

Theory of Constraints as Related to Improved Business Unit Performance

**Martha Lair Sale
Florida Institute of Technology**

**R. Samuel Sale
Lamar University**

This paper provides an overview of the importance of The Goal by Goldratt and Cox twenty-five years after its publication introduced the Theory of Constraints (TOC). It highlights the degree of acceptance TOC has gained in practice. In light of the continued paucity of empirical support for the technique, it reports the results of an empirical analysis of TOC adopters. The study results support several of the elements of TOC as significantly related to business unit performance.

INTRODUCTION

In 2009, over twenty years after publication of The Goal, it was chosen to be included among the one-hundred best business books of all time as chosen and reviewed by noted business book reviewers Jack Covert and Todd Sattersten. Among only eleven management books chosen The Goal was included with such classics as The Essential Drucker and Toyota Production System (Covert & Sattersten, 2009 p.147). Not only has The Goal been recognized as one of the most influential business books of all times, with over 3 million copies having been sold, a cursory search of any comprehensive publication database shows it has spawned a tidal wave of academic and business research.

The theory of constraints (TOC), as introduced in The Goal, has grown far beyond the shop-floor scheduling technique for which it was first recognized to be applied to such diverse processes as army recruiting (Kohli, *et al.*, 2009), teacher training (Corpuz, 2009), health care (Pauker, 2006) and improving high school graduation rates (Goldratt & Weiss, 2005). Despite this diverse interest, a review of refereed journal articles dealing with TOC and its applications between 1980 and 1995 found that of the 89 refereed journal articles published the majority dealt with the manufacturing environment and associated problems of production. Empirical research and that applying TOC to other areas besides production continues to be limited (Rahman, 1998).

Along with just-in-time, and balanced scorecard, TOC has gained a place in the academic accounting curriculum (see for example, Jiambalvo, 2010; Horngren, *et al.* 2010; Blocher, *et al.* 2010). A review of over 100 case studies supported the ability of TOC to reduce cycle times, lead times and inventory levels giving companies better ability to meet promised delivery dates and thereby improving profitability (Mabin & Balderstond, 2000). However, despite this anecdotal evidence of success, and the application of the principles of TOC to almost every segment of business, government and non-profit organizations, there continues to be little empirical support for the ability of TOC to improve the financial performance of adopters.

In *The Goal*, Goldratt outlined the three processes elemental to the Theory of Constraints. In addition to introducing what Goldratt called a Drum-Buffer-Rope (DBR) scheduling system and a Five-Step Continuous Improvement Process, Goldratt questioned the absorption costing methods currently used in industry and suggested alternate accounting measures that have subsequently become known as throughput accounting.

Drum-Buffer-Rope Scheduling

The DBR approach to synchronized manufacturing assures that the inventory buffer in front of a capacity constrained resource remains at adequate levels without being too large (Goldratt, 1984, pp. 112-134). The constrained resource becomes the drum that determines the timing for the system. The buffer is the time related supply of inventory before the constrained resource that assures the constrained resource will not be idled by fluctuations in the system leading up to it. The rope is "tied" between the constrained resource and the lead operation in the system assuring that too much inventory does not develop in front of the constraint.

In *The Goal*, Goldratt developed an illustration for the idea from a group of scouts. The scouts are marching single-file along a trail and are unable to pass one another. The slowest scout, located somewhere in the middle of the group, represented the drummer determining the pace for the group. The buffer was the natural spacing that spreads between the faster marching scouts in front and the slowest scout. The rope determined the maximum physical distance allowed to develop between the first scout and the slowest scout. The spacing between all scouts following the slowest scout varied somewhat as they change their pace or are detained temporarily, but, being faster, they naturally caught back up to the slowest scout without intervention. In this analogy the trail traversed represented product moving through the system.

The Five-Step Continuous Improvement Process

The Five-Step Continuous Improvement Process is based on finding the constraints in the system (Goldratt, 1984, p. 297).

1. Identify the system's bottlenecks.
2. Decide how to exploit (get the most from) the bottlenecks.
3. Subordinate everything else to the above decision (make the bottleneck the drummer).
4. Elevate the systems bottlenecks (find a way around the bottlenecks).
5. If, in a previous step, a bottleneck has been broken go back to step 1.

Goldratt emphasizes that the completion of all five steps will lead to continuous process of improvement and, as it does, the nature of the bottlenecks will change. In a manufacturing environment, for instance, the constraint may change from being a physical constraint within the plant to insufficient market demand or a company policy that must be changed (Goldratt, 1984, p. 297).

Throughput Accounting

During the decade following the publication of *The Goal*, academics began an attempt to define what accounting for the TOC requires of cost accountants. Simultaneously, Activity Based Costing was gaining support as a way to allocate fixed overhead cost to products. Managers following ABC recognize the inappropriateness of direct labor as a base for cost allocation. In other companies Just-in-Time concepts have been adopted which impact inventory valuation. Many recognize that traditional cost systems are inadequate for management decision-making.

Goldratt suggested abandoning all these traditional costing methods, and even the language associated with them in, favor of a more direct system to measure performance.

According to Goldratt (1986, pp. 28-31) a relatively simple accounting approach is required by TOC in place of current costing systems. He claims that this new approach, termed Throughput Accounting

(TA), is consistent with the common goal of all profit-seeking organizations to make money. In Throughput Accounting Goldratt advocates three "global operational measurements."

- Throughput is the rate at which the system generates money through sales. (This is essentially sales less raw material and any other cost, such as commissions, that actually vary directly with sales volume.)
- Inventory is all the money the system invests in purchasing things the system intends to sell. (This would include what traditional accounting systems consider investments in plant and equipment. Intuitive justifications for including plant and equipment in inventory include the concept that these resources will be used up or worn out as productive assets and then will be sold to recoup any residual value.)
- Operating expense is all the money the system spends in turning inventory into throughput.

Companies can generate more money by increasing throughput, decreasing inventory, or reducing operating expenses (including direct labor). Increasing throughput has the greatest potential for generating more money, followed by reducing inventory, then by decreasing operating expenses (Goldratt, 1986, pp. 39-51).

The current study examines the relationship between the reported use of these three elements of TOC and business unit performance through examination of the following hypotheses. Stated in the null they are:

H₁: There is no relationship between the practice of Theory of Constraints and business unit performance.

H_{2a}: There is no relationship between the practice of Throughput Accounting and business unit performance.

H_{2b}: There is no relationship between the practice of Drum-Buffer-Rope scheduling and business unit performance.

H_{2c}: There is no relationship between the practice of the Five-Step Continuous Improvement Process and business unit performance.

METHODOLOGY

Measures

Organizational performance was evaluated using both financial and non-financial criteria. Multiple measures of performance help to avoid misleading interpretations resulting from use a single dimension or a narrow definition of the performance construct. Because, even within the same industry, different performance criteria are appropriate for evaluating the effectiveness of different management strategies it is important to use a performance measure that is not strategy specific. Following Covin, Slevin, and Schultz (1997), Gupta and Govindarajan's (1984) scale was chosen.

Financial performance was measured using a self-rating instrument. Because different standards of performance are expected for each industry, the performance of a particular firm is best defined in the context of the industry in which it operates (Swamidass & Newell, 1987). Moreover, it has been shown that differences in the acceptability of performance due to industry differences is taken into account by manager's satisfaction with their firm's performance. Respondents first were asked to indicate on a 5-point Likert-type scale, ranging from 1 = of little importance to 5 = extremely important, the degree of importance the upper management of their business unit attaches to each of thirteen different financial and non-financial performance criteria. The respondent was then asked to indicate the extent to which the upper management of the business unit was satisfied with the unit performance on each of these performance criteria. This response was also captured on a 5-point Likert-type scale where 1 = not at all satisfied and 5 = highly satisfied. As in Gupta and Govindarajan (1984) the importance scores were

mathematically adjusted to 1.0 to minimize the impact of response bias on the performance scores. This adjustment prevented the performance score of a respondent from being upwardly biased because the respondent marked all the performance measures as “extremely important.” Individual satisfaction scores were multiplied by the standardized importance score for that criterion and the products summed to create a weighted average performance index for each firm (Covin, et al., 1997).

The weighted average performance score equation is:

$$\text{Performance} = \frac{\sum (\text{Criterion Satisfaction Score} \times \text{Criterion Importance Score})}{\sum (\text{All Criteria Importance Scores})}$$

If the raw satisfaction data were used in this equation the resulting performance score for respondents who indicated the managers were “not at all satisfied” with unit performance on a criteria they considered “extremely important” would equal 5 (1 x 5). This would be higher than the performance score for respondents who indicated managers were “not at all satisfied” with unit performance on a performance criteria they considered “of little importance” which would equal 1 (1 x 1). To avoid this problem the raw satisfaction scores are re-coded to a -2.0, -1.0, 0, 1.0, 2.0 scale prior to development of the above index. This transformation procedure has no adverse effect on the measurement properties of the scale (Covin, et al., 1997).

Self-rating scales are criticized for potential bias, but this is less a concern where such a bias is generic and where the ratings are used in a relative rather than absolute measure as in the current study. Following Chenhall (1993) and Perera, et al. (1997). For the current study subjects were asked to rate the performance of their business units both concurrently with the survey and three years prior. Performance as measured in this study is the improvement in performance indicated by the difference between the performance scores.

Respondents indicated "yes" or "no" to the question of whether their business unit employed TOC. Similar questions asked them to indicate whether or not managers of their business unit employed the individual elements of TOC—Drum-Buffer-Rope scheduling, VAT Analysis, the Five-Step Continuous Improvement Process, and the Thinking Process associated with TOC. Other questions asked them if their unit employed Throughput Dollar Days and Inventory Dollar Days. Responses for these two questions were combined and subjects were defined as users of Throughput Accounting if they responded positively to both questions.

Research Design

An email questionnaire was developed for the survey. A sampling frame was adopted consisting of individuals in business units identified as being actively involved in TOC. The TOC Special Interest Group of APICS (American Production and Inventory Control Society), Discussion Groups devoted to TOC, and the guest books of TOC web sites were chosen as appropriate sources to contact employees of targeted business units.

Data Collection

The questionnaire and a cover letter explaining the nature of the study were made available to the potential participants. An email consisting of the cover letter and research instrument was sent to 742 email addresses. Respondents were given the option of responding directly via email or through a form posted on the Web. Both forms of return captured the data and returned it through the form-filler capability of the server. It was then forwarded via email from the server, assuring anonymity. A reminder to the original email was sent ten days later. The instrument and cover letter were also posted on four listserves devoted to TOC discussions. In total 191 responses were received and 180 were usable. Because of the way the instrument was administered, it is impossible to form firm conclusions about the response rate and sample. Because the responses arrived in three waves corresponding with the two emails and the posting to the discussion groups, it was possible to test the data from these separate activities to determine

if there were significant differences in the three segments of the sample. Three different tests of sample bias were conducted and supported the conclusion that there was no significant difference between the responding groups. The target population consisted of individuals from business units in which TOC was practiced, and an effort was made to contact these individuals. Although there is no firm assurance that the sample is representative of the population, the fact that there are no significant differences between the three segments of the sample supports the assumption that the sample was drawn from one population.

Results

Analysis of Variance was used to test the hypothesis that differences in performance are related to TOC.

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
CHANGE	Between Groups	8.04	1	8.04	7.716	.000
	Within Groups	190.68	183	1.04		

In this analysis the sample was grouped based on whether or not the respondent had indicated their business unit employed TOC and the change in performance was compared between the two groups. The results indicate that Hypothesis 1 (There is no relationship between the practice of Theory of Constraints and business unit performance) can be rejected. The mean improvement for users of TOC was greater than the mean improvement of non-users.

The second set of hypotheses was designed to examine whether practice of individual identified elements of TOC is related to performance. Summary results are provided in the table below

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Model		88.91	13	6.840	10.65	.000
Main Effects	Throughput Accounting	.00	1	.00	.01	.93
	Drum-Buffer-Rope	20.32	1	20.32	31.64	.000
	VAT Analysis	2.34	1	2.34	3.64	.058
	5-Step Improvement Process	17.39	1	17.39	27.08	.000
	Thinking Process	13.49	1	13.49	21.01	.000

The results were computed using alpha = 0.05 and the R-squared and Adjusted R-squared for the model were 0.45 and 0.41 respectively. All variables were entered simultaneously. The results support hypotheses that, individually, certain elements of TOC are related to higher business performance. The use of Drum-Buffer-Rope scheduling, use of the Five-Step Improvement Process, and use of the Thinking Process were individually significant at the chosen level. Therefore, it was possible to reject the following hypotheses:

H_{2b}: There is no relationship between the practice of Drum-Buffer-Rope scheduling and business unit performance.

H_{2d}: There is no relationship between the practice of the Five-Step Continuous Improvement Process and business unit performance.

An important step in examining a two-way ANOVA is the construction of a table of cell means. This allows an overview of the results of interest. The cell means for the ANOVA model using mean change in performance as the response variable are presented in the table below.

CELL MEANS						
Practice of TOC Element	Element					
			DBR		5-Steps	Thinking
	Yes		.5777		.4619	.3027
No		-0.2188		-0.4538	-0.2058	

The above table shows that performance improved for users of the elements of TOC, while performance deteriorated during the same period for non-users. These results are encouraging for users of TOC. However, caution is advised in interpretation of the results.

This study shows support for a significant positive relationship between use of Drum-Buffer-Rope scheduling and business unit performance, the Five-Step Improvement Process and business unit performance, and the Thinking Process and business unit performance.

The results show the relationship between VAT Analysis and business unit performance to be marginally significant, if one accepts the growing use of the term "marginal significance" to reflect significance at a level of alpha between 0.05 and 0.10.

No conclusions can be drawn for this sample about the relationship between the use of Throughput Accounting and business unit performance. However, Noreen, et al. (1995) found in their work that many adopters of TOC did not practice Throughput Accounting as outlined by Goldratt (1986, pp. 28-31). They found business units that were successfully using TOC had adapted a variety of individual measures to reflect these general concepts and called them different things. In addition, the term "Throughput Accounting" has been used by others (Macarthur, 1993; Dugdale & Jones, 1996) to mean different things. This makes it difficult to determine from a simple questionnaire, to what extent practitioners of TOC are using the accounting concepts suggested by Goldratt.

Limitations

The current study suffers from several limitations. First, results would have been more convincing had the sample size been larger. Because of the size of the sample and empty cells, it was impossible to examine the combinations of two-way and three-way interaction between the elements. Second, this study was of an exploratory nature—no previous studies have measured TOC, so no accepted measures of the constructs were available. In addition, the sample was drawn from individuals who were active participants in discussion groups and special interest groups devoted to TOC. It is likely that these individuals perceive TOC as being of value or they would not have participated. This introduces a possible bias.

Despite these limitations, this study contributes important information on the value of TOC as a tool to improve business unit performance. It provides a basis to further explore and define appropriate measures of TOC.

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