{Total\ Variable}{units} + \frac{Total\ Fixed}{units}$$

$$ATC = AVC + AFC \qquad \text{(Eq. 2)}$$

This average fixed cost could be incorporated into the transportation problem's decision variables' costs, and hence increase the considered costs. The reasoning could proceed like in Figure 4, and a transporation problem solution like in Figure 5.

> From Equation 3:
> Average cost of "Making" 600 units:
> 50 + 10,000/600 = P66.67
> \>
> Average cost of "Buying" 600 units: P62.50.
>
> Therefore, "buy".

Fig. 4: Applying Fixed costs across units made

	Produce at month 1	Produce at month 2	Produce at month 3	Buy/ Purchase	Demand Qty
Month 1	66.67	M	M	62.5 / 600	600
Month 2	71.67	66.67	M	62.5	0
Month 3	76.67	71.67	66.67	62.5 / 600	600
	0	0	0	1,200	

Fig. 5: Incorporating the fixed costs into the average total costs of making the product

But this simplifying mindset did not consider the advantages of producing more units to stock: it could (and actually would) be cheaper to produce the second 600 units together with the first months' production run and carry the future month's demand in inventory than to put up another production run in the third month.

2. PRODUCING TO STOCK IS FORWARD-THINKING

2.1. Another breakeven quantity is applicable

The previous section's last statement could be verified: the costs of carrying 600 units in inventory for two months is cheaper than incurring a production run on the third month. *Additional Costs to Carry inventory*: 600 units x P5 carrying cost per month x 2 months = P 6,000 which is less than the *cost of a production run*= P 10,000.

Let us formulate this decision rule for breakeven quantities for stock keeping:

Let F_{make} = fixed costs of a production run
C = carrying costs of keeping one unit for one month in inventory

Then: breakeven quantity of demand that justifies a separate production run is given by equation 2:

$$Q_{produce} = \frac{F_{make}}{C} \qquad \text{(Eq. 3)}$$

Applying Equation 2 to the illustrative problem in table 2 gives:

$$Q_{produce} = \frac{F_{make}}{C} = \frac{P10{,}000}{P5/unit \cdot month} = 2{,}000\ units$$

This quantity means that if the demand quantity reaches 2,000 or more, then it is justified to begin a production run for that month's demand. Otherwise, any quantity demanded below 2,000 units justifies that it be produced from a previous month and just carried forward from inventory, but <u>only if</u> buying the item outsource is not an option.

2.2 Further Illustrative example

We now give examples of varying the demand data in Table 2 to show how the production "make" options dynamically change with the demand. Table 3 shows a large demand change, but all costs remain the same.

Table 3. Illustrative Sample data for monthly staggered demand

Option	Make in-house	Buy from outside supplier

Fixed costs of production run	P 10,000	n/a
Variable Cost	P50/unit	P62.50/unit
Carrying cost	P 5/unit per month	

Month	1	2	3
Demand	600	3,000	1,000

Aggregate demand = 600+3,000+1,000 = 4,600 units

$$Q_{BE} = \frac{10{,}000}{62.5 - 50.0} = 800 \text{ units}$$

Table 4: Make or buy based on Breakeven quantity

Month	1	2	3
Demand	600	3,000	1,000
$>Q_{BE}=800$?	no	yes	yes
Decision	Buy	Make	Make

Now since Months 2 and 3 are "make" decisions, we have two options:

Option 1: Produce each month's demand with no carried inventory.
Option 2: produce in month 2 the total demand for the two months, with carried inventory for one month.

The costs associated with each option can be determined to be P215,000 for Option A and P220,000 for Option B, as shown in Table 5.

Table 5: Breakdown of costs for producing in Months 1 and 2

Option A: Produce each month [3000,1000]			
	Month 1	Month 2	Total
Fixed	10,000	10,000	20,000
Production	3,000x50	1,000x50	200,000
Stocking	0	0	0
		Total Costs	220,000
Option B: Produce once [4000, 0] and carry stock			
	Month 1	Month 2	Total
Fixed	10,000	0	10,000
Production	4,000x50	0	200,000
Stocking	0	1,000x5	5,000
		Total Costs	215,000

Choose Option B.

Short-cut solution: If we use the proposed breakeven quantity formula for making and keeping to stock, $Q_{produce}$(Eq. 3) we get:

$$Q_{produce} = \frac{F_{make}}{C} = \frac{P10{,}000}{P5/unit \cdot month} = 2{,}000 \ units$$

Table 6: Applying production quantity cut-off values

Month	2	3
Demand	3,000	1,000
$>Q_{produce}=2{,}000$?	yes	no
Decision	Produce, since first batch.	Produce to stock in month earlier

Correct decision is confirmed for Option B: it is economical to produce in month 2 for demand for both months 2 and 3.

The complete answer can be summarized in Table 7.

Table 7: Final Decision for Table 3 problem

Month	1	2	3
Demand	600	3,000	1,000
Decision	Buy	Make 4,000	Use stock
Cost	600x62.50	10,000 +4,000x50	1,000x5
		Total Cost	252,500

3. TECHNICAL NOTE

The uncapacitated aggregate demand problem can be solved using a dynamic programming approach called the Wagner-Whitin procedure (Wagner and Whitin, 1958) This paper is an attempt to simplify the underlying iterative approach of the Wagner-Whitin procedure, but readers are encouraged to compare this paper's procedure with the computationally more challenging alternative. (c.f. Hopp and Spearman's Factory Physics, 2000).

4. CONCLUSION

The make-or-buy decision has another multi-layered dimension if dynamic periods' demand quantities are considered. This paper presents one version of that decision, and shows how the transporation problem formulation of aggregate planning could be used erroneously. The breakeven analysis using the relationships fixed and variable costs produce guidelines on how to choose when to make or to buy. Stocking carrying costs are also considered in multiple period production planning. The tools presented based on Operations Research applications in Industrial Engineering decision-making are handy and quickly applicable for a range of production planning problems.

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