The Theory of Constraints and the Make-or-Buy Decision – An Update and Review

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Abstract

The make-or-buy decision is an important one for many organizations. Traditionally it has been made using standard cost accounting methods. Gardiner and Blackstone (1991) showed in this journal that a better decision in the one bottleneck-one product case could be made if bottleneck capacity was incorporated into the decision. In this paper a method based on spreadsheet LP is suggested that gives better solutions for the more complicated make-buy decision, which is usually the case in practice. It also allows for quick what-if analyses. Thus it is a general procedure and will be of practical use to decision makers. We also provide a conceptual comparison of the two approaches.

Key words: Make-or-buy, costing, linear programming, theory of constraints
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Introduction

This paper discusses a make-or-buy decision method that combines traditional cost accounting and the effect of capacity limitations. It is shown that if these two factors are not considered simultaneously, the firm may incur unnecessary additional expenses as a result of suboptimal make-or-buy decisions. This work is based on earlier work by Gardiner and Blackstone (1991). However the method described in that research did not guarantee the best solution for the more complicated make-or-buy problem while the method described here does.

Another important advantage of the proposed method is that a spreadsheet based optimizer is used to implement it. Thus it is one that gives optimal solutions and at the same time uses a widely used medium, the spreadsheet, for implementation. So the proposed method should be a practical tool for decision makers.

Outsourcing Research and Contributions of this Paper

The make-or-buy issue involves determining whether a particular component should be made in-house or purchased. It is an important one for many manufacturing organizations today as they rationalize their supply-chain for improved productivity and profit (Matthews 2000). It is clear that the make-or-buy decision has to incorporate strategic considerations. Research by Prahalad and Hamel (1990), Porter (1991),
Venkatesan (1992) and Sturgeon (2002) deal with strategic and organizational issues such as core competence and organizational flexibility. Hoyt and Lee (2001) discuss the evolution of outsourcing at Lucent.

A major issue in make-or-buy is to distinguish between strategic and non-strategic parts. Generally strategic parts would be produced in-house for competitive reasons. For example, Honda would be unlikely to outsource its engine manufacturing since engine design and manufacturing forms part of its core competence and outsourcing this might result in Honda becoming vulnerable strategically. On the other hand items such as batteries that go into its products would be considered standard items not part of its core competence. These would generally be purchased. Thus both Honda and the battery supplier would concentrate on their core competencies, in the expectation of a win-win situation. Other strategic issues in make-or-buy include the cost of the updated technology required to continue manufacturing the part in-house, asset utilization, whether outsourcing would reduce significantly the barriers to entry (generating more competition), whether it would reduce the company’s leverage in the supply chain, and whether it would hinder or help time-to-market for new products. Organizational issues include the ability to change the organization in order to reflect any changes in the future supply chain, and the ability to cooperate with suppliers if outsourcing is done.

While these and other strategic issues, such as uncertainty in technology and volume, and competition among suppliers are important in the make-or-buy decision (Walker and Weber 1987), financial implications are also important (Burt et al. 2003). This financial
analysis often utilizes traditional cost accounting measures. However these measures do not examine the effect on the existing products when a purchased component is brought in-house for production. Recent publications using traditional cost accounting for the make-or-buy decision include van Damme and van der Zon (1999). However they do not address the issue of capacity constraints. The importance of including capacity constraints in sourcing has been referred to briefly by Anderson and Katz (1998). But no detailed analysis was done in that paper.

Thus little research has focused on the integration of operational and managerial accounting issues in the make-or-buy decision. As Blackstone and Gardiner (1991) showed in their paper it is important to take an integrated approach to the make-or-buy. In addition as discussed later in the managerial issues section, make-or-buy issues are becoming an increasingly important as outsourcing becomes common place. Thus it is also becoming a relevant and critical research topic. Further given globalization, it is also becoming an increasingly complex topic. Thus there is a need for models that can reflect the reality of today’s make-or-buy issues facing managers. This means integrating operational and financial aspects of the make-or-buy decision.

This paper focuses on the tactical issues in the make-or-buy decision. Assuming that the organization has decided that certain parts are candidates for outsourcing, the proposed model should help decide which products to purchase and which ones to produce in-house. The Blackstone and Gardiner (1991) approach illustrated a basic issue in make-or-buy – that capacity issues have to be integrated with financial issues for better decisions.
Here the model is extended further to reflect the increased ability of decision tools to accurately model the realities of outsourcing. Thus this research should provide researchers with more insight into the outsourcing decision and provide a spring board for further research into an issue of importance in today’s business.

This research deals with the area of management thought called Management By Constraints (MBC), which by itself is not recent (Trietsch 2003). However, the Theory of Constraints (TOC) philosophy (Goldratt 1990), as explained in next section, has recently re emphasized MBC. In addition, it was often difficult to implement MBC in complex situations where factors such as multiple bottlenecks, products and production stages existed. As stated, over the past few decades, however, software for handling complex manufacturing and supply chain situations have become more powerful and affordable. In this paper it is demonstrated how a computerized decision support tool, specifically spreadsheet LP, can convert management thought into practice.

The TOC Approach to the Make-or-Buy Problem.

The TOC has been used by Blackstone and Gardiner (1991) to analyze the make-or-buy decision. The TOC advocates managing by focusing on the removal of the constraints in a system to enhance profitability. These constraints may be physical such as machine capacity, or it may be some management policies such as pricing. TOC has five steps which imply continuous improvement:
1) Identify the system constraints. This is analogous to identifying the weakest link in the operations chain, the link which limits the system capability.

2) Decide how to exploit the system constraints; i.e., maximize the performance of the system given the constraints identified in Step 1.

3) Subordinate everything else to that decision. The rest of the system should be geared towards helping achieve Step 2, even if it means inefficiency in the other parts.

4) Elevate the system constraints; i.e., if performance is not satisfactory, acquire more of the constrained resource.

5) Go back to step 1 for improvement if the previous steps result in new constraints.

Several techniques such as drum-buffer-rope, evaporating cloud, and cause-and-effect analysis are used in the TOC process of continuous improvement. Rahman (1996) provides a detailed review of the TOC literature and applications to various business problems. More recently Blackstone (2001) in an update on the field shows how TOC techniques such as drum-buffer-rope, evaporating clouds and reality trees can be used in performance measures, supply chains, marketing, and managing people, in addition to the traditional production applications. Goldratt along with the APICS-The Educational Society for Resource Management (formerly the American Production and Inventory Control Society) has been successful in re-emphasizing the importance of process bottlenecks. While the role of bottlenecks (through MBC) in process management has been recognized for a long time, Goldratt has been successful in translating these bottleneck issues into principles that can be understood by any audience. In a recent book Critical Chain, (Goldratt 1997), TOC principles are applied in project management, emphasizing the importance of resources on the project scheduling. For a recent critical review of the TOC principles see Trietsch (2003).
Traditionally this decision was made based on standard costs. Gardiner and Blackstone (1991) discussed the influence of shop floor capacity on the make-or-buy decision. If the component being considered for in-house production has to share a resource with existing products and this resource is being fully utilized at present, then the only way to produce this new component is by taking capacity on that resource away from existing products. This might affect profit adversely. The contribution per constraint minute (CPCM) criterion discussed by Gardiner and Blackstone (1991) addresses this issue. The CPCM is the contribution generated when a bottleneck resource contributes one minute to the processing of a product. They showed that the standard cost method for making the outsourcing decision is inferior to the CPCM approach. From a managerial accounting perspective, The CPCM follows the TOC principle of variable costing where labor is considered fixed (Noreen et al. 1995). The Gardiner and Blackstone (1991) example consisted of a one-product, one-bottleneck situation where one of the components of the product could be purchased.

The advantage of the CPCM method over standard costing can be illustrated using Example 1. Product M is sold for $174 per unit. It requires the processing of $4 worth of raw material on Workstation A for 15 minutes. Then it is processed on Workstation B for 20 minutes after which it goes to final assembly where component C is inserted (for simplicity the assembly time is negligible). Prior to this component C also has to be processed on Workstation B for 12 minutes and uses $6 worth of raw material. Thus in all 32 minutes of processing on Workstation B are required for the completion of Product
M, making it the only bottleneck or constraint. The weekly capacity of each workstation is 2400 minutes. The labour rate is $20 per hour and the variable overhead is $30 per hour. Alternately component C can be purchased for $29 per unit. The company can sell as much as they make. Table 1 shows the Make-or-buy analysis using standard costing.

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Per unit Make cost</th>
<th>Per unit Buy cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Labour 12 minutes @ $20 per hour</td>
<td>$4</td>
<td>-</td>
</tr>
<tr>
<td>Material $6/unit</td>
<td>$6</td>
<td>$29</td>
</tr>
<tr>
<td>Variable Overhead 12 minutes @ $30 per hour</td>
<td>$6</td>
<td>-</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$16</td>
<td>$29</td>
</tr>
</tbody>
</table>

Table 1: Standard Costing based Make-or-Buy Analysis for Example 1

Based on this analysis it is more profitable to make this product. Note that there is no consideration of the effects of the Make-of-Buy decision on production capacity.

The CPCM focuses on Step 1 and 2 of the five TOC process. Thus the CPCM helps identify the constraint and exploit it. It also helps identify the resources that should be elevated (acquired) in Step 4. The CPCM incorporates both the savings in costs due to avoiding the higher purchase price as well as the decreased profit due to taking resources away from other products. If the CPCM value is higher for the ‘make’ option, it implies that the decreased profit due to taking resources away from other products is more than
offset by not incurring the purchase price and vice versa. Thus it provides better results than the traditional costing approach which ignores the resource trade-off. The non-bottleneck resources (Workstation A and final assembly) are ignored as they have idle time and thus they will not be affected by the introduction of this new component into the system. The CPCM analysis for Example 1 is shown in Table 2.

<table>
<thead>
<tr>
<th>Row</th>
<th>Make component C</th>
<th>Buy component C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sales price of product M</td>
<td>$174</td>
</tr>
<tr>
<td>2</td>
<td>Material cost</td>
<td>$20 + $6 = $26</td>
</tr>
<tr>
<td>3</td>
<td>Contribution per unit for M</td>
<td>$148</td>
</tr>
<tr>
<td>4</td>
<td>Minutes required at constraint (workstation B) for M</td>
<td>20 + 12 = 32</td>
</tr>
<tr>
<td>5</td>
<td>CPCM (Row 3 ÷ Row 4)</td>
<td>$4.63</td>
</tr>
<tr>
<td>6</td>
<td>Minutes available at B (weekly)</td>
<td>2400</td>
</tr>
<tr>
<td>7</td>
<td>Possible production (Row 6 ÷ Row 4)</td>
<td>75</td>
</tr>
<tr>
<td>8</td>
<td>Total Contribution (Weekly) (Row 7 x Row 3)</td>
<td>$11,100</td>
</tr>
</tbody>
</table>

Table 2: CPCM analysis for Example 1

The analysis in Table 2 shows that the CPCM for the ‘buy’ option in Row 5 is higher than for the ‘make’ option. Thus the component should be purchased because the purchase price avoidance saving from making component C is not enough to offset the loss due to the reduced production in M (Row 7) when some of the bottleneck capacity is
allocated to C in the ‘make’ option. This reduced production in turns results in lower total contribution (Row 8) for the ‘make’ option.

So the CPCM is a better criterion than standard costing in determining the make-or-buy decision. However, The CPCM method also has some shortcomings. A review of the more recent literature, which combines TOC and traditional costing, by Kee and Schmidt (2000) reveals that these shortcomings have not been addressed in the make-or-buy context. This is addressed next using Example 2 in the next section.

**The Make-or-Buy Decision with Multiple Products and Bottlenecks**

Consider Example 2, where a company produces two products P and Q. Figure 1 shows the product tree. Both products have to be processed on machines A, B, C and D with the processing times shown in the figure. Each unit of P requires $20 worth of raw material (RM1) and sells for $174 while each unit of Q requires $10 worth of raw material (RM3) and sells for $159. Moreover, with each product, one of the required components can be purchased or made in-house. For P this component, called P(c), costs $29 per unit if purchased. If made in-house, the raw material (RM2) cost is $4 per unit and it needs to be processed on machines B, C and D and then assembled at machine A as shown in the figure. In the case of Q, component Q(c) may be purchased for $33 or produced in-house using the same raw material as for P(c) for $4 and then processed as shown. However note that the processing times to produce P(c) and Q(c) are different, so they are actually different items. The market demand for each product is 100 units. Each machine has 2400
minutes available for processing. The issue here is to determine the most profitable product mix and also to decide whether to purchase P(c) and Q(c) or whether to make them in-house.

![Product structure and process times diagram](image)

**Figure 1: Product structure and process times**

In order to do this the CPCM criterion is used. Initially a spreadsheet is set up as shown in Figure 2 to determine the constraint. In Figure 2, the range E25 to H28 gives the
processing times on each machine for P, Q, P(c) and Q(c). The range I25 to I28 shows that the maximum time available on each machine is 2400 minutes. The range E8 to H8 gives the units of P, Q, P(c) and Q(c) produced in-house and sold respectively. In order to determine the constraint or bottleneck machine, it is assumed that all market demand is satisfied and also that P(c) and Q(c) are produced in-house, thus giving the maximum possible usage of the four resources. Therefore 100 units each of P, Q, P(c) and Q(c) are assumed to be produced. The range E17 to H20 shows the minutes required on each machine for P, Q, P(c) and Q(c) for this production plan.

![Spreadsheet](image)

Figure 2: Spreadsheet for example problem

The advantage of a spreadsheet is that relationships can be set up quite easily. For example, E17 = E8*E9. This logic can be copied to the other cells in the E17 to H20

...
range. The range I17 to I20 determines the total usage of each machine. This has to be less than or equal to 2400. Finally, the range L17 to L20 gives the utilization of each machine. It is clear that machine B is the only one that is overloaded (more than 100% utilization). Hence this is a two-product one-bottleneck case. Based on the TOC resource B would be the system constraint. To exploit the constraint, Figure 3 which is similar to the decision table used in Gardiner and Blackstone (1991), is examined. Note that the contribution margins in cells E9 and F9 of Figure 2 come from the contribution margins for the ‘make’ options for P and Q in Figure 3. Cells G9 and H9 in Figure 2, which represent the additional contribution margins if P(c) and Q(c) are made in-house are also determined from Figure 3 as follows.

Figure 3: The CPCM analysis for Example 2
If P(c) is made in-house, the contribution margin for P would increase by the difference between the Make P(c) and Buy P(c) material costs; i.e., ($29 - $4) or $25. Similarly for each unit of Q(c) produced, the contribution margin for Q would increase by $29. It is important to remember that this additional contribution of $25 or $29 also results in the increased usage of resources. Thus when P(c) or Q(c) is made in-house, the corresponding times on the machines are added in the relevant cells in the range E17 to H20 (Figure 2) to reflect the additional processing times.

To determine the make-or-buy decision based on TOC, the CPCM numbers for resource B (the constraint) in Figure 3 are examined. For item P since 8.06 is less than 8.11, it will be concluded that it is better to make P(c). For item Q since 8.92 is greater than 8.79, it is concluded that it is better to buy Q(c). This is equivalent to saying that the decision is to make P, P(c) and Q while purchasing Q(c). As there is not enough capacity to satisfy market demand for all of P, P(c), and Q (this can be easily confirmed from the spreadsheet), the priority for fulfilling each product’s demand has also to be determined. Since producing Q and buying Q(c) has a higher CPCM, (8.92), than making P and P(c), (8.11), the demand for Q gets first priority, resulting in the production of 100 Qs (and purchasing 100 Q(c)s). By trial and error it can also be determined that there is enough capacity left to produce 59.45 Ps and 59.45 P(c)s as seen in Figure 4. The total contribution margin is $20517.5 However, it is possible to find a better solution with a higher total contribution as shown in Figure 5. This was obtained using an spreadsheet based LP optimizer add-in.
### RESULTS

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>Q</th>
<th>P(c)</th>
<th>Q(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units sold</td>
<td>59.45</td>
<td>100.00</td>
<td>59.45</td>
<td>0.00</td>
</tr>
<tr>
<td>CM per unit</td>
<td>125.0</td>
<td>116.0</td>
<td>25.0</td>
<td>29.0</td>
</tr>
<tr>
<td>CM per product</td>
<td>7431.3</td>
<td>11600.0</td>
<td>1486.3</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Total Contribution = 125P + 116Q + 25P(c) + 29Q(c)

Figure 4: Results from the CPCM analysis for Example 2

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Units sold</td>
<td>40.54</td>
<td>100.00</td>
<td>40.54</td>
<td>100.00</td>
</tr>
<tr>
<td>CM per unit</td>
<td>125.0</td>
<td>116.0</td>
<td>25.0</td>
<td>29.0</td>
</tr>
<tr>
<td>CM per product</td>
<td>5067.5</td>
<td>11600.0</td>
<td>1013.5</td>
<td>2900.0</td>
</tr>
</tbody>
</table>

Total Contribution = 125P + 116Q + 25P(c) + 29Q(c)

Figure 5: LP solution for Example 2
This sub-optimality occurs because the CPCM numbers based on Gardiner and Blackstone’s (1991) method (shown in Figure 3) are not detailed enough in the two-product case. If Q were the only product, the make-or-buy decision would be for Q(c) only based on the trade-off at resource B. However with the existence of product P, the trade-off on resource B between P and P(c) on one hand and Q(c) on the other, has to be examined. The CPCM analysis is not able to make this tradeoff effectively. LP, on the other hand, is guaranteed to give the best solution.

The situation also becomes more complex if there are multiple bottlenecks, i.e., more than one machine has a projected utilization of 100% or higher to satisfy demand. Again it can be shown that CPCM can give sub-optimal results while LP will give the optimal solution.

When there are multiple products or bottlenecks, in addition to suboptimal solutions, there can also be errors in evaluating the effect of an increase in the available capacity of bottleneck machines, when using the CPCM method. Since the CPCM may not use the bottlenecks in an effective manner, it may recommend increasing the capacity at the wrong bottleneck machine (in Step 4 of the TOC), which may result in forgone additional profit. In addition, the CPCM method may also ignore improvements in productivity of a non-bottleneck machine, when in fact that improvement could have been translated into additional profit, through product mix adjustment. LP with its ability to answer what-if questions in an optimal manner can provide valuable assistance in these situations. For further reading on LP modelling using spreadsheets, the reader is referred to Winston
and Albright (2003), or other textbooks that deal with quantitative analysis using spreadsheets.

**Limitations and Further Research**

Since LP was used as the decision tool, some of the limitations in this research arise from the use of this tool. For example, if the prices of different components or parts vary simultaneously because of global price fluctuations, the problem may have be re-optimized multiple times in a what-if format. Further if machine breakdown resulted in changes in capacity, the solutions provided by LP might not be implemented easily. If uncertainty is a major concern other tools such as computer simulation may have to be used to examine the robustness of a decision. Further if the problem is very large or complex, non-spreadsheet based LP optimizers may be needed.

The problem is also modeled based on a single objective, cost minimization. In practice the decision maker may have multiple objectives such as making the cost-quality tradeoff between suppliers, the supplier’s reliability, technical capability, financial strength and so on. As global competition increases, it is important to have a supplier that is strong in multiple dimensions. This could be an important future avenue for research and would involve the use of multiple objective decision tools such as Goal Programming (a variant of LP) or the Analytic Hierarchy Process (AHP). AHP (Saaty 1980) uses pairwise comparisons between different alternatives to arrive at a multi-attribute based decision.
Further research might also involve some of the make-or-buy considerations not included in this paper. For example, if a product is outsourced there might be an implied fixed cost associated with managing the outsourced product. If there are multiple vendors offering the same part, one consideration might be the possible economies of scale derived if the contract was offered to an existing vendor. There could also be interactions between the products themselves. For example, if there are two products that use similar resources in design and manufacturing, a relevant issue would be whether outsourcing one might result in the ability to produce the other effectively being diminished. Incorporating these issues would make the problem more comprehensive for actual situations that many companies face.

**Managerial Implications**

Outsourcing has become a buzzword in business today. Among manufacturers of telecom equipment such as Cisco, Nortel, and Lucent it has become the norm to outsource to companies like Solectron, Celestica, and Flextronics (Matthews 2000). Even products that are closely identified with a company are being outsourced so that the companies can focus on their core competence. For example, Proctor and Gamble (P&G) has outsourced its soap manufacturing in order to focus on product development (Pitts 2003).

Even when a product is not outsourced permanently, companies often temporarily have other companies assemble products. For example, Kellogg places great importance on allocating production of different types of cereal to its five North American plants. As part of this planning it also has to decide how much if any to have done by outside co-
packers (Brown et al. 2001). In the case of Kellogg if this allocation is not done effectively it can mean millions of dollars in additional costs annually. Thus for many companies, the make-or-buy decision can be a major one, and is an issue that an increasingly greater number of managers are grappling with.

At the same time many managers have difficulty making decisions that integrate different functional aspects. For example marketing managers find it difficult to evaluate the effects on manufacturing of their decisions. Operations managers may not be able to evaluate the costs effects of their decisions. One of the authors has noticed that even Executive MBA students have difficulty analysing in-class cases that involve integrated problem solving. They are effective at solving finance problems or operations problems separately but integrating both fields can be a challenge.

However, in recent years, the user friendliness of computerized decision support tools has increased greatly. These tools are useful in modelling decisions in an integrated manner and doing what-if analysis to help make robust decisions. In this paper the use of linear programming (LP) to help make effective make-or-buy decisions was discussed. While computer solutions for LP have been available for decades, they required access to and knowledge of specialized and expensive software. Thus most decision makers were not able to use LP. Currently add-in LP software is available in most spreadsheet packages. Thus decision makers have easy access to LP software and the discussion in this paper should help decision makers with achieving more effective solutions for the make-or-buy problem.
Summary and Conclusion

Gardiner and Blackstone (1991) showed that using the traditional costing method to decide whether to make or buy an item could result in poor decisions because it ignores the capacity aspects. Their paper introducing the CPCM method therefore makes an important contribution in understanding the make-or-buy decision. However the method described in that research suffers from some disadvantages. Since the publication of the Gardiner and Blackstone (1991) research, the advent of spreadsheets with in-built Linear Programming (LP) based optimizers, which are widely used and allow quick what-if analyses, has allowed decision makers to obtain better solutions for the complicated make-buy problem type.

Table 3 provides a conceptual comparison of the two approaches. As discussed the CPCM method is guaranteed to give the optimal solution only for the one product-one bottleneck problem while spreadsheet LP is more general – it can be used to provide optimal solutions for the multiple product-multiple bottleneck problem.

Both the CPCM method and the spreadsheet LP method address the same type of problem where costs and times are assumed to be deterministic. In addition both work on the principle that the best make-buy decision can be made by examining and exploiting the bottleneck to maximize the profit rather than just looking at costs alone as was done previously. CPCM looks at only one bottleneck at a time while LP can consider multiple bottlenecks simultaneously.
<table>
<thead>
<tr>
<th>Application</th>
<th>CPCM Method</th>
<th>Spreadsheet LP Method.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One bottleneck, one product situation (special situation)</td>
<td>Multiple bottleneck, multiple product (general situation)</td>
</tr>
<tr>
<td>Assumptions</td>
<td>1) Linearity</td>
<td>1) Deterministic System</td>
</tr>
<tr>
<td></td>
<td>2) Deterministic System</td>
<td></td>
</tr>
<tr>
<td>Solution principle</td>
<td>Exploit the bottleneck to maximize profit</td>
<td>Exploit the bottleneck(s) to maximize profit</td>
</tr>
<tr>
<td>Solution Tool</td>
<td>Manual Analysis</td>
<td>Add-in Linear Programming software</td>
</tr>
<tr>
<td>Type of solution</td>
<td>Heuristic (not guaranteed to be optimal)</td>
<td>Optimal</td>
</tr>
<tr>
<td>What-if analysis</td>
<td>Heuristic (not guaranteed to provide the best solution in the different scenarios)</td>
<td>Optimal</td>
</tr>
<tr>
<td>Approach in handling uncertainty</td>
<td>Limited (through buffers)</td>
<td>Limited (through what-if analysis)</td>
</tr>
<tr>
<td>Ability to handle non linearity</td>
<td>Limited</td>
<td>Good (though not necessarily optimal by using Integer or Non-linear Programming)</td>
</tr>
<tr>
<td>Ability to handle multiple objectives</td>
<td>Limited</td>
<td>Good (by using Goal Programming)</td>
</tr>
</tbody>
</table>

Table 3: Comparison of CPCM and Spreadsheet LP Methods

In practice however, there may be uncertainties such as machine breakdowns. In such situations TOC (of which CPCM is a subset) advocates use of buffers. However there is not much guidance in TOC on the setting of buffers thus limiting the ability of CPCM to handle uncertainties. In the case of spreadsheet LP, uncertainties can be handled only through manual what-if analysis for the most part. CPCM gives no guidance on uncertainties in costs while in spreadsheet LP, again manual what-if analysis would be the method to address it. Thus both these approaches are somewhat limited in their ability to handle uncertainties. As discussed earlier, computer simulation software would have to be used to enhance the ability of the decision maker. With what-if analysis, spreadsheet
LP would give the optimal solution under the different scenarios, where as CPCM would provide only heuristic solutions.

Spreadsheet LP can also handle various types of non linearity better. For example assume that the potential supplier has some fixed costs, minimum purchase quantities, or economies of scale that should be included in the make-or-buy analysis. With CPCM analysis this would introduce computational complexity that would be difficult to handle since CPCM uses manual analysis where it assumes that relationships are linear. Options are available in spreadsheet LP software that use special procedures to provide optimal or near optimal solutions in these situations, making it a better option in non linear situations.

Further as discussed previously, spreadsheet LP can also be used to handle multiple objectives through Goal Programming though this would have to be done manually. CPCM on the other hand assumes maximization of profit and there is no guidance on how one would address multiple goals.

Thus spreadsheet LP is a better tool in the make-or-buy analysis than CPCM. Of course, as in other decision analysis approaches, the spreadsheet LP approach is not without caveats. Being a more sophisticated approach, using spreadsheet LP would requires more education and training on the part of the decision maker than in the case of CPCM. Further spreadsheet LP is limited in handling uncertainty (which is true in the case of CPCM also), which would necessitate the use of approaches such as computer
simulation. Also further research is needed to address issues such as combining bottleneck analysis with strategic aspects such as competitiveness.

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