The Enhanced Make-or-Buy Decision: The Fallacy of Traditional Cost Accounting and the Theory of Constraints

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We present a model for finite capacity scheduling in situations where the market demand exceeds the company's manufacturing capacity. Subcontracting to fill in the gap between the market demand and production capacity is an excellent tool to elevate the manufacturing constraint in the short term. Our model prescribes a simple ratio rating a product's priority for the constrained manufacturing resource. The ratio, developed from a linear programming analysis, enhances the Theory of Constraints (TOC) for the make-or-buy situation. We use a well known TOC example to illustrate fallacies of the TOC when outsourcing is possible.

Keywords: Theory of Constraints, outsourcing

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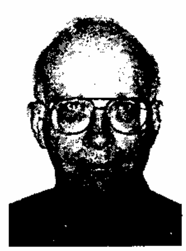
1. Introduction

Manufacturing companies often function in situations where internal production resources constrain their throughput. Such situations are characterized by market demand in excess of the company's production capacity. This problem, of finite capacity scheduling, is treated throughout the literature. This study examines the case where market demand exceeds the company's capacity to manufacture. Management needs to decide what quantities of each product line to manufacture and what quantities to buy from external contractors.

Information pertinent to the production vs. outsourcing problem apparently includes the cost of raw materials, the company's hourly rate, the product's sale price, total machine time dedicated to the product, work time at the constraint, product flow through the different resources, etc.



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Since different models provide radically different answers to the outsourcing problem we compare three alternatives: standard cost accounting, standard Theory of Constraints (TOC) [4,5,3,7], and our Linear Programming (LP) enhancement of the TOC.

The TOC offers a seven-step Constraint-Management-Cycle (CMC) [1] methodology for the identification of organizational constraints and their elevation [7,2]. The methodology is verbalized as follows:

1. Define the system's goal.
2. Determine measures of performance.
3. Identify the system's constraints.
4. Decide how to exploit the constraints.
5. Subordinate everything else to the above decision.
6. Elevate the system constraints.
7. If, in the previous steps, the constraint was violated, go back to step three, but do not let inertia become the system's constraint.

In this paper we consider the sixth step: elevate the system constraints, in terms of extending capacity through usage of subcontractors. The TOC, ignoring the outsourcing problem, prescribes in some instances solutions that are inferior in terms of throughput.

2. The Enhanced Make or Buy Model

While the first preference of any company is to manufacture its own products to the extent that its capacity permits, it is only sensible to fill in the gap between its production capacity and the market demand by subcontracting. In the short term, subcontracting elevates the company's internal constraint.

Faced with the make or buy decision the manager aims to maximize the company's total throughput from manufactured and subcontracted products.

Since the throughput of manufactured and outsourced products is computed as their sale price minus the cost of raw materials minus the contractor's markup (for subcontracted products), we aim to maximize the throughput over the company's set of products. This maximization is subject to two constraint types: manufacturing capacity and market demand. Thus we aim to utilize the constraint to its maximum while not exceeding the market demand for any product. The number of constraints thus equals the number of manufacturing resources plus the number of products.

Mathematical development of the equation set results in a simplified formulation of the LP problem. The simplified formulation of the LP problem ignores the constant expressions in the objective function:

$$\text{Max} \quad \sum_{i=1}^{\text{No.\_of\_products}} (\text{Contractor\_price}_i - \text{Raw\_materials}_i) * \text{Quantity}_i.$$

Subject to:

$$\sum_{i=1}^{\text{No.\_of\_products}} (\text{Product}_i \text{ time on resource}_j) * (\text{Manufactured quantity}_i) \leq \text{Capacity}_j;$$

$$\text{Total Quantity}_i \leq \text{Demand\_for\_product}_i;$$

for all products.

The implication of the last expression is that product price, cost of raw materials, total working hours per product or hourly rate are totally irrelevant to the outsourcing decision. Only two variables are relevant: contractor markup per product: contractor_price − cost_of_raw_materials; and the time per product at the constraint resource, j. In most cases a single resource constrains the capacity of the whole facility. It is now possible to prioritize the products for production. This model eliminates the need to solve an LP set each time the problem is applied. Products with a high ratio of contractor markup per constraint minute are of the highest priority to manufacture. We allocate them until the constraint is exploited to its fullest. The remaining market demand is subcontracted to the extent that it is marginally profitable.

The implication of this ratio is that products whose outside contractors are relatively 'greedy' (in terms of markup per constraint minute) are at the highest priority to manufacture in-house. The less 'greedy' the outside contractor, the stronger the incentive to outsource.

Thus, whenever outside contractors are available, the standard TOC ratio of Throughput-per-Constraint Time is replaced by the Contractor Markup-per-Constraint Time ratio.

The following example illustrates the differences between standard accounting, standard TOC and our LP model in terms of pertinent variables, mode of analysis, and total throughput.

3. An Example of the Outsourcing Problem

We now demonstrate the problem and its solution on a well known example taken from Goldratt [5]. Consider a production facility consisting of four resources: A, B, C and D, manufacturing two products: P and Q. The facility operates five days a week for one eight-hour shift per day. Capacity thus totals 2400 working minutes per week.

Fig. 1 depicts the flow layout throughout the production floor. Each of the two products incorporates two of three raw materials: 1, 2, and 3. The cost of each unit of raw material is $20; thus the total value of raw materials in each unit of final product Q is $40. Product P incorporates in addition a $5 part, raising the cost of its raw materials to $45. The products are sold on the market at $90 for one unit of P and $100 for one unit of Q. The weekly market demand is 100 units of P and 50 units of Q.

As illustrated in Fig. 1, the current demand level requires 3000 minutes of resource B per week, which constitute 125% of the resource's capacity. Resource B thus constrains the facility's capacity.

The company's operating expenses of $6,000 account for salaries, benefits, energy, financing, etc.

4. Production with no Subcontracting

When no subcontractors are available, the company has to optimize its resource allocation to maximize its production throughput.

4.1. Standard Accounting

Standard accounting procedures give preference to products that are more profitable per production time unit. To compute the cost of each work hour, the company's operating expenses of $6,000 are

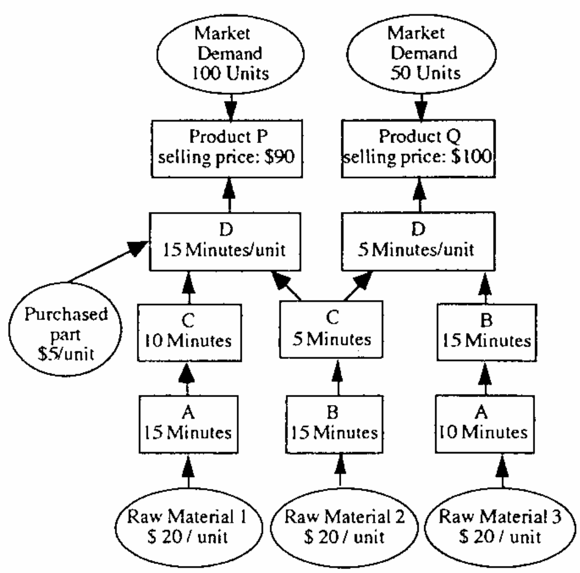

Fig. 1. Resource time per product in minutes.

divided by the number of resources – four, and by the work minutes per week – 2400. Thus, the cost of a work minute at any resource equals (6000/4)/2400 = $0.625.

The cost of a product unit is the sum of its raw materials ($45 for a unit of product P and $40 for a unit of product Q), plus its total working minutes at all four resources, multiplied by the company's minute rate ($0.625). A unit of product P thus costs $45 + 60 minutes * $0.625/min = $82.5 and a unit of product Q costs $40 + 50 minutes * $0.625/min = $71.25.

The profit per product is computed as its market price minus cost. To determine the product's profit per work minute, the profit per product is divided by the total work time in the facility: a profit of $7.50 for a unit of product P and a profit of $28.75 for a unit of product Q. By standard accounting criteria, Q is the most attractive product to manufacture since its profit per work minute is the highest. P is unattractive, but the company will manufacture it as part of its competitive strategy to supply the market demand. Resource B will therefore manufacture 50 units of product Q – the full demand, but only 60 units of product P due to the constrained capacity of 2400 minutes per week.

We proceed to the throughput of this product mix solution. The throughput of each manufactured unit (Table 1) is the market price less the cost of raw materials. This figure is multiplied by the number of units manufactured. From the total facility throughput of $5,700 we subtract its operating expenses of $6,000, generating a net loss of $300.

We next examine the standard TOC approach when policy constraint eliminates the use of subcontractors.

4.2. Standard Theory of Constraints

The Theory of Constraints (TOC) rates the attractiveness of manufacturing a product based upon its throughput per time unit spent at the constraint. The product's throughput is defined as its sale price minus the cost of raw materials. We divide the throughput by the time spent by the constraint resource B on the product. Product P's throughput per constraint minute equals $3/constraint minute (vs. product Q's $2/constraint minute) and P is therefore the first preference to manufacture. We thus manufacture 100 units of product P – the full market demand. Due to resource B's constrained capacity we can only manufacture 30 units of product Q – our second choice for production.

This solution produces a throughput of $300 (Table 2).

The next section considers the same situation when the policy constraint against using subcontractors is removed.

5. Production with Subcontracting

We take Goldratt's example one step further by introducing the availability of subcontractors. The company provides subcontractors with raw materials and pays an additional $15 for an assembled unit of product P and $39 for an assembled unit of product Q. It is company policy to supply the full market demand through the use of subcontractors, as a barrier against new entrants into the market.

Our example will demonstrate a reversal of the order of preference. Standard accounting prefers product Q for manufacturing, while the TOC pre-

Table 1
Standard accounting throughput

	Product P	Product Q
Demand in units	100	50
Units to manufacture	60	50
Throughput/manufactured unit	$45	$60
Total product throughput	$2,700	$3,000
Total facility throughput	$5,700	
Operating expenses	$6,000	
Net profit (loss)	($300)	

Table 2
Standard TOC analysis – no subcontracting

	Product P	Product Q
Demand in units	100	50
Units to manufacture	100	30
Throughput/manufactured unit	$45	$60
Total product throughput	$4,500	$1,800
Total facility throughput	$6,300	
Operating expenses	$6,000	
Net profit (loss)	$300	

fers product P for manufacturing. The example demonstrates that the TOC solution is inferior to standard accounting since it ignores the subcontractor markup per constraint minute ratio.

5.1. Standard Accounting

In the above solution we manufactured the full 50 unit demand for Q (Table 1) but only 60 units of the 100 unit demand for P. The next step is to subcontract the remaining 40 units (Table 3). The throughput per subcontracted unit of P is its market price of $90 less the cost of raw materials: $45, less the subcontractor's markup of $15, giving a total of $30. The 40 subcontracted units produce an additional throughput of $1200.

The $900 net profit consists of a $300 loss on manufactured units and a $1200 profit on subcontracted units.

We next examine the standard TOC approach to the outsourcing problem.

5.2. Standard Theory of Constraints

In the solution without subcontractors we manufactured the full 100 unit demand for P (Table 2) but only 30 of the 50 unit demand for Q. The next step is to subcontract the remaining 20 units. The throughput per subcontracted unit of Q (Table 4) equals its market price of $100 less the cost of raw materials – $40, less the subcontractor markup – $39, to a total of $21. The 20 units produce an additional throughput of $420.

The surprising outcome is that with the introduction of subcontracting, the standard accounting throughput of $900 exceeds the TOC throughput of $720. The next section presents the enhanced make-or-buy analysis, demonstrating that the best outcome is predictable using our markup per constraint minute ratio in a TOC framework.

5.3. The Enhanced Make-or-Buy Model

The enhanced model (Table 5) replaces throughput with the markup measure in the subcontracting situation. Product P's contractor markup of $15 is divided by its time at the constraint – 15 minutes, producing a ratio of $1.0/minute.

Table 3
Standard accounting throughput – no subcontracting

	Product P	Product Q
Demand in units	100	50
Units to manufacture	60	50
Throughput/manufactured unit	$45	$60
Subcontracted units	40	0
Throughput/subcontracted unit	$30	$21
Total product throughput	$3,900	$3,000
Total facility throughput	$6,900	
Operating expenses	$6,000	
Net profit (loss)	$900	

Table 4
Standard TOC analysis – with subcontracting

	Product P	Product Q
Demand in units	100	50
Units to manufacture	100	30
Throughput/manufactured unit	$45	$60
Subcontracted units	40	20
Throughput/subcontracted unit	$30	$21
Total product throughput	$4,500	$2,220
Total facility throughput	$6,720	
Operating expenses	$6,000	
Net profit (loss)	$720	

Table 5
Enhanced make-or-buy throughput – with subcontracting

	Product P	Product Q
Contractor markup	$15	$39
Bottleneck minutes	15	30
Markup per bottleneck minute	$1.0/min	$1.3/min
Demand in units	100	50
Units to manufacture	60	50
Throughput/manufactured unit	$45	$60
Subcontracted units	40	0
Throughput/subcontracted unit	$30	$21
Total product throughput	$ 3,900	$3,000
Total facility throughput	$6,900	
Operating expenses	$6,000	
Net profit	$900	

Product Q's contractor markup of $39 is divided by its time at the constraint – 30 minutes, producing a ratio of $1.3/minute. Since product Q's ratio is higher than P's it is prescribed to manufacture product Q to the full capacity of resource B (50 units). The remaining capacity is used to manufacture whatever quantity of P is possible (60 units). The gap between the manufacturing capacity and the market demand for product P is filled through subcontractors supplying the remaining 40 units.

6. Conclusion and Implications

The example demonstrates that availability of subcontractors, an important short-term tool for constraint elevation, adds a new dimension to the constraint management problem. The indiscriminate aggregation of constraint and non-constraint hours by standard accounting generates a lower throughput than the TOC. However, the TOC analyses the make (products to manufacture) or skip (demand beyond our capacity) decision. The make-or-buy decision, on the other hand, is determined by the subcontractor's markup per bottleneck minute rather than by the product's throughput. Managers using our make-or-buy enhanced model will outperform those using the standard accounting or standard TOC models.

Enhanced make-or-buy analysis is just as important for subcontractors in the process of service pricing. A subcontractor familiar with the client's decision-making framework and bottleneck can price services so as to maximize total throughput. Under the assumption that costs are comparable among competing contractors, knowledge about the customer's constraint provides insight into the customer's value chain [6] and guides the contractor's value engineering.

Finally, the model presents a reasonable market scenario. Under the assumption that subcontractors define their markup in relation to their marginal costs, the model predicts that companies will do business with complementing partners. Partners complement each other when one's constraint is at a low utilization rate (a free resource) by the other partner. Such a relationship also maximizes supplier and customer surpluses.

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