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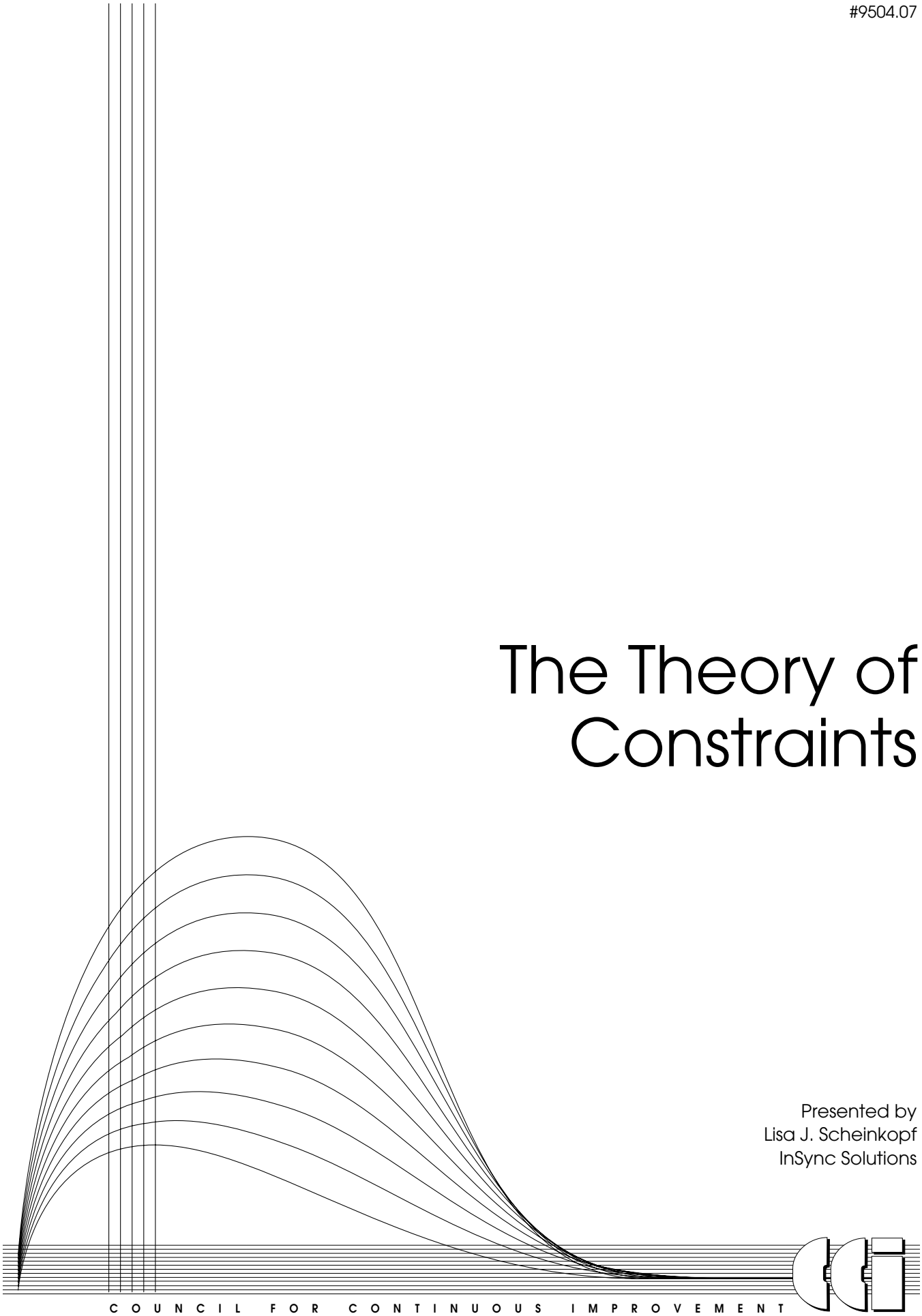
The Theory of Constraints



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COUNCIL FOR CONTINUOUS IMPROVEMENT

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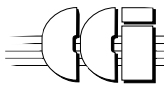
Executive Summary

The theory of constraints (TOC), also known as synchronous manufacturing, is a management approach that focuses on the constraints in an organization in order to leverage improvement. Lisa J. Scheinkopf, president of InSync Solutions, explains the notion of system constraints. She demonstrates a concise five-step method for identifying constraints and using this awareness to optimize and improve performance. TOC not only enhances productivity for competitive advantage, it helps guide investment strategies for future profitability.



The Theory of Constraints

At the April 1995 General Session of the Council for Continuous Improvement (CCI), **Lisa J. Scheinkopf**, president of **InSync Solutions**, introduced the theory of constraints (TOC) in breakout meeting attended by interested CCI members. "The *theory of constraints* is also called *synchronous manufacturing*," Ms. Scheinkopf noted. "It is not the opposite of cost accounting, although it has been claimed to be. I have had the opportunity to teach this five-step process and see it applied in scores of companies."

This theory is built on the assumption that every organization has a *purpose*. Ms. Scheinkopf called this a "goal," after the popular business text by **Eliyahu Goldratt**. Other companies call it a "mission." As examples of broadly applicable goals, she quoted **Stephen Covey** as well as Dr. Goldratt [*see citations in Ms. Scheinkopf's handouts, which are reproduced as attachment 9504.07a*]. Dr. Goldratt's assertion that the *goal* of for-profit organizations is *to make more money now and in the future* has been controversial, because it has been interpreted to endorse making money at the expense of other people's welfare. In recent writings, however, he has acknowledged the importance of both employee and customer satisfaction in the money-making equation.

Ms. Scheinkopf suggested that the organization's purpose is achieved by people interacting with technology as interdependent resources performing dependent activities. This process occurs whether the product is computers, mail delivery, or care of sick people. The organization could be described as a chain (or a network of chains in a complex organization). But a chain is only as strong as the weakest link.

"The same holds true for an organization," Ms. Scheinkopf said. "Thus, the key to improvements in any organization lies in what it is doing — or not doing — with its weakest link." Improvement requires measuring the organization's performance against its goals with regard to customer, employee and stockholder satisfaction. Without addressing all three of those areas, the results may not be commensurate with the effort expended.

Ms. Scheinkopf identified three types of constraints: physical, policy, and paradigm constraints. Physical constraints include materials, capacity (which includes time, space, or capability), and the market. Policy constraints might be rules, training, and measurements. These, in turn, are driven by paradigm constraints — mental models and assumptions that help formulate the policies.

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The P&Q Company

To help breakout attendees examine the impact of all three of these constraints, Ms. Scheinkopf used a game called *The P&Q Company*, which was developed at the **Goldratt Institute**. "It provides an opportunity to scrutinize our existing paradigms," she explained, "to find the assumptions our company is making and to do something with them."

The premise of the game is that participants play the part of consultants called in to help make improvements at the P&Q Company, which manufactures widgets. "The company only sells 2 products: Ps and Qs. A forecast from the sales group tells us not how much we will sell, but the real opportunity we have in the marketplace. In any given week we have the ability to sell 100 Ps and 50 Qs. There is only one selling price for Ps and Qs, and there are no deals: every P sells for $90 and every Q for $100. For every P we pay our vendors $45 for materials, for the Qs we pay $40. Fifty-five minutes of direct labor goes into every P, 50 minutes for every Q. Operating expenses are $6,000 a week. This does not include materials, and $2,400 of the $6,000 is for direct labor; we pay them all the same amount of money. "

Ms. Scheinkopf presented the process flow for each product [*see chart in attachment 07a*]. "Here is a picture of interdependent resources performing dependent activities. We have four different manufacturing resources (A,B,C and D, representing different workstations, people, etc.) who are not cross-trained with each other. Each of those four resources works five days a week (there is only one shift, working eight hours a day Monday through Friday), which translates into 2400 minutes a week for each resource."

The manufacturing process for a P requires raw materials W, X, and Y, with a total cost of $45. Both X and Y go through some processing (at stations A, B, or C) before being assembled with W in the assembly department (D). The process flow chart indicates the amount of time per unit required at each step.

Product Q is also an assembly of materials Y and Z. Y has to go through station B for 15 minutes and station C for 5 minutes. Z needs to go through station A for 10 minutes, then station B for 15 minutes. Then both components are assembled by D in order to make a Q. "Notice that material Y is a common part to both P and Q," Ms. Scheinkopf pointed out.

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Beginning to Focus

"We want to improve for customers, employees and shareholders. What else do you need to know in order to make improvements to the company? What are we going to do with all this data now that we have it spread it out on our desk?" Ms. Scheinkopf asked. "Try making all Ps or all Qs and see which one makes you more money. How much money can this company make versus how much it is making now? I think we have got enough data to calculate that, which may give us a focal point for making improvements."

With market demand for Ps at 100 per week, a sale price of $90, minus material costs of $45, could yield a total of $4500 for Ps. Qs have a demand of fifty, so at $100 each, minus materials of $40, Qs could bring in $3000 a week. Together that would make sales of $7500 a week. Subtracting the $6000 in operating expenses leaves a profit of $1500 a week.

"What assumptions are we making?" Ms. Scheinkopf asked. "Infinite capacity — at any given point in time, there is not infinite capacity. Maybe we should take that into account in our planning scenarios. Another assumption is that all resources are equal."

To address capacity, she looked at the four resources. "Each of those gives us 2400 minutes in the week. This means we have a total of 9600 man minutes available every week. If we calculate the number of minutes it takes to make a P and a Q, multiply it by the quantity that we have the opportunity to sell, we only need 8000 minutes in the week. We should have enough capacity. This is how layoffs are done. We can do away with 10% of capacity."

Realizing that not all resources are equal leads to the five focusing steps in the theory of constraints. First, *identify the system's constraints*. "Look at the company as if it were a chain," Ms. Scheinkopf suggested. "Identify the weakest link. What is the link that will inhibit us from making the most money? Why can't we satisfy the entire demand? What is there not enough of? Where is inventory piling up?" She advised examining the data, using intuition and experience to validate conclusions.

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Ms. Scheinkopf demonstrated how to identify an internal capacity constraint [*see "Step #1" in attachment 07a*]. "Simulate what the load on the resources would be if you were able to take all of the market demand and turn it into orders. If we were to make all the Ps and all the Qs, the demand on resource A would be 2000 minutes. 2000 out of 2400 minutes is 84% of capacity. To make all the Ps and Qs, the load on resource B would be 3000 minutes, which is 125% of capacity — this is obviously a capacity constraint. Similar computations show resource C is at 73% of capacity and D is at 52%. It is pretty clear that there is a physical internal capacity constraint in this company: resource B."

Exploiting Constraints

Rather than arbitrarily choosing solutions (like cross-training resource D to help resource B), a more complete understanding of current capability is required in order to get the most out of the system. The second of the five focusing steps examines how to *exploit the system's constraints*. This includes looking for the most profitable product mix, as well as looking at scheduling decisions and working rules.

"We want to make sure we set B to work at 100% of capacity on the most profitable product. How do we determine which is most profitable of our product? Each P brings in $45 and each Q brings in $60. If we were to stop our decision making process at this point (which some companies do), based on the product which gives us the highest gross, we would look at Qs. But we cannot do that because we know it takes effort to produce them. Taking a look at direct labor, we have 55 minutes in every P and 50 minutes in each Q. Without getting into product cost calculations, we know that Qs give us the higher contribution to begin with and consume less direct labor than Ps, so everyone would agree to focus on Qs. A conventional approach to product cost prioritizing suggests producing as many Qs as possible and filling up the rest with Ps.

"What would profits be using that approach? Q is our highest contributor, giving us $60 a piece. It takes 30 minutes of B's time to produce a Q. With 1500 minutes going into Q production we yield $3000. We want to fill in the additional 900 minutes with Ps, giving us 60 of them. Those 60 yield $2700. That gives us $5700 during the week — minus $6000 in expenses, that is a *net loss* of $300. What assumption is this system ignoring? These calculations ignore the fact that all resources are not equal. In the decision making process itself, we are not recognizing the underlying constraints.

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"Go back and try to exploit the constraint. We want B to squeeze the most dollars out of the system that it can. We know that B is a limited resource. We want to look at how much each product is contributing relative to the time they are demanding on the constraint, because the capacity of the constraint is the capacity of the company. If product P consumes 15 minutes of resource B's time and contributes $45, we can say the company is making $3 per minute producing Ps. Qs consume 30 minutes of B's time for $60, or $2 per minute. *Priorities change*. There is a difference between constraints and non-constraints in the impact on our companies."

Based on this analysis, the company can use 1500 minutes of B's time in order to produce all 100 Ps which would bring in $4500. With the remaining 900 minutes, resource B can produce 30 Qs worth $1800. The total product value is then $6300, which would yield a $300 profit for the week instead of a loss.

"We are not making physiical changes yet," Ms. Scheinkopf noted, "just understanding how to maximize the capabilities we already have. We look at scheduling and work policies to synchronize things already inside our organization."

Aligning to the Constraint

The third step in the focusing process, Ms. Scheinkopf suggested, is to *subordinate everything else* to the decisions made in steps one and two. This means synchronizing the outputs of all the other links in the chain to that of the constraint. "If B is the constraint, let's make sure that A is feeding it. Once B is done, make sure we are not inhibiting the assembly operation or distribution. We are going to load B to 100% of its available time every week."

Ms. Scheinkopf examined the impact of this strategic decision on resource A. "We want A to feed B for all that it is worth. However, we do not want to load A with any more than the 30 Qs it needs to work on, because we do not want excess inventory. Nor do we do want A giving B less than B needs." She presented a chart showing the raw materials and time required to meet the chosen sales forecast [*see attachment 07a*]. Based on these requirements, resource A would consume 1800 out of 2400 minutes every week in order to support the decision about the constraint.

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The dilemma this situation raises is that resource A is only being utilized at 75% of its available capacity. If the company's reward system penalizes this seemingly low rate of productivity, the supervisor of that department will be motivated to increase production, paradoxically suboptimizing the larger system. "What are the rules that govern this? What is the work ethic?" Ms. Scheinkopf asked. "We must redefine productivity. Maybe what is healthy for the company is to let people use the other 25% of their time to find their dream or hobby and grow into whole people. A given is that in most companies, this scenario will not give people a raise."

The ability to exploit the constraint in this example does mean that all the products produced must be sold, Ms. Scheinkopf noted. "How are commissions set for your sales people? In most companies it is by sales volume. If it is just as easy for the sales person to sell a P as it is a Q, I am going to sell all the Qs I can first, because that hits me directly in the pocketbook. That's another measure that needs to be changed. Once you have identified the constraint and figured out how to exploit it, make sure everything else in the organization is aligned to that. Some change in mindset is all that it takes."

Elevating the Constraints

The fourth focusing step seeks to make the weak link stronger by *elevating the system's constraints*. "This is the point that will usually involve some kind of investment, such as buying another B machine; paying for overtime; improving processes; cross-training; or increasing sales. In our example, we could say there is another constraint in this company: the sales/market potential for P."

Ms. Scheinkopf offered an example of a subtle but substantial improvement. "Step 4 alters the physical system itself. We have an engineer on our staff who wants to spend $5000 on tooling and fixtures that will allow part Y (which currently travels through this process in 20 minutes) to be produced in 21 minutes. What do you think? She would get fired! Now let's take a look at her reasoning: the process time at resource C increases from five to seven minutes in order to reduce the amount of time B spends on each part from 15 to 14 minutes. This adds a minute in direct labor and costs $5000 to do so! The real impact of that decision, however, can be seen in terms of constraints versus non-constraints. Currently we are satisfying the market with 100 Ps and 30 QS. If we take up the engineer's offer, it gives us an extra 30 minutes of capacity for resource B, allowing us to produce 4 more Qs and adding another $240 to the bottom line — 80% more profit every week!"

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Such improvements could not be justified in a company that is not thinking in terms of constraints and non-constraints, Ms. Scheinkopf pointed out. Typically the engineer would be asked to go back and find a way to reduce C's process from five to four (without the concurrent savings for constrained resource B). The engineer would then be rewarded, and the $5000 would spent on "improvements" that deliver no real benefit to the system.

Avoiding Inertia

The final focusing step seeks to *prevent inertia from becoming a system constraint*. "We need to go back to step one," Ms. Scheinkopf said, "because rules based on one constraint will not work on another. P is the star and Q is the dog in this system only because B is the constraint. If the constraint were another resource, it would be a different story. We based our policies on the fact that B is the constraint, and we elevated B, so now it has moved."

Ms. Scheinkopf recommended that management proactively take responsibility for managing constraints. Elevating the constraint should be a strategic decision at the highest levels: "Decide where the constraint should be. If it should still be B, then when you buy another machine, you need to buy enough of the rest of the resources to insure that B is still the constraint." If management decides to change the constraint, they must be sure that the market will support the new product configuration and that the rest of the organization is synchronized with that decision.

"Many companies have gotten short-term benefit to the bottom line by doing what I call 'Herbie Hunting': identify the constraint, exploit it, elevate it...identify the constraint, exploit it, elevate it. We just go around like kids in an arcade, slapping down the weasel heads as soon as they pop up so that another one pops up. That can get very tiring. We can do continual improvement and still have some sense of stability, if we take responsibility and make decisions proactively. It is difficult to do, but worth it in the long run."

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The Five Focusing Steps

Ms. Scheinkopf quickly reviewed the five focusing steps:

1. Identify the system's constraint(s). Look internally to find the weakest link. If it is not internal, it is in the market or materials. For most companies, the constraint is in the market — that is why they have excess capacity. They can decide what they want the constraint to be, so they can start focusing on which market segments to go after, how that will impact the internal workings of the company, etc.
2. Decide how to exploit the constraint(s). One decision is product mix. Another is scheduling.
3. Subordinate everything else to the exploitation of the constraint(s). If it is internal capability, make sure that constraint is being supplied. If it is market share, make sure the customer is being well served.
4. Elevate the system's constraints: get more of what you do not have enough of, but do it carefully. Often that means growing the company, and with that comes responsibility.
5. Do not let inertia become the system's constraint. Examine the *assumptions* that go into every decision and measure them against *reality*.

"The better the solution," Ms. Scheinkopf observed, "the faster it obsoletes itself, so we need to look back at the assumptions that went into the decisions and policies in the first place."

Scheduling

Ms. Scheinkopf discussed how the steps of identifying, exploiting, and elevating applied to the scheduling mode. Using the P&Q company example, with resource B as the constraint, the schedule for B should be determined first, and all other schedules should conform to that.

"Subordination comes into play," Ms. Scheinkopf said. "I always want to keep B working on the right stuff at the right time. I am going to take a look at the statistical fluctuations we are dealing with in reality in our manufacturing company on a daily, weekly or monthly basis. Understanding that reality gives me an idea of how long I can reasonably expect it to take, from the time I release materials in the plant until they get to resource B to process. I am going to add a huge "Murphy factor" to that. In order to support the constraints, releasing materials to the plant should not necessarily be done just-in-time. If enough fluctuations happen — if Murphy hits us enough — B is going to go down, and we will lose time on B and

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sales for the week. We always want a little pile of material sitting in front of B to work with. That little pile needs to be in the right sequence and on time — a buffer of material, several hours worth, or however much gives me a comfort level. Subordination says I want to release material into the shop a certain amount of time before the constraint needs it and at the rate that the constraint consumes the material."

Ms. Scheinkopf observed that this implies that a formal schedule is usually only necessary for the constraint — almost everyone else can work on a first come, first served basis. If material is being properly released into the system, it becomes a very simple process from the scheduling perspective. By contrast, a normal scheduling procedure starts by loading the first resources in the process, rather than the constraint, and it pushes the work up to its finite capacity and material piles up in bottlenecks.

"We have determined how much time's worth of inventory we want to see in the system before the constraint. Most of this time's worth of inventory is waiting around. The reason we have so much more inventory than the specific amount of actual processing time is because of statistical fluctuations that happen in the system. The companies that are doing buffer management have replaced their expediters with people monitoring what is happening in this buffer. Realistically, we will never do away with statistical fluctuations. As long as we have statistical fluctuations and dependencies, negative accumulation is going to happen. I am going to have a constraint somewhere."

Kanban (a Japanese inventory management technique) and TOC are two different approaches to the reality of statistical fluctuations and dependencies, Ms. Scheinkopf noted. "Both systems deal with statistical fluctuations and dependencies. In Japan, it's by having excess capacity throughout the line. When the line shuts down to address fluctuations, throughput is lost. Through TOC, I have found that the throughput of the system can be protected with a minimal amount of inventory — not by spreading inventory over all the resources, but by focusing it in the direction of the constrained one."

Ms. Scheinkopf warned her audience not to let inertia become a constraint. "If what you are doing works, it is going to obsolete itself over time. You have got to be on the look out for the point of diminishing returns. We must all go through our continual learning process."

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Questions for Ms. Scheinkopf

Question: How do you convince people that the theory of constraints is a better model for managing resources?

Ms. Scheinkopf: There was a study done by three renowned professors of accounting through IMA (Institute of Management Accountants), that might help convince doubters. Most folks are after the ultimate objectives of the company — as long as they do not get improved out of job. People want to make sure they have got the right systems in place. One of the biggest arguments that I used to hear about TOC was that it did away with cost-accounting, so what would it replace that with? Over the last year or two there have been a lot of papers and books addressing what to replace it with — how to measure with things like throughput, inventory and operating expense. What local performance measures are there? If you are not going to schedule everybody on the shop floor, how do we measure them? There is a lot of good writing and experience beginning to come out of companies.

Question: When you say cost-accounting, do you mean traditional cost-accounting or ABC/ABM?

Ms. Scheinkopf: I mean both. We recognize the allocation process and the assumptions upon which cost-accounting were based were incorrect. The activities of process mapping and understanding why we are doing things that surround the activity-based management movement are right on. But when we get into the calculations of activity-based costing and making decisions like these using activity-based costing, it still does not recognize the difference between constraints and non-constraints, and so we are making lots of incorrect decisions for our companies based on the assumption that any activity carries a cost.

Question: You talked about the company as a chain and locating the weakest link. Obviously there are two other end-points that control constraints on either end: the marketplace and the suppliers. Is there more or less leverage at those points? Are all three equally important in the theory of constraints?

Ms. Scheinkopf: The theory of constraints applies equally. Obviously there are different rules you need to pay attention to, depending on what the constraint happens to be. If your constraint is with suppliers and truly is a lack of materials, you want to control things like product yield — you do not want to throw stuff away in the process when your constraint is material.

There is a lot of new information about market segmentation and how we really look at our companies and markets. If I really buy into this logic, what happens to my approach to the marketplace, and how do I define what kind of markets we want to go after, depending on where we want to apply the leverage. I like to think that we are not necessarily at the whims of the market unless we put ourselves there. There are markets that fluctuate, but there is no reason to go after 100% market share in any mar-

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ket. You create a lot of opportunity for competitors to come up. Find different markets that oscillate at different points in time. There are seasons — put yourself in more than one market and make sure that the peaks are different so that you can have a stabilized company. The third thing is to look at your potential market in terms of the capabilities inherent in the organization. I think that addresses things like core competencies — do not define yourself so narrowly as the products that happens to come off the machines. Define yourself in terms of the real capabilities inherent in the organization and you can find lots of diverse marketplaces.

Recommended Reading

The Goal, by Eliyahu Goldratt

The Haystack Syndrome, by Eliyahu Goldratt

The Race, by Goldratt and Fox

Synchronous Manufacturing, by Shrikanth and Umble.

Reengineering Performance Measures, by J. Cox

attachment

9504.07a Ms. Scheinkopf's handout