Performance measurement in a theory of constraints environment

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There is an increasing recognition of the critical role played by an organization’s performance measurement system in achieving competitive success. The success of an organization may well depend upon the compatibility between the performance measurement system in operation at subordinate organizational levels and the organization’s global goals. An increasing amount of research in operations management addresses the relationship between the operation’s performance measurement system and its apparent incompatibility with global organizational goals. The performance measurement system associated with the theory of constraints (TOC) has been advocated by some researchers as a mechanism for linking operational objectives to the global goals of an organization. However, empirical research is lacking to determine and test the relevance of the proposed performance measurement system presented in TOC. This study examines the application of a TOC-based performance measurement system in an operating environment and reports on the results. A set of propositions are also provided to further future research.

1. Introduction

Recently, performance measurement research has focused on measurement problems attributed to traditional cost accounting systems in manufacturing organizations transitioning towards world class manufacturing. The theory of constraints (TOC) as a means of achieving manufacturing excellence has also seen an increase in interest. However, little research has been published exploring the implications of TOC in relation to performance measurement. TOC research to date has focused on the production planning and scheduling methods (known as drum-buffer-rope and buffer management), rather than on an examination of the performance measurement methods. Discussions of TOC performance measurement have tended to be advocatory in nature and lack empirical results. This paper examines the results of the use of TOC performance measures in an actual manufacturing setting.

1.1. Purpose of study

The purpose of this research is to examine the use of TOC performance measures in an actual operating environment for comparison with the existing literature. By examining theory and practice, hypotheses can be generated and tested to validate areas of agreement and explain areas where theory and practice diverge. Given the exploratory nature of this study, the paper’s primary focus is on proposition generation for future TOC performance measurement research.
1.2. Organization of paper

The paper is organized as follows. Section 1 provided the motivation for and purpose of the research study. Section 2 reviews prior literature on performance measurement and TOC. The purpose of this section is to provide a theoretical foundation for the application of TOC performance measures. Section 3 provides an overview of the TOC performance measurement system. Section 4 describes the research methodology used in conducting the study. Section 5 contains a case study of the use of TOC performance measures at the Macon facility of Trane Corporation. Finally, § 6 examines similarities and differences between TOC performance measurement theory and practice. Propositions based on comparing the case study findings to the literature are also provided in § 6.

2. Performance measurement literature

2.1. Review of the performance measurement literature

The majority of the first performance measurement articles written focused on either plant or business unit performance. For example, (Clay 1977, Gold 1979, Brown 1980 and Janson 1980) were among the first to research how plant-wide productivity can be assessed and measured. However, during the same time period, other researchers focused their efforts on the assessment of the performance of the entire business unit (typically division level performance). Other researchers (Taylor and Davis 1977, Pursell 1980 and Cox 1995) were among the first to examine performance criteria, standards and measures for appraising overall business unit performance. With researchers focusing on either plant or business unit performance, the performance measurement literature lacked integration.

As performance measurement research progressed, articles began to focus on functional areas within manufacturing operations. For example, same researchers (Chamberlain 1981, Janson 1981, Dollar 1982, Hunt 1982, Raedels 1983, Tetz 1983, 1986, Betchel 1984, Axsalter 1986, Busher and Tyndall 1987) focused on how to measure performance in the materials management function. Although some of the functionally-based performance measurement literature examined performance relationships across functional areas, little was written about how functional performance was linked to overall business unit objectives. Contrarily, many of these articles focused on the local optimization of the functional area with little regard for how either other functions or the business unit itself may be impacted.


Others (Canada 1986, Kaplan 1986, Doll and Vonderembse 1987) began to explore performance measurement issues in computer integrated manufacturing (CIM) environments. Seidmann et al. (1985) and Young and Murray (1986) assessed the performance of flexible manufacturing systems (FMS). The research focus towards manufacturing system performance began the process of examining how plant systems are related to and affect business level performance. Thus, the integration between plant and business level performance measurement research began.
Although the literature began to suggest that manufacturing system performance was important to overall business performance, little was written at this point about how the manufacturing system should support plant and business unit strategy and/or the selection of appropriate performance criteria to ensure congruence between manufacturing system performance at the plant level and strategy at the business unit level.

Kaplan (1983) was among the first to identify the shortcomings of traditional cost accounting in today’s manufacturing environment. Goldratt and Cox (1984) challenged the operating assumptions made by traditional cost accounting and proposed a different performance measurement system in developing the theory of constraints. In 1989, Finch and Cox wrote an article challenging the assumption that inventory was an asset and illustrated how this assumption misrepresented plant and business unit performance. Fry and Cox (1989) then wrote an article describing how traditional cost accounting systems promote local optimization of resources within a manufacturing facility. The authors called for the adoption of global performance measurements which would optimize the performance of the entire business unit. Plossl (1990) stated that advances in the technology of manufacturing planning and control, and operations have made conventional cost accounting practices not only obsolete, but even counter-productive.


Lockamy (1991) explored the performance measurement systems used in world-class manufacturing environments and concluded the following: (1) The systems must encompass the entire product-delivery system, from the supplier to the customer; (2) The systems must be consistent with the manufacturing objectives of the facility; (3) The systems must be consistent with the manufacturing environment; (4) System information must be shared between organizational levels to provide organizational focus; and (5) System information must be shared across functional areas. Lockamy and Cox (1994) developed a performance measurement system model for aligning an organization’s functional performance measurement systems. The model provides a framework for ensuring an integrative approach in using organizational resources and monitoring resource effectiveness in supporting organizational goals.
2.2. Review of the theory of constraints literature

The theory of constraints emerged in the mid-1980s. Its predecessor, the OPT software, has been more fully discussed in research literature. Unfortunately, the two terms, TOC and OPT, are used somewhat interchangeably when discussing production planning and control. In 1984, Goldratt and Cox (1984) presented the basic performance measurement principles and logic of TOC in the form of a novel and a series of illustrative vignettes. Later, Goldratt and Fox (1986) developed the production planning and control techniques further, and identified that component of TOC as drum–buffer–rope. These planning and control techniques were further developed into buffer management as described by Schragenheim and Ronen (1990, 1991). The success of the planning and control techniques rests upon a unique performance measurement system that will be treated as a separate component of TOC in this article.

Jacobs (1983) reported the first examination of OPT software and concluded it would work best in high volume, large batch-size environments with few production operations. He concluded that economic justification of OPT would be difficult. Jacobs (1984) concluded, ‘OPT represents a new approach to the problem of operations planning and material control. The concepts in the set of rules COI (Creative Output, Inc.) has developed are relevant and could be applied to many production environments, with or without the use of the OPT software package’ (p. 41). Meleton (1986) reported on OPT results and concluded, ‘The description of how OPT operates and the philosophy that drives it leads to the conclusion that OPT would be most beneficial in scheduling a traditional job shop and in modelling and simulation’ (p. 19). Vollum (1986) described how OPT was used to enhance a CIM application for which MRP could not synchronize production because of MRP’s assumptions. Wheatly (1989) wrote, ‘The experience of all these [OPT] companies demonstrates that the OPT approach does yield substantial performance improvements. The underlying philosophy does work…Yet the software will do little without the philosophy being in place; and the philosophy relies chiefly on a challenge in the way manufacturing managers currently think’ (p. 43). Tobis (1990) and Pence et al. (1990) also compare the critical nature of managing a production bottleneck to the achievement of organizational goals. Ptak (1991) views the OPT philosophy as embracing the precepts of Just-in-Time and builds upon the requirements of MRP. Fawcett and Pearson (1991) support Ptak’s view as does Reimer (1991) who reported on a case study concerning MRP and TOC used in combination that supports Ptak’s conclusions. It appears that the success of OPT-TOC is determined to a large degree by the relative success of the performance measurement system and its underpinning philosophy. This observation is further supported by the first survey results concerning the OPT software by Fry et al. (1992), although the focus of the survey was on implementation issues rather than performance measurement results.

Additional research focused on the implementation of TOC scheduling methods into existing production planning and control systems. Spencer (1991), Fawcett and Pearson (1991), and Reimer (1991) examined how TOC could be used in an MRP system, while Lockamy and Cox (1991) examined V-A-T analysis to facilitate JIT implementation. V-A-T analysis is a constraint management procedure for determining the general flow of parts and products from raw materials to finished products within a manufacturing facility. Once the general parts flow is determined, control points can be identified and managed (Cox et al. 1995).
Since 1991 increased attention has been given to the effect of the TOC performance measurement system on production planning and control. Patterson (1992) and Lee and Plenert (1993) examined the effect of TOC measurements on the product selection and mix decisions. Luebbe and Finch (1992) used TOC and linear programming to make product mix decisions and found that the two approaches yielded similar results. They also highlighted the global nature of TOC as a philosophy versus LP's role as a single optimizing technique. Fry (1992) and Spencer (1994) showed how TOC’s performance measurement system was valid within the context of economic theory. Spencer also showed, using a case study, how TOC-based product mix decisions were used successfully when traditional cost accounting would have led to a different product decision. Umble (1992) applied TOC measurements more broadly in analysing a set of manufacturing problems. Lockamy (1993) also examined TOC principles more broadly using a case study.

Goldratt (1993) wrote the first article moving TOC away from production planning and control to a general examination of managerial problem solving. Gardiner et al. (1994) traced the development of TOC by citing several successful implementations, and explored the use of TOC methods, such as the five step focusing process and buffer management, for developing a continuous improvement process. They further compared the TOC scheduling methods with Kanban, concluding that TOC methods are more suitable for multi-product environments. Ennis (1996) also demonstrated the continuous improvement nature of TOC using a simulation technique. Dettmer (1995) collated many of the problem solving methods used by Goldratt in his text examining TOC as a continuous improvement management system. Spencer and Cox (1995) traced the evolution of TOC from OPT and created a classification system consisting of (1) a logistics branch, (2) a problem solving branch, and (3) a performance measurement branch to facilitate further research. They concluded, ‘However, the other aspects of TOC, such as the performance measurement system... should be explored for the potential impact to the operation of an organization’ (p. 1502). This research continues that exploration.

3. The TOC performance measurement system

As developed in Goldratt and Fox (1986), the performance measurement system in TOC is driven by the global goal of a business organization to make money now and in the future. TOC performance measurement systems contain three global measures for assessing a business organization’s ability to obtain the goal. These global measures are net profit, return on investment (ROI), and cash flow. Net profit is seen as an absolute measure of the organization’s ability to make money now and in the future. Return on investment is a relative measure given the amount of investment made in the organization. Cash flow is a measure of survival, a type of ‘go–no go’ gauge for actions. When cash is sufficient it is not important. However, when cash is insufficient, the other two measures become unimportant. Thus, cash flow is included as a global performance measure in TOC.

According to Goldratt and Fox, ‘While these bottom line measurements are sufficient to determine when the business is making money, they are woefully inadequate to judge the impact of specific actions on our goal’ (Goldratt and Fox 1986, p. 20). The authors identify the cost concept and cost procedures as the bridge between the actions of the firm and the global measures. They conclude that the use of current cost accounting procedures leads to mismanagement and a failure to achieve the goal.
In place of the traditional cost accounting procedures, an additional set of global performance measurements is introduced. These new measures are reported to support the goal by supporting the original performance measures of net profit, ROI, and cash flow. These measures have the following unique definitions under TOC:

*Throughput* – the rate at which the system generates money through sales.

*Inventory* – all the money the system invests in purchasing things the system intends to sell.

*Operating Expense* – all the money the system spends in turning inventory into throughput.

(Goldratt and Fox 1986, p. 29).

Using these definitions, Goldratt and Fox present a relationship among the global performance measures. If throughput increases and inventory and operating expense decrease, then net profit, ROI, and cash flow will increase. Conversely, if throughput decreases and inventory and operating expense increase, net profit, ROI, and cash flow will decrease.

Further, since operations managers are able to see more easily the impact of their decisions on throughput, inventory levels, or operating expenses than on net profit, ROI, and cash flow, the performance measures are also likely to be used as local performance measures. Therefore, under TOC, there is a linkage between the global performance measures used by the business unit, and the local performance measures used by the individual units. Because of this linkage, actions taken on the local level of an organization support the objectives of the entire business unit if those actions are in accordance with the relationships discussed in the previous paragraph.

Goldratt and Fox suggest that the failure of the traditional cost accounting system is caused by its inability to create performance measures that are able to be used locally and support the global performance measures. Several points have to be considered in comparing the TOC performance measurement system to the traditional cost accounting system. First, throughput is equal to final net sales rather than to shipments or any other measures of production commonly used in industry. Second, contrary to traditional cost accounting, inventory is valued at the cost of raw material rather than on a cost accumulation basis. TOC considers all other costs to be an operating expense. For example, all overhead costs that are traditionally allocated to inventory as it migrates through the production process are considered as operating expenses. The direct labour of employees is considered part of operating expense. Third, as a result of these specific definitions of inventory and operating expense, there is no distinction made between the cost of employee wages, computers, or floor wax. Each of these cost elements is viewed as an operating expense.

For example, under TOC, a supervisor of a machining department will make operating decisions leading to actions based on whether or not the results will increase throughput, decrease inventory, or decrease operating expense. If the overall result is positive, than the action will be taken. If the overall result is negative, then the action is not taken. Suppose a decision to schedule overtime within the machining department is being considered. It is determined that the result of the action will increase operating expenses and have no effect on inventory. Using a TOC approach, the overtime will be scheduled only if it will increase throughput (i.e. final sales). Under a traditional cost accounting system, overtime may or may not be scheduled depending on the status of the operating budget.
Additionally, under TOC, accounting performance measures change. Net profit is defined as throughput minus operating expense. Inventory has no direct impact on net profit, but affects it through its impact on throughput and operating expense (in terms of additional staff, administrative or labour costs). Inventory is valued at raw material cost only, and there are no overhead accounts. An account for departmental operating expenses accumulates the cost of converting inventory into throughput.

Three general questions emerge concerning the application of TOC in manufacturing environments and its impact on the performance measurement system. First, can a manufacturing organization operate under the performance measurement system proposed by TOC? Second, how does a manufacturing company manage using TOC principles? Third, what changes to the existing performance measurement system are needed prior to employing TOC measures? There are relatively few TOC applications available for research. Some TOC implementations are operating in selected pilot areas and have not implemented the performance measurement component. Other applications of TOC are in companies that view their results as proprietary. This research is based on the experiences of a single company. As a result, the research is exploratory in nature. The company does report that it has fully implemented TOC, including the performance measurement system, and has been operating using TOC since 1989.

4. Research methodology

Due to the exploratory nature of this study, an empirical research methodology was required. In order to gain the depth of understanding necessary to compare TOC performance measurement theory and application, the case study method was the primary methodology used. Survey methodology was also used in the form of questions asked prior to and during the case study.

Yin (1984) states that the case study is the preferred methodology when examining contemporary events in which the relevant behaviours cannot be manipulated. A case study is an empirical inquiry that:

- Investigates a contemporary phenomenon within its real-life context; when
- The boundaries between phenomenon and context are not clearly evident; and in which
- Multiple sources of evidence are used.

Babbie (1986) and Eisenhardt (1989) report that one of the strengths of the case study method is the in-depth understanding of the dynamics present within single settings. Case studies can involve either single or multiple cases and various levels of analysis. Also, case studies can be used to accomplish various objectives:

1. To provide description;
2. To test theory;
3. To generate theory.

This research study consisted of examining the use of TOC performance measures in a manufacturing setting for the purpose of generating propositions (theory) for future validation (testing).

Site visits were made to collect the required data. Interviews were conducted with division and plant staff managers to explore the use of TOC performance measures. A case study was written reflecting all data collection methods used, including
observation, company documents and interviews. The results of the case study was compared to the literature for the development of testable hypotheses.

5. Case study: Trane Corporation-Macon manufacturing facility

5.1. Background

The Trane company is a large industrial organization consisting of 18 factories organized into two divisions. The Commercial Systems Division consists of 11 factories and has a decentralized organization with each factory operating as a strategic business unit. The Commercial Systems Division’s business unit in Macon, Georgia produces the company’s line of large self-contained air conditioner units for commercial and industrial buildings. The Macon facility produces four distinct product lines: large units ranging from 20 to 80 tons; smaller units of less than 20 tons; a building service unit; and a freon evacuation unit. This case will concentrate on the large unit product line which dominates in manufacturing space and the other resources of the facility.

The large air conditioner units are produced to design specifications developed by a building contractor or architect to meet specific building requirements. The product is assembled-to-order from more than 5000 components and subassemblies. There are over 9 million unique designs possible. The general product is about 7 feet high, 5 feet wide, and 4 feet deep.

The Macon facility operates on an 8 hour-per-day, 5 days-per-week basis. Total plant employment is about 150 employees. There are about 90 direct and 60 support employees. All permanent employees at the Macon facility are salaried. Temporary employees are hired from a local employment company on a daily basis as required to support production. There is a general but unwritten understanding that permanent employees will not be subject to any layoff. The facility’s annual sales are about $30 million.

5.2. Production planning environment

The Macon facility uses a team concept to manage the production organization. The operations manager is the chief operating officer for materials, manufacturing, and other plant operations. The operating manager reports to the factory general manager. Reporting to the operations manager are three manufacturing cell managers, a facilities manager, and a manager of material/production control.

The cell managers act as key coordinators for their respective cells rather than a traditional production supervisor. Production employees are organized into three cell teams. These production teams operate their cells as separate business units. Operating decisions, such as overtime and employment levels, are made by consensus among the cell members. Key performance measures for the manufacturing cells are safety, housekeeping, delivery performance, inventory accuracy, quality, and productivity. The productivity measure is based on a comparison of the total actual hours-per-unit produced and the planned hours-per-unit equivalent. For example, the largest unit has a 1.3 equivalent unit (EU) while the smallest has a 0.8 EU. The master production schedule (MPS) is based on the EUs per day.

Current demand levels require a production rate of 20 EUs per week. The EUs are multiplied by each cell’s demonstrated productivity rate to determine cell manpower requirements. The demonstrated productivity rate is the average of the previous four weeks of production. The demonstrated production rate (also based on the previous four weeks) is used to adjust the planned number of production tech-
nicians employed in the cells. Additional hours are added for training and other non-production tasks including team meetings.

5.3. Production planning and control system

The production planning and control (PPC) system used at the Macon facility is a combination of JIT, MRP and TOC. A MRP system was purchased in early 1989. The software package used by Macon is CONTROL produced by Cincom, Inc. The decision to purchase CONTROL was made primarily based on a comparison of manufacturing needs to various available software packages.

The MRP system consists of several generic modules linked together by customized interfaces. The Macon facility currently uses the MPS module, the MRP calculation module, accounting module, and the bill-of-material module. A separate purchasing management system was installed during the MRP implementation. A shop floor control module was not implemented, although the CONTROL package did have one available. The decision not to implement the shop floor control module was based on management’s desire to avoid using labour reporting. Labour reporting was the driver in the CONTROL shop floor module. Management believes that the MRP system provides a framework for the other PPC methods used at the factory.

The MRP system is used for MPS, capacity planning, and the generation of purchasing requirements, in addition to the engineering bill-of-material function. MRP data is used to help establish customer promise dates, and to support traditional product costing calculations that are used in external reporting.

The factory employed an outside consultant in 1988 to facilitate the implementation of JIT concepts. The Macon facility utilizes the following JIT manufacturing approaches: (1) A levelled MPS to provide schedule linearity to production operations; (2) A total preventive maintenance (PM) program with scheduled PM included in the production rate calculations; (3) Multi-skilled employees to provide manufacturing flexibility; and (4) A revised plant layout to accommodate JIT methods. Macon facility management states that they do not have a set-up reduction program, and that one is not anticipated.

The Kanban method of material movement for subassemblies to final assembly is used. Suppliers also use triggering systems to replenish hardware and other finished components. There is no quality assurance department or inspectors at the facility. There is a total quality management program in place and quality is viewed as the responsibility of all employees. Quality control graphs are displayed throughout the facility; however, statistical quality control charts are not used. Management explains that no statistical quality control charts are needed, ‘Because no constraint to the business unit needs SPC at this time’.

The Macon facility began implementing TOC in 1989. TOC performance measures are used to support internal management decision making. The five focusing step process is also used as a means of implementing continuous improvement in the facility. Management also reports the use of the ‘thinking system’ techniques such as evaporating clouds and effect–cause–effect diagrams to facilitate decision making by management. These techniques help managers to challenge conventional thinking and to find the root causes of a problem. Finally shop floor control is accomplished by using the drum–buffer–rope and buffer management aspects of TOC. However, there are no plans to use the OPT software or any other TOC software. The current
operations manager has had formal training in TOC and has conducted TOC training for other managers.

5.4. The performance measurement system

Raw material is about 70% of the facility's total inventory investment. Work-in-process is about 10% of the investment, valued in TOC terms. Finished goods is the remaining 20% of the facility’s total inventory investment. Material costs are about 60% of the total sales dollars. Direct labour is about 10% of the total sales dollars, and traditional overhead is about 30% of the total sales dollars. The key performance measurement for inventory is the turnover rate. The 1992 rates were approximately 12 times per year for raw material, work-in-process of 250 times per year, and finished goods at 15 times per year. Total manufacturing lead time is 2.5 days.

The accounting function consists of the factory controller, a cost accountant, a general accountant, and an accounting clerk. The factory uses a dual accounting system. External reports are generated for Trane headquarters using traditional cost accounting procedures, based on the total direct labour hours per week. Profit and loss calculations are based on the traditional cost accounting system. Key performance measurements external to the factory are the traditional calculation of operating expenses before interest and taxes, cash flow, inventory turns, and outstanding days of billing.

Internal facility management reports contain the TOC performance measures of throughput, inventory, and operating expense. Cell decisions are based on the TOC performance measures. For example, inventory dollar days as well as the other TOC measures are computed for each cell. Inventory dollar days are the amount of inventory valued at raw material cost divided by the amount of inventory required per day to support planned throughput. The lower the inventory-dollar-days, the better the cell performance.

TOC performance measures are used to relate functional measures to the global goals of the organization. The measures also provide the facility with a mechanism for assessing if current individual functional activities may lead to possible sub-optimization situations. For example, superior master production schedule (MPS) performance is a critical factor in a low volume/high variety environment. Since each product configuration is unique, MPS deviations can be caused due to delays in marketing, engineering, procurement and/or manufacturing. Therefore, each functional area has developed MPS performance measures to assess their impact on the weekly schedule. Examples of such measures are: engineering tracks the average engineering change notice (ECN) backlog and throughput rate weekly; manufacturing monitors weekly order cycle time; and procurement examines the percentage of on-time and defect-free deliveries for each vendor weekly. These measures allow the functions to assess their contribution to the global goal of throughput. The measures also pinpoint areas requiring additional improvement.

6. TOC performance measurement: theory and practice

In this section, a comparison of TOC performance measurement practices is made against examined performance measurement literature. Hypotheses are provided based upon the comparisons.
6.1. Managerial Decision Making

Proposition 1. The measurement system proposed in TOC does successfully link local performance measures to the global goals of the organization.

The previous literature review suggests that traditional cost accounting systems commonly used in manufacturing promote local actions which contradict the overall goals of the firm. The Macon facility used TOC measures to evaluate the impact of functional activities on the global goal of throughput. TOC measures may provide a successful ‘missing link’ between local actions and global results.

Proposition 2. The performance measurement system proposed in TOC enables managerial decisions to be made which promote the global utilization of organizational resources.

Finch and Cox (1989) and Fry and Cox (1989) both suggest that traditional cost accounting measures often lead to the misuse of organizational resources. The Macon facility used TOC measures to ensure the proper utilization of labour resources within the manufacturing cells. Thus, labour usage was ‘optimized’ based on the global goal of maintaining throughput.

6.2. Changes to the current measurement system

Proposition 3. Measures which are inconsistent with organizational goals must be eliminated prior to adopting TOC measures.

Plossl (1990) warns of the danger of using obsolete measurement practices in advanced manufacturing environments. Such measures can promote decisions in direct contradiction with organizational goals. The Macon facility decided not to implement the MRP shop floor module to avoid labour reporting. Since direct labour reporting was determined to be inconsistent with TOC measurement, the measure was eliminated as a candidate for adoption.

Proposition 4. Financial accounting systems are still required to complement the TOC performance measurement system.

The literature does not address how external reporting requirements should be handled upon adopting TOC measures. The Macon facility maintains its financial accounting system and issued external reports to various components of Trane Corporation. Financial accounting systems are still needed to fulfill external reporting requirements regulated by the SEC, FASB, and other governing bodies.

7. Conclusions

TOC measurement systems provide a means for monitoring local performance in relation to the overall goals of the organization. The measurement system can be used in conjunction with existing systems, provided all measures are consistent with the organization’s goals. However, an additional system will be required to provide regulated external information. Further research is required to understand how to effectively integrate TOC measures into manufacturing environments. Empirical studies are needed which provide additional insights concerning TOC performance measurement systems.

References


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