Illuminate

The theory of constraints in practice – at Quality Engineering, Inc.

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Abstract

Applies theory of constraints principles in a five-step focusing process in a US engineering firm, OMM Engineering, to assist in improving the overall productivity of the survey department. Assesses the needs of the firm, and concludes that the use of a global positioning system would double the capacity of the survey and engineering departments and increase throughput. Shows that the five-step focusing process can be used successfully to eliminate bottlenecks within organizations.

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The framework of the theory of constraints (TOC) rests on the fact that an organization must always have constraints that limit the organization from achieving higher performance in terms of its goal. The TOC identifies the weakest links within the organization as constraints.

In this paper, the authors illustrate how they applied Eli Goldratt's five-step focusing process in an engineering firm, for improving the overall productivity of the survey department[1]. This paper is an extension of two papers written by the primary author which appeared in previous issues of *Managing Service Quality*. In the first paper, which appeared in Vol. 6 No. 1, 1996, the authors explained the basic principles of TOC and how they can be applied to service and not-for-profit organizations. In the second paper (which appeared in Vol. 6 No. 2, 1996) the authors showed how the TOC principles were applied in a health-care environment. In this paper, the authors illustrate a specific application of TOC in a service organization, specifically an engineering firm.

This paper comprises three sections. First, the steps involved in the focusing process are briefly explained. Then, a brief description of the company and the actual application of TOC are discussed. Finally, recommendations to the management of our case-study company, OMM Engineering, are suggested.

The focusing process

TOC utilizes a five-step focusing process to obtain ongoing improvement in a system's performance towards its goals:

(1) *Identify the system's constraint(s)*. A constraint may be a physical resource such as time in a particular work centre or raw material. It might be money. It might also be a policy or regulation or the market. Most constraints in system performance turn out to be policies. For example, a company could create a constraint by issuing an edict that limited production to one, eight-hour shift per day.

(2) *Decide how to exploit the system's constraint(s)*. Exploitation of a constraint requires that its output, relative to a system's goals, must be maximized. The general approach is to maximize the *return per constraint unit*. If the constraint is a policy, exploitation means that the

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policy must be changed or eliminated, so that better performance towards the system's goals can be achieved.

(3) *Subordinate everything else to that decision*. Subordination often deals with the process of scheduling. Typically, this means that the work must be started and sequenced in such a way that the constraint can always work.

(4) *Elevate the system's constraint(s)*. Elevating the constraint means identifying ways that will improve the performance of the system relative to its goals. If the constraint is a work centre, elevation might include additional preventive maintenance, or it might involve purchasing additional machines to increase capacity.

(5) *If a constraint has been broken in the previous step, go back to step 1*. If all internal constraints are broken, then the constraint may be in the marketplace. The five-step focusing process can be used to improve large systems as well as small subsystems and is just as applicable in the service sector as it is in manufacturing.

Case study

OMM Engineering is a civil engineering and surveying firm located in Grand Rapids, Michigan, USA. The company has been in business since 1982 and currently employs 27 people.

OMM employees comprise five professional engineers; three graduate engineers; one interning engineer; two drafters; one planner; one professional surveyor; three field surveyors; four inspectors; six support and administrative staff and one wastewater treatment plant operator. OMM also utilizes the services of an accountant and an attorney outside of the firm.

OMM is led by four directors, including the co-founders. The firm is divided into eight departments: administrative; drafting; construction; surveying; planning; client management; engineering and operations and maintenance.

OMM's clients consist of municipalities and private developers. OMM's services include design of highways, water systems and sanitary sewer systems. They provide construction administration services including survey staking and inspection.

Since last year, OMM Engineering has been struggling to meet contract deadlines. The management of the company was very concerned with the inefficiencies within their organization. They hired the authors of this paper to assist them in identifying and solving the problems within the organization. On extensive discussions with the management, it was mutually agreed that applying the TOC philosophy may be the best solution. The application mentioned below is just one example of how we applied the TOC principles at OMM Engineering.

In applying TOC to OMM Engineering, the first step was to identify the constraint. After several discussions with management, we identified the major constraint at OMM Engineering to be in the survey department.

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The survey department consisted of one professional surveyor and three field surveyors. The three field surveyors (usually working as a team) typically took a day to complete a field survey job. The information gathered by the surveyors was then downloaded into the computers at OMM's offices for use by the engineers in preparing drawings. Sometimes this information was downloaded at the end of the day and at other times it was done the next morning, depending on when the field surveyors returned to the office. The field surveyors usually waited for instructions from the professional surveyor before leaving for their job in the morning, although sometimes they received their instructions the night before.

The activity driver for measuring performance in the survey department was the number of shots (pictures) taken. It is estimated that the field surveyors can take 700-800 shots during an eight-hour day. There are three categories of jobs usually performed by these surveyors: a dense job, where the shots are taken close together, incurring more shots per job, involving a longer job time; a wide open job, where the shots are far apart and a lot of walking is involved; however, fewer shots are needed, incurring a shorter job time;

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and the medium job, lying in between the other two.

On extensive discussion with the management and all related personnel it was agreed that the major constraint facing the company was that the engineers were always waiting for results from the survey department. The engineers were unable to perform a significant portion of their job until the surveyors had performed their jobs. The survey was the first step in preparing a set of plans, the end product. Therefore, jobs stacked up as the survey crew became backlogged, thus resulting in delays in performing the jobs.

The second step in TOC was to exploit the constraint (or get more out of the system). In order to put more working hours in the day, we felt that the professional surveyor needed to establish a system of giving instructional orders the night before, so that the field survey crew could be ready to leave for a job site early in the morning. By leaving early, the field surveyors could return to the office earlier, thus allowing sufficient time to download the day's information into the computers by the end of the day, rather than the next morning – allowing engineers to get the information a day earlier. It was felt that if the survey crew completed their job early enough, they would also be able to complete another smaller job before the end of the day. Another option discussed was to make the field surveyors work overtime, but this was decided against. It was felt that this option provided a very limited solution, as the crews could only work a certain number of hours per day.

> **'…the management agreed that those engineers who were waiting for information from the surveyors before starting a job could be doing other activities before they received the survey…'**

The third step in TOC was to subordinate the rest of the system to the constraint. One way of doing this would be to cross-train some of the junior engineers to do surveying. Grand Rapids Community College, a local college, offered a surveying class that would be an inexpensive way to give engineers survey training. It was felt that when the engineers were not busy they could assist in surveying. Also, the management agreed that those engineers who were waiting for information from the surveyors before starting a job could be doing other activities before they received the survey. For example, management indicated that meetings with clients, utilities and regulatory agencies (to obtain job requirements), cost estimates and research could all be done before the engineers received the survey. It was suggested that the management devise a checklist of these pre-survey activities and have the engineers check-off each activity that pertains to their job that they can do while waiting for surveys. Utilizing their time in this manner would decrease the amount of time it took for the overall job to be completed. The management agreed with these recommendations and the checklist was immediately introduced.

The fourth step in TOC was to elevate the constraint. Several options were presented to the management. The obvious solution was to hire more surveyors. However, OMM had been advertising for surveyors in the newspaper for the past two years with not much success. A possible alternative to advertising in the newspaper for surveyors would be to recruit directly from colleges and universities. Michigan Technological University and Ferris State University, two regional universities, offered a four-year surveying programme. OMM could also obtain a list of surveyors who had taken the surveyor's professional licensing exam from the State of Michigan. They could then contact these people directly and recruit them for a position. OMM could also advertise for surveyors in the magazine of the Michigan Society of Registered Land Surveyors, *Point of Beginning*.

Another way to elevate the constraint was to outsource or use outside surveyors. As this results in a loss of revenue to OMM (for surveying services), it was felt that this alternative should probably be reserved for jobs that were extremely backlogged or very critical.

However, the best solution appeared to be to take advantage of new technology. A global positioning system (GPS) is a new technology that reduces the number of people and time needed to do a survey. A GPS uses satellite signals to locate where the unit is on earth. It then programs the co-ordinates and elevation into a hand-held computer. This reduces timely set-ups of a traditional survey crew which requires at least two people to record measurements.

With the use of a GPS, we felt that OMM management could increase the capacity of the survey department substantially. The cost of buying a GPS was estimated to be $90,000. A GPS could be rented at the cost of $600 per day. It was decided to explore both options in detail to determine which would produce the greatest profit.

First, based on discussions with management and surveyors, it was agreed that a five-day survey job could be done in three days with a GPS. The cost of a three-man crew was $70 per hour and the revenue was $90 per hour.

Three-man crew

Job time: five days

Job cost: 5 × 8 × 70 = $2,800 per week

Job revenue: 5 × 8 × 90 = $3,600 per week

Monthly profit: 4 × (3,600 – 2,800) = $3,200 (Assuming four jobs per month)

GPS crew

For this the job time was three days and the job cost was as outlined in Table I.

To obtain the same revenues as the three-man crew, the GPS would need to be billed at $150 per hour: $150 × 8 × 3 = $3,600.

The cost to the client would be the same whether using a three-man crew or a GPS; one has a lower billing rate but more hours, the other a higher billing rate at fewer hours.

Now the decision would be whether to rent the GPS or buy it. We know it costs $600 per day to rent it. In estimating the cost of owning, we computed the following: $90,000 loan at 10 per cent amortized over five years. The monthly payment would be $1,912. The total cost would be $90,000 in principal and $24,734 in interest, for a total cost of $114,734. The cost of renting a GPS is $12,000 per month or $156,000 per year (assuming it was used daily). Taking the increase in profit by using a GPS as calculated above, the cost of the system would be recouped in two years assuming no reduction in job time. This is calculated as follows:

5 days: 8,100 – 3,200 = $4,900 increased profit

4,900 × 24 months = $117,600

3 days: 15,930-3,200 = $12,730 increased profit

$12,730 × 9.25 months = $117,752.

We also did an owning versus leasing analysis using net present value (NPV) to determine the present value of future cash flows of either option. Assuming that the survey department only rented a GPS for 50 per cent of the year, the net present value of future cash flows for renting a GPS was (minus) $228,261. The net present value of future cash flows for owning a GPS assuming a $90,000 loan at the above-mentioned terms was $59,805. Therefore, even if a GPS were only used 50 per cent of the time, it would still be financially advantageous to buy rather than rent.

The increase in profits calculated above was just for the survey department. This does not include the increase in billable hours by the engineers. Additionally, a GPS could reduce the number of times a survey crew needed to go out to the job. An engineer could use the system at the job site if he/she needed more information rather than sending the survey crew out again.

Therefore, in addition to bringing in additional revenue, a GPS would also increase throughput, or the number of jobs going through the system. The engineers would not have to wait to begin their drawings.

'…Doubling the capacity of the survey department would increase throughput (revenue generated from engineering services) and lower inventory (jobs waiting to be performed)…'

Doubling the capacity of the survey department would increase throughput (revenue generated from engineering services) and lower inventory (jobs waiting to be performed). The result would be an increase in revenue and clients who are satisfied with no schedule plans. A measurement that OMM Engineering would now need to use to

Table I

	Rent	Own
GPS cost	$600	$95[a]
Surveyor 10 × 2.75 × 8	$220	$220
	$820 per day	$315 per day
	$820 × 3 = $2,460	$315 × 3 = $945

Note: [a]loan of $90,000 at 10 per cent amortized for five years; $1,912 per month/20 days

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measure the effectiveness of a GPS would be throughput/number of shots. In this way, OMM could determine if adding capacity to its survey department would result in increased revenue. An advantage of a GPS over new survey personnel was that a GPS will not leave OMM for another job. The downside of a GPS is that it could become obsolete in a short time as new technology emerges.

The last step in TOC was to go back to step one and identify any new constraints. It is important for OMM to continue to monitor any new constraints that may occur in other departments, so that they can be managed as well. It is also important to note that a constraint can be physical or a policy. Goldratt[1] states that 99 per cent of constraints are policies or lack of them.

Recommendations

In this particular case, our recommendation would be for OMM Engineering to rent a GPS initially and determine if it did reduce job time. If it did, OMM would achieve a profit by either renting or buying a GPS and thereby elevating the capacity of the survey department. However, buying would result in a bigger profit. OMM should determine the amount of use they would get out of a GPS when determining whether to rent or buy. If it does not reduce job time, renting may be impractical because their survey fee would have to be raised substantially. Buying would still render a profit, however. In any event, a GPS would at least double the capacity of the survey department and increase throughput. Using a GPS is consistent with OMM's mission statement of providing services which are timely, economical and of the highest professional and technical quality. A GPS would also increase the capacity of the engineering department which presently has excess capacity. Increasing the capacity of the engineering department will produce overtime for the engineers which is where OMM makes its greatest profit. However, it is important to note that any increase in throughput is advantageous to the firm.

In this paper, we have shown how the five-step focusing process can be used to eliminate and elevate a constraint/bottleneck within an organization. We feel that the approach used in this paper can be used by other service organizations that wish to eliminate bottlenecks within their organizations.

Reference

1 Goldratt, E.M., *What Is This Thing Called the Theory of Constraints and how Should it be Implemented?*, North River Press, Croton-on-Hudson, New York, NY, 1990.