Techniques

A classified model for applying the theory of constraints to service organizations

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Abstract

The general principles of TOC can be applied to improve the performance of service organizations. A classified model is proposed for such applications based on Schmenner's classification of service organizations. The flow of "material", inventory and throughput is identified at various service organizations of the four quadrants of the service matrix. The definition of these terms might be dependent on the service. Since system constraint is at the heart of TOC, the recognition of the nature of organization constraint is the first step towards continuous improvement.

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Introduction

Some management techniques developed for manufacturing organizations may not be appropriate for service organizations. There are clear differences between manufacturing organizations and service organizations that make manufacturing management techniques inappropriate for service management. Manufactured goods can be inventoried to provide products during times when demand exceeds capacity. Services cannot be pre-produced and held in inventory. Maintaining the balance between capacity and demand is a different problem for manufacturing organizations than for service organizations. However, there are similarities that make some management techniques usable in either environment. Just In Time and Total Quality Management are examples of such techniques (Duclos, *et al.* 1995).

Theory of Constraints (TOC) is a management philosophy that has been successfully used in a wide variety of manufacturing and it is time to transfer it to service.

What is TOC?

The Theory of Constraints (TOC) is largely the result of the work of Dr Eliyahu M. Goldratt. TOC is an overall management philosophy that recognizes constraint on any system restricts the maximum performance level that the system can obtain in relation to its goal. For most manufacturing and service organizations the goal of the organization is to make a larger profit now and in the future. Since the goal is to make a profit, constraints on manufacturing and service organizations keep the organization from making a higher level of profit.

The TOC philosophy could be applied to every day operations decisions as well as to continuous improvement effort. The TOC consists of two main branches; logistics (every day operations) and continuous improvement.

Logistics branch

The logistics branch has three elements, V-A-T analysis, scheduling process and performance measures.

V-A-T analysis

This is a method to classify plants based on the product and the process flow. The "V"

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plant has very few raw materials and many final products. The "A" plant has many raw materials and a limited number of final products. The "T" plant has many final products that are assembled in many different ways from a limited numbers of components and subassemblies. This analysis is very important in recognizing the type of problems, issues and concerns associated with each type.

Scheduling process

The TOC has a unique method of scheduling process with constraints, called Drum-Buffer-Rope or DBR. To maintain a system at maximum performance we must design the system so that capacity constraints within the system are always operating at peak capacity.

The *Drum* is the capacity constraint. The capacity constraint sets the pace for the system as a drum sets the pace for marching soldiers.

The *Buffer* isolates the capacity constraint from negative effects of the rest of the system.

The *Rope* ties raw material release to the capacity constraint buffer to assure that inventory is at the lowest level that will maintain capacity constraint performance at maximum.

Performance measures

We must use measures of performance that accurately indicate the system's performance relative to its goal. For manufacturing, three global measures are suggested by Goldratt and Cox (1992). The three measures are:

(1) Throughput (T): the rate at which the system generates money through sales.
(2) Inventory (I): all the money invested in purchasing things the system intends to sell.
(3) Operating Expense (OE): all the money the system spends in turning *inventory* into *throughput*.

Although these measures are different from traditional measures they can be converted to more traditional measures with simple mathematical operations (Finch and Luebbe 1995). For example:

Net profit = *throughput – operating expense*
Inventory turns = *throughput /inventory*
Productivity = *throughput /operating expense*

For most service businesses *throughput* (T) and *operating expense* (OE) are appropriate measures. However, *inventory* (I) as defined above may not be appropriate for all service businesses.

The measures T, I, and OE are global indicators of system performance. Organizations should work to increase overall system T while simultaneously reducing I and OE. Unfortunately these global measures cannot be transferred verbatim to individual processes for use as local measures of performance. For example, a non-constraint work center that increases its output without regard to events at downstream work centers could increase the system's total inventory without increasing the system's output. We must be cautious that we select local performance measures that drive individual processes toward improved global performance.

Continuous improvement branch

The continuous improvement branch has two elements: effect-cause-effect (ECE) diagrams and the five-step focusing process.

ECE diagrams

The process of developing these diagrams forces managers to think about the true causes of problems. Utilizing critical thinking and Socratic methods, the root cause of a problem is identified. A plan is developed for eliminating the root cause rather than treating symptoms of the problem.

This approach answers three questions, what to change, what to change to, and how to change.

Five-step focusing process

Considering the TOC philosophy, improvements in performance can only be achieved by focusing on system constraints. This focus is achieved by a series of five steps suggested by Goldratt and Cox (1992). The steps are generic in that they can be applied to any system, including service businesses. The five steps are:

(1) Identify the system constraint(s). A system cannot be maintained at maximum performance unless we know what constrains the system so we can design control mechanisms appropriate to the constraints.
(2) Exploit the system constraint(s). We must make the best possible use of the constraints. For example, physical constraints within the system must be scheduled to produce the most profitable products.

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(3) Subordinate the non-constraint(s). Non-constraints, by definition; do not limit maximum performance of the system. Decisions affecting constraints must take priority over those affecting non-constraints.
(4) Elevate the constraint(s). After completing the above steps, further improvements in performance of the system require changing a constraint. Increasing the capacity of a machine that constrains profit is an example of this step.
(5) Return to step 1. After a constraint is changed, new system constraints may surface. Return to step 1 to identify new constraints.

To apply the full range of TOC principles to any organization we must apply the five steps focusing process, develop proper local and global performance measures, and design a system for logistical control. TOC principles have been successfully applied to a variety of manufacturing organizations. Since manufacturing and service organizations have significant differences, application of TOC principles to service organizations may require some modifications.

Purpose of the paper

To show how the TOC principles might be applied to various service industries, and to "transfer" the TOC vocabulary to service vocabulary. The identification of raw material, inventory, and throughput will facilitate the transfer of TOC to service organizations.

Service organizations

Not all activities that take place in service organizations are specific to individual businesses. Service organizations that view themselves as unique miss the opportunity to apply techniques that apply generically to services. Some authors suggest that a path to better service management is the classification of service operations and the application of methods appropriate to the service classification. Chase (1978) classifies service by the extent of customer contact. Customer contact refers to the time the customer is physically in the system. At the high contact end is the "pure service" and at the low contact end is the "quasi-manufacturing".

Silvestro *et al.* (1992) used information from their empirical study to develop a service-process matrix (Figure 1). This form of service-process matrix has the volume of customers processed on the horizontal axis and the service classification on the vertical axis.

Another approach involves translation of a successful classification scheme from manufacturing to service. In manufacturing, a method for classification is the product-process matrix (Hayes and Wheelwright, 1984). Analogous to the product-process matrix in manufacturing is the service process matrix developed by Schmenner (1986) (Figure 2). Two key elements are used to classify service delivery processes, labor intensity, and customer interaction and service customization. A two-by-two matrix can be generated from these two classification categories.

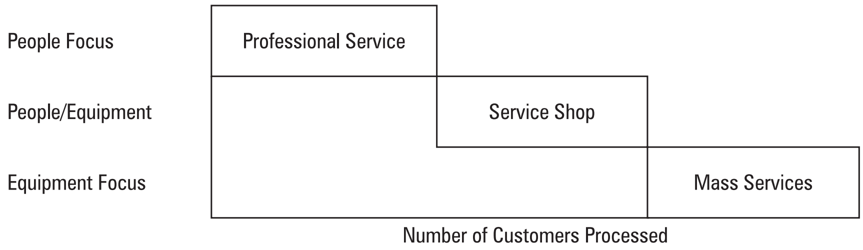
'... The underlying idea of TOC is that constraints, by definition, limit the performance of any system. We can only get continuous maximum performance from a system by driving the system against its constraints. ...'

Unfortunately classification schemes are only descriptive. The purpose of classification is the identification of managerial problems for a class of service processes that will lead to a class of solutions to the problems. For example, Chase (1978) recognized that high customer contact systems are difficult to control. Obviously, properly identifying a problem is the first step toward solving it. We still must figure out how to control the system efficiently day to day. This is another reason for investigating the application of the TOC to the service sector.

There are two issues that TOC deals with in manufacturing that are also of importance in the service sector. The issues are, maintaining short-term operations as close to maximum performance as possible (logistics) and, improving long term maximum performance (continuous improvement).

The underlying idea of TOC is that constraints, by definition, limit the performance of any system. An addendum to this idea is we can only get continuous maximum perfor-

Figure 1 Service process matrix



Source: Silvestro *et al*. (1992)

Figure 2 The service process matrix

Degree of Labor Intensity		Degree of Interaction & Customization: Low	Degree of Interaction & Customization: High
	Low	**Service Factory:** • Airlines • Trucking • Hotels • Resorts & Recreation	**Service Shop:** • Hospitals • Auto Repair • Other Repair Services
	High	**Mass Service:** • Retailing • Wholesaling • Schools • Retail Aspects of Commercial Banking	**Professional Service:** • Doctors • Lawyers • Accountants • Architects

Source: Schmenner (1986)

mance from a system by driving the system against its constraints. We should be aware that we might not be able to drive a system against all its constraints simultaneously.

In the next section we will present the few articles that were published on the application of TOC to the service industry.

Literature review

Both academic researchers and practitioners have been slow to consider moving TOC from the factory floor to non-manufacturing environment. The author performs an extensive literature review, which covers both refereed and non-refereed journals. The objective is to study and analyze the various applications of TOC techniques to service organizations, and to develop a classified model for these applications. Few publications were found (total of 12) and they are summarized below.

Adelman (1991), Green and Larrow (1994), Spencer and Wathen (1994), Motwani, *et al.* (1996a, b) and Bramorski, *et al.* (1997) and Olson (1998) reported some of the few attempts in this direction. Adelman (1991) reported one of the early applications of TOC to service. He describes the successful application of the principles of TOC to both the accounting and the production systems at a donut shop. Goldratt's five-step focused process was applied to the order entry process in a furniture manufacturing company (Spencer and Wathen 1994), the result was a substantial reduction of shipment time and improvement in customer services. Green and Larrow (1994) report similar ideas where they applied TOC principles to an accounting firm.

Constraints in some service organizations are found to be policies and procedures rather than physical capacity constraints. Motwani *et al.* (1996b) examined the contribution of the TOC to non-profit service organization. They presented a hypothetical implementation of the drum-buffer-rope control technique to the Red Cross operation in Florida, USA, following hurricane Andrew. They also reported actual application in two initiatives at the University of Michigan Hospital, USA.

Motwani and Vogelsang (1996) reported another successful application of the TOC Principles. A US engineering firm used the five-step focusing process to eliminate bottleneck and to improve the overall productivity. Bramorski *et al.* (1997) illustrated the application of TOC to some of the processes in commercial banks. The application of TOC to the mortgage department resulted in reducing the time needed to process an individual home mortgage application. Olson (1998) presented a case study on TOC applications. American Security and Alarm Co. was able to achieve the ultimate goal of high profitability by increasing sales and decreasing expenses and inventory costs. This was accomplished by redesigning the existing system and managing its constraints.

TOC as a continuous improvement tool is compatible with other management techniques such as TQM and re-engineering. Ronen and Paas (1994) explained how TOC enabled the manager to identify the best starting point for implementing TQM. A significant improvement in operations was realized in a short time.

Dettmer (1995) emphasizes that TOC does not replace TQM. Rather TOC integrates and focuses TQM tools towards the organization goal. It provides the means to know when each of these process tools is necessary and appropriate to improve overall system performance. He also emphasizes the fact "the sum of local optima is not the system optimum". Tanner and Honeycutt (1996) report other applications to the re-engineering process of sales force. They describe the application of TOC philosophy to analyze workforce process, identify the bottleneck and eliminate them.

This paper proposes a classified model for a TOC application, which is based on Schemenner's classification of services. Schmenner identified a set of features and issues related to service organizations in each classification. By applying TOC principles to the issues in each classification, an overall picture of the general application of TOC to services will be developed.

In evaluating the use of TOC in each area of the service matrix, the importance of TOC definitions of performance measures will be investigated, as it may facilitate finding better solutions. In evaluating the use of TOC in each classification of the service matrix, the emphasis will be on TOC as a continuous improvement tool.

Service factory

Schmenner describes the service organizations in this quadrant as having relatively low labor intensity and low degree of customer interaction and customization. Examples are transportation, hospitality industries and the back-room operations of financial institutions. The service process tends to have limited varieties and the introduction of new services is very infrequent, so it is a very stable environment. The competitive advantages are in the area of price, speed and the personal touch. Capacity decisions, managing demand to avoid peaks and promote off-peaks, and scheduling on-time service delivery are some of the challenges that face managers in the service factory organization. Typical hierarchical structures of the organization and policy constraints tend to be important issues.

Applying the theory of constraints requires identifying the performance measures. Inventory here is the unused "service", e.g. a seat on a flight, a room in a hotel or resort or a space in a truck. Inventory is physical in nature. The throughput is the money generated from selling the "service". Operating expense has the standard TOC definition. The five-step focusing process requires a multi-stage or multi-process system to be applied meaningfully.

The service factory by nature is a multi-process system. Part of the service is "prepared" and "checked" ahead of time before the delivery. Service factory can be viewed as a "T" system (borrowing from the VAT definition of manufacturing). There is little difference in the preparation for delivery of the service. However some customization can be achieved at the delivery point, e.g. various menus, special room requirements,...etc. Due to the nature of the "T" system, misallocation of resources to end products could cause poor due-date performance and lower throughput. TOC can help elevate some of the above mentioned problems, by identifying the constraints in the system and applying the principles of the DBR.

The Delta Airlines utilized a TOC approach to recover funds owed to the airline when mistakes are made in ticket prices. There are different fare rates on each specific flight, and it is common to have ticketing/travel agent gave discount that is not authorized by Delta Airlines (Kingman, 1995). Delta's loss on this was about $98 million dollars. However, time, capacity and budgetary constraints, prevented the company from recovering all their money.

A solution was devised to identify the ticket errors that allowed the most recovery, given that different ticketing errors take various amounts of time to process and have discrete amount of recovery worth. A Current Reality Tree was done for the finance department. The constraints were identified and the contribution in dollars per constraint minute for each error type was determined. Delta was able to increase the amount of money recovered by applying a solution based on dealing with these constraints.

The applications of TOC to airline problems are endless. Consider, for example, a flight route Chicago-Atlanta-Miami. Bad weather in Atlanta causes delays into and out of Atlanta. If the flight from Chicago is allowed to take off it will increase the congestion at Atlanta. Using buffer management, when the "inventory" of flights on the ground at Atlanta increases, the release of "raw material" is stopped, this would reduce the congestion and the delay that would occur if the flight is allowed to take off as originally scheduled.

'... In a medical environment, the length of time it takes to heal a patient is highly stochastic. Symptoms of a problem may not lead directly to the actual cause of the problem....'

Another example from hospitality industry shows how TOC can improve capacity and resource allocation: A hotel begins to fill to capacity, management enforces the check-in and checkout times that otherwise are not enforced. Delaying check-in slows raw material release increasing the buffer of unfilled rooms and expediting checkout also increases the buffer. This allows time to clean rooms and replenish room supplies making the room ready for occupancy.

Olson (1998) presented the case of a security-system company, which is a typical service factory firm. The company is the American Security and Alarm Co. and is located in Lubbock, Texas. They were unable to satisfy the market demand. The management revised the installation process as a whole, rather than several smaller processes, and found the technicians to be the bottleneck. The installation process was redesigned to allow technicians to work in teams and perform multi-task in parallel. The productivity of the technicians increased, the throughput increased and the demand was met.

Service shop

The "Service Shop" quadrant includes hospitals, auto repair shops, and other repair services. High degree of interaction and customization and a low degree of labor intensity characterize the organizations in this quadrant. These organizations consider a high mix and variety of services offered as their competitive advantage. However, these make the service shop difficult to control.

In a medical environment, for example, the length of time it takes to heal a patient is highly stochastic. Symptoms of a problem may not lead directly to the actual cause of the problem. A specific symptom may have several causes. Several plans for care may have to be followed until a successful result is obtained. Highly specialized surgery may be required, but a surgeon with the proper skills may not be immediately available. A heart transplant candidate may have to wait a significant amount of time for a compatible heart to become available. The failure of one body function may cause damage to another otherwise good part of the body.

Dependent events where an event A must be accomplished before an event B can begin are common to theses service organizations. Patient records and medical history are obtained before diagnosis. The nature of a medical problem is diagnosed before treatment is started.

A specific diagnosis does not necessarily lead to a specific plan of care. Plans of care are probabilistic in that some plans of care are more probable than others. Patient diagnosis and patient history can lead to different plans of care. An older patient may not be able to tolerate an aggressive plan of treatment that might be prescribed for a younger patient. A young patient may not be able to tolerate aggressive treatment because of allergic reactions to specific medications. Before diagnosis preparation for care can only be probabilistic.

The interaction of stochastic cure times, dependent events and probabilistic care plans create a highly volatile and unpredictable environment. Demand in this environment is hard to manage, bottlenecks occurred frequently and consequently scheduling is difficult. Lack of standard processing time adds to the complication of the problem. TOC is unique in that it recognizes these problems and offers solutions. DBR, for example, avoids the problem of standards by scheduling only the constraint, which immensely reduces the amount of the data needed (Guide and Ghiselli, 1995).

Guide and Ghiselli (1995) describe an example of this environment. They describe the application of TOC at the Alameda Naval Aviation Depot (NAD) engine division. NAD remanufactures a variety of military assets from entire aircraft to avionics. Engines that come to the depot may require anything from routine maintenance to complete remanufacturing. Little, some or all of the maintenance requirements for any given engine may be known before the engine arrives. The demand for engine components is likewise highly variable and uncertain. Demand for engine assembly varies from less than five to as many as nine engines per week. In-house developed production and inventory control methods similar to Material Requirements Planning (MRP) systems were used before the application of TOC.

NAD applied several features of TOC. Goldratt's five focusing steps were used to identify bottlenecks in flow of materials through the facility. A modified version of Drum-Buffer-Rope (DBR) was used to schedule production. A buffer was established prior to the bottleneck to ensure the constrained resource was not idle. Buffer management was used to control the release of raw materials. Local performance measures were replaced with global performance measures. This was achieved by developing the causal relationship between individual actions and the common goal.

Significant improvement in the performance of Alameda NAD are attributed to TOC. After one year of implementation turn around time was reduced by 40 percent and WIP was reduced by 50 percent.

Mass service

Schmenner describes the service organizations in this quadrant as having relatively high labor intensity and low degree of customer interaction and customization. Examples are Retail and wholesale industries. Service organizations in this quadrant tend to have limited service mix and compete in price and offering of choices. The service process is rigid and it has limited ties to equipment. The common challenges facing services in this quadrant are scheduling of workforce, managing fairly rigid hierarchy with standard operating procedure, managing growth and developing methods and control.

Applying TOC principles to the above challenges can prove to be successful. To illustrate the application, we will refer to a case of a doughnut shop (Adelman, 1991). The case is about a retail shop (a typical mass service) that has to compete in price and quality while facing problems of workforce scheduling, capacity and on time delivery. According to TOC measurement system, production labor is part of operating expenses. So, moving wages from the cost of sales to the operating expenses allows the company to recognize its true marginal cost, which leads to competitive pricing. This in turn could help the company in acquiring more contracts using competitive bids that reflect actual costs rather than inflated accounting cost. The challenge of properly scheduling workforce, so that capacity and production may be increased without adding operating expenses or compromising quality can be met by applying the five-step process and drum-buffer-rope techniques. Identifying the system constraint, which is typically a physical one in mass services, is the first step. The constraint was identified when it was noticed that another process had excess capacity, and components to be processed by the constraint process were continuously in a queue. If these components had a shelf life, quality would also suffer. To exploit the constraint, the length of the buffer had to be determined and the arrival rate of components match the service rate. This required tying the rope to the constraint process. To subordinate everything to the constraint process, all duties performed by other processes had to be changed (workforce rescheduling). To elevate the constraint, it might require adding an extra capacity.

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Professional service

The "Professional Service" quadrant includes doctors, lawyers, accountants, and other organizations where the basis of the service is the professional skills of one or a very few individuals. High degree of interaction and customization and high degree of labor intensity characterizes the organizations in this quadrant. A major problem in this quadrant is that the professional may have to spend time dealing with low skill activities as well as high skill activities. There are usually a limited number of other individuals available for delegation of low skill activities. It is more difficult to optimally match the level of skills required with the level of skills available. As in the service shop, professional service has the additional complications of stochastic service time, dependent events, and probabilistic activities.

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If an internal resource constraint exists it is the professional, i.e. the doctor, lawyer or accountant. Therefore Goldratt's five focusing steps are reduced to exploiting the constraint, subordination of other activities to activities of the constraint, elevating the constraint, and repeating the process. Exploiting the constraint might involve, for example, using a receptionist to gather paperwork and direct the patient to an examination room, using a nurse to check vital signs and record patient symptoms. When the doctor is ready to see the patient the activities of the nurse are subordinated and resumed after the doctor is finished. Several doctors sharing a practice elevate the constraint.

DBR and buffer management are indeed good tools to be used in this quadrant. The usual method for scheduling is to schedule patients at equal time intervals without regard to the actual time that might be required. To keep the doctor working a buffer of patients is built up in the waiting room. If too many people are waiting patients might be contacted to delay their arrival.

Green and Larrow (1994) explain the uniqueness of TOC solution as applied to an accounting firm. The bottleneck was the tax department, and the traditional solutions include increasing working hours and/or number of staff. Applying TOC and looking at "the steps before the bottleneck occurs", it was found that some data needed for the tax preparation are missed. By identifying information needs before tax return preparation begins and communicating these needs to accounting staff, the bottleneck was elevated.

This is the quadrant that has the least likelihood of application of TOC. The service organizations tend to have few people. The service is usually based on the professional skills of one or two people such as a doctor or dentist. However, doctors and lawyers are joining forces to form clinics and legal firms. This creates new logistical problems that did not exist in single person operations.

Conclusions

The general principles of TOC can be applied to improve the performance of service organizations. It is important to identify the flow of "material", inventory and throughput at various service organizations of the four quadrants of the service matrix. The definition of these terms might be dependent on the service. Since system constraint is at the heart of TOC, the recognition of the nature of organization constraint is the first step towards continuous improvement (See Table I). Constraints are sometimes found to be policies and procedures rather than capacity or equipment. Although the drum-buffer-rope methodology was originated as a control technique for the shopfloor, it could be transferred to service organizations and used to exploit the system constraint and subordinate the resources to it. Table I summarizes the application of TOC to the four service types in the service matrix. Table II summarizes the TOC unique solutions to various service organizations.

Although the examples used in the paper are from US companies, the author believes that the characteristics of the service organizations are universal. So, the TOC applications could be utilized universally.

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Table I Applying TOC to the four types of service organizations

Service type	Constraints	Inventory	Throughput
Service factory	Scheduling – balancing capacity and demand	The "unused" services, e.g. unsold seats in airlines	The income generated from selling the "service", e.g. tickets, rental,...etc
Service shop	Handling the customization of the service and the stochastic processing time	The turnover rate, e.g. tables in restaurant or space in repairing shop	The income generated from offering the "right" service to customers
Mass service	Controlling the policies and processes	The "delay" in delivering services, e.g. insurance policy not issued on time	The income generated from "timely" deliverance of the service
Professional service	Matching "workforce" and demand	The initialized human resource capacity, e.g. doctors need to keep their schedule full	The income generated from "adequate" utilization of the "workforce"

Table II TOC solutions

Service type	Issues and problems	TOC solutions
Service factory	Capacity decisions Demand management On-time service delivery Hierarchical structure Policy constraints	TOC develops the causal relationship between the individual process and the global goal, thus, greatly improving on-time service delivery and increasing throughput DBR controls the release of items
Service shop	High mix and variety of services High degree of customization Lack of standard processing time Hard to schedule	DBR avoids the problem of lack of standard by scheduling only the constraints, thus, greatly reducing the amount of data needed Buffer management ensures the bottleneck is not idle. This is done by "setting the rope" to control the arrival of "items" at the constraint
Mass service	Workforce scheduling Growth managing	Applying the five-step process to properly schedule workforce and manage capacity Applying TOC measurement system, e.g., moving the labor wages from the cost of sales to the operating expenses. This allows companies to recognize their true marginal cost, which leads to competitive pricing
Professional service	Scheduling Peak demand management Capacity management	Exploiting the constraint by using "triage" Buffer management to keep the "professional" busy Exploiting the constraint by shifting some responsibility to lower level skill

Future research

Although the number of published articles on the topic of TOC application to service organizations are limited, the author is confident that TOC is a common sense approach to the service operations.

For future research, the author suggests contacting Avraham Y. Goldratt Institution and obtaining a list of service organizations, which have experience with TOC techniques. A survey instrument could be devised to study the extent and the success of TOC applications in services. The survey may cover the following issues:

- The category of services (e.g. service factory, service shop, etc?) that are most likely to implement TOC techniques successfully.
- The need for a new set of vocabulary to be explored. This set of vocabulary may facilitate the TOC application to services in the future.
- The benefits expected from applying the TOC techniques to every service category.

- The synergy effect of applying TOC along with TQM or any other quality improvement technique.
- The various methods of initiating the change due to TOC applications.

The results of such study should be of tremendous importance to both researchers and managers. Managers should be able to use this knowledge to identify what prevents their firm from achieving their highest objectives and apply TOC principles to reach their goal. Managers need to have a new look at the problem and make "common sense a common practice".

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