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Theory of constraints - A status report

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Theory of constraints — a status report

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The Theory of Constraints (TOC) was first applied to production scheduling. For many people this application is the only one TOC brings to mind. Over the past several years TOC has been applied to other areas such as performance measures, supply chains, marketing, sales and managing people. In this paper I review how TOC has been applied to these areas.

1. Introduction

The Theory of Constraints (TOC) is an approach to continuous improvement of an enterprise, developed primarily by Eli Goldratt,‡ which asserts that constraints determine the performance of a system. Goldratt defines a *constraint* as 'Anything that limits the performance of a system relative to its goal'. Note that this definition differs from conventional usage of the word 'constraint'. In conventional usage, 'constraint' often means something that *might* limit a system (as in constraints given in a linear programming model), while in TOC a constraint is actively limiting a system's performance. Webster defines *System* as 'a set or arrangement of things so related or connected as to form a unity or organic whole' (Guralink 1984). In our case 'system' is taken to mean a business. The *goal* of a business is 'to make money in the present as well as in the future' (Goldratt and Fox 1986) and thus the *performance* of a business is measured by net profit and return on investment.

(A system might also be a not-for-profit enterprise such as a school. TOC has been applied to such systems, but these systems will not be discussed in this paper.)

A constraint is usually considered to be something negative, something to be eliminated if possible. What makes TOC different from traditional approaches to management is that TOC considers a constraint to be a focusing point around which a business can be organized or improved. Every business has at least one constraint; without a constraint a business would earn infinite profit. Since no business does earn infinite profit, each must have a constraint. A constraint might be lack of market, a policy imposed internally or externally, or a resource internal to the company. In this paper we will explore how constraints can be used as focal points in organizing a business.

Ten years ago, TOC had been applied only to production. Today it has been applied to a wide range of things including Operations, Finance and Measures,

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‡ Goldratt has written several books on the Theory of Constraints including *The Goal, It's Not Luck, The Theory of Constraints, The Haystack Syndrome,* and *Critical Chain*. Much of the material presented here is presented in a series of tapes totalling approximately 24 hours in length called the Holistic Approach Workshop. More information on the Theory of Constraints can be obtained from The Goldratt Institute at http://www.goldratt.com

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Projects, Distribution and Supply Chains, Marketing, Sales, Managing People, and Strategy and Tactics.† This paper briefly overviews how TOC is being applied in each of these areas.

2. Operations

The Operations function is the function of a business that transforms inputs into outputs in order to make money. In its simplest form operations can be viewed as a series of activities, as shown in figure 1.

The goal of the system of activities illustrated in figure 1 is to make money by producing commodities that the market will buy. To keep this example simple, suppose that the system produces only one type of item (I will call it a *widget*) and that the market will buy 8 widgets an hour. Also suppose that the output capability of the line is 10 widgets per hour. Then the constraint of this system is market demand. TOC says that the line should operate at the pace of the constraint, the market.

What would happen if the line produces 10 widgets per hour? Because the market will buy only 8 per hour, there will be a build up of 2 finished widgets per hour. Eventually, these excess widgets will have to be written off or sold at bargain-basement prices.

TOC has an application called *drum-buffer-rope*. In it, the constraint acts as a drum that beats out a pace for the system to follow. In this case, the drumbeat is 8 widgets per hour. The *buffer* is a set of material that insulates the constraint from the rest of the system. At a pace of 8 widgets per hour, one widget is completed every 7.5 minutes on average. But there is variability in this pace. One widget might be completed 5 minutes after the previous one while another might not be completed for 10 minutes. In any event, the consumer may not wish to wait for the widget to be completed, so sales are helped if a stock of completed widgets is kept on hand. This shipping buffer separates the market from production. The *rope* is a signalling mechanism that runs from the constraint to material release; in this example, the rope causes material to be input into the system each time a widget is sold. In this fashion the buffer is maintained at a constant level; no increase in finished widgets occurs. Drum-buffer-rope is illustrated in figure 2.

In the situation described in the above example, a manager should focus his or her effort on marketing and sales. Making the production line more efficient is wasted effort; the line already can produce more widgets than are being sold. Suppose that by adding a salesperson demand is increased to 12 widgets per hour, while the output of the line is held steady at 10 widgets per hour. Then the situation might be as shown in figure 3. Note that not every workstation produces 10 per hour. Such balance is not achievable when machines have different purposes and come in

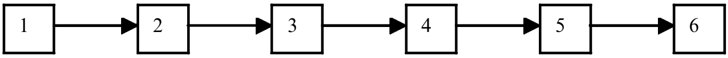

Figure 1. A system of activities.

† Each of these eight areas is the topic of a 3-hour tape in the Holistic Approach Workshop. Each will be a major section of this paper.

only discrete sizes. The output of a line is determined by the output of the slowest station, in this case station 4, which has an output of 10 items per hour.

In figure 3 the drum and buffer are moved to workstation 4. Now material is input into the system at the rate of 10 per hour (subordinating stations 1, 2 and 3 to the constraint). There is a rope that connects from the constraint drum to material release, pulling material into the system at the constraint's pace. A second rope connects the shipping buffer to the constraint and controls material after it clears the constraint to ensure material is shipped on time. Stations 5 and 6 can sustain the output of 10 per hour dictated by station 4. The constraint buffer is needed so that if there is a problem (breakdown, poor quality, absent worker) at stations 1, 2 or 3, station 4 is able to keep working as long as the buffer or material holds out. Note that stations 1, 2 and 3 need to have extra capacity, called *protective capacity* so that if a problem holds material up on its flow to the buffer, all stations have the capacity to work faster than the constraint in order to restore the protection at the constraint before another problem strikes one of the stations. In order to keep workstation 4 working 100% of the time, all other stations need to have this protective capacity in order to maintain the buffer. (Analogously, there needs to be a *space buffer* between stations 4 and 5 so that if station 5 or 6 has a problem, the constraint can keep working and has somewhere to place completed parts. Protective capacity at stations 5 and 6 allows this material to be worked off once the problem is solved.)

Running at the drum's pace seems to be an obvious conclusion from this simple example. However, most operations are more complex than this simple example. Many managers therefore manage in such a way as to maximize the efficiency of individual resources. Efficiency is defined as actual output over rated output. Rated output of station 1 is 15 units per hour. Since it is permitted to make only 10 units per hour, station 1 is operating at only 67% efficiency. Running the line to raise station 1's efficiency to 100% would result in the building of unneeded output at

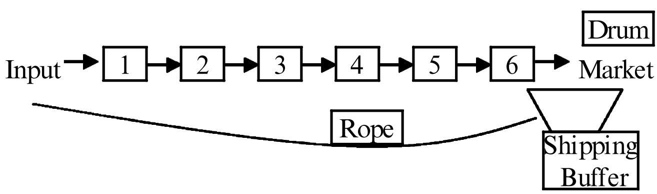

Figure 2. Drum-buffer-rope illustrated.

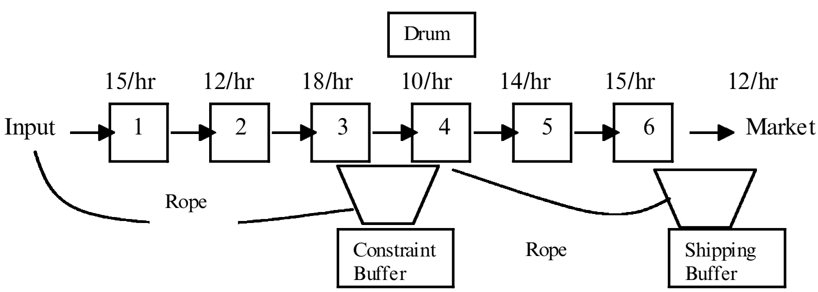

Figure 3. Drum-buffer-rope with an internal constraint.

slower stations. Of course, the cost per part is lowered if the station produces 15 per hour and the cost of the station is divided over 15 items rather than 10. But this measure is misleading if only 10 of the 15 are built into finished widgets. Thus, a business must be operated to make money rather than to save cost. This conflict between saving cost and making money is highlighted by Goldratt in the generic cloud of operations, shown in figure 4.

Figure 4 is an example of an *evaporating cloud*, one of the key tools of TOC. An evaporating cloud is a way of representing a conflict in order to improve understanding of the conflict and to break the conflict by breaking one of the assumptions that underlie the conflict. The objective of the cloud is to (a) be a good manager. In order to accomplish this objective there are two necessary conditions (requirements): (b) constantly fight to reduce waste and (c) constantly fight to increase flow. Both of these requirements must be achieved to achieve the objective. People act as they are measured (for example, students study only what they think will be on a test) so a prerequisite of reducing waste is (d) to use efficiencies as the prime measurement. However, keeping stations 1, 2 and 3 efficient in figure 3 means releasing 15 widgets per hour into the system, which will cause a build-up of work-in-process inventory, both at station 2 and station 4. To sustain flow properly, all other workstations must be subordinated to the constraint, i.e. run at the constraint's pace, so local efficiency must not be used at these stations, yielding (d′): do not use efficiencies as a measurement.

The purpose of building an evaporating cloud is to discover the assumptions that underlie the arrows between entities in order to find one that can be broken in order to break the cloud. The assumption that underlies arrow BD is 'A resource standing idle is a major waste'. Assumption BD is almost universal today. Figure 3 shows, however, that this is wrong. If a build-up of unneeded inventory is to be avoided, station 1 should produce only 10 units an hour instead of the 15 units an hour that is its capacity, meaning that it needs to be idle 1/3 of the time. Stations 2, 3, 5 and 6 similarly have some necessary idle time. Breaking assumption BD means that entity D needs to be replaced by a new entity, such as 'Non-constraint stations are measured versus the constraint's pace'. Figure 4 then becomes figure 5.

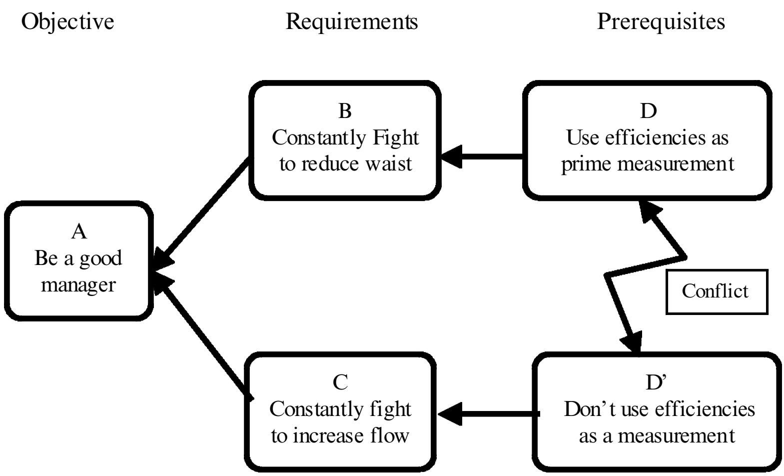

Figure 4. The generic conflict of operations managers.

Now the manager can focus on the constraint station, workstation 4. Perhaps the output of this station can be raised by maintaining the buffers in order to keep the station working all the time. Many companies have implemented drum-buffer-rope with remarkable results. For example, Kent Moore Cabinets of Bryan, Texas, USA, implemented drum-buffer-rope in 1989 and, within a year, improved from \$6 million sales to \$10 million sales while maintaining employment at 120 people.

TOC maintains continuous improvement by constantly cycling through the three questions.

What to Change?
To What to Change?
How to Change?

In each section of this paper I will address these three questions. In Operations, *What to Change* is the assumption that a resource standing idle is a major waste. *To What to Change* is to Drum-Buffer-Rope, focusing on the constraint to maximize throughput and sales. The difficulty in operations is *How to Change*. Overcoming the assumption that a resource standing idle is a major waste requires a paradigm shift throughout the organization. One way to accomplish this is to have everyone read *The Goal*, a best-selling business novel by Eli Goldratt (Goldratt and Cox 1984), which addresses the issue of local efficiencies as a major theme.

Another aspect of the continuous improvement approach of TOC is what is called the Five Steps of TOC. These are as follows.

Step 1. *Identify* the constraint(s).
Step 2. Decide how to *Exploit* the constraint(s).
Step 3. *Subordinate* everything else to the decision taken in step 2.
Step 4. *Elevate* the constraint(s).
Step 5. If, in any of the above steps, a constraint is broken, go to step 1. Do not let *Inertia* cause the next constraint.

Perhaps the best way to explain the Five Steps is to apply them to the previous examples.

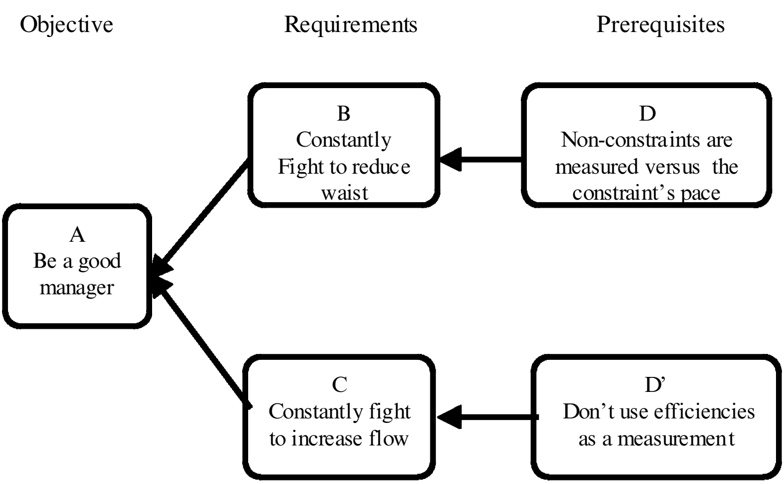

Figure 5. Breaking the generic conflict of operations managers.

In figure 2 we *Identify* the market as the constraint. The market constraint is Exploited by producing at the constraint's pace — 10 widgets per hour. All six workstations are *Subordinated* to this decision by releasing only 10 widgets per hour into the system; they are not allowed to work at their own pace, which would result in building more inventory than is needed by the constraint. The original market constraint was *Elevated* by adding a salesperson, raising demand from the original 8 widgets per hour to 12 widgets per hour (in figure 3). Because a constraint is broken, step 5 says go to step 1 and identify the next constraint (which is station 4) and to avoid *Inertia*. If we continue to work at the market's pace, 12 units per hour would be released to the system, causing a build-up of inventory beyond what is needed at the constraint. The system must now be exploited by producing at workstation 4's pace, 10 per hour. All stations are subordinated to this pace by releasing 10 widgets per hour to the floor. The process stops at this point because, in figure 3, station 4 is not elevated.

A related issue is where should the constraint be. Suppose that, in figure 3, the management decides that the constraint should be at station 4 and that it is desirable to elevate station 4 to 12 widgets per hour (the market's pace) by adding a machine. Then, to keep the constraint at station 4, station 2 must also be elevated, raising its capacity above that of the constraint in order to maintain protective capacity at station 2.

3. Finance and measures

Most companies have certain products they call stars — products with high demand and high profit margins — and others they call dogs — products with low profit margins that may no longer be offered in the near future. Let us examine the validity of this notion. To do so we will need a somewhat more complex example than those used in the previous section — an example of a facility producing multiple products.

Figure 6 depicts a hypothetical company that we will call Widgets, Inc., making three products, X, Y and Z. Widget X sells for \$90 and has demand of 50 units per week. Widget Y sells for \$100 and has demand of 75 units per week. Widget Z sells for \$70 and has demand of 100 units per week. By *demand*, I mean that if Widget, Inc. builds that many widgets they all will be sold. Figure 6 shows that product X starts with the purchase of 2 units of RM2 at \$15 each. Each item is processed at station A for 10 minutes. One item is then processed at station C for 15 minutes while the other is processed at station D for 15 minutes. Station E then takes 10 minutes to assemble a \$10 unit of RM1 with the items just processed at C and D to make a completed X. A unit of X sells for \$90 and has \$50 in raw material content.

Further study of figure 6 reveals that Product Y begins with the purchase of one RM2 for \$15 and one RM3 for \$15. The RM2 is processed at A for 10 minutes, then at D for 15 minutes before proceeding to assembly at E. RM3 is processed at B for 10 minutes, C for 5 minutes, and D for 10 minutes before proceeding to E. Assembly station E takes 10 minutes to assemble the two items just processed at D. A unit of Y sells for \$100 and has \$30 in raw material content.

Finally, Product Z begins with the purchase of one unit each of RM3 for \$15 and RM4 for \$10. RM 3 is processed at B for 10 minutes, C for 5 minutes, and D for 10 minutes before proceeding to assembly at E. RM4 is processed at A for 5 minutes and then goes to E. Station E requires 5 minutes to assemble the units just processed by stations D and A. A unit of Widget Z sells for \$70 and has \$25 in raw material.

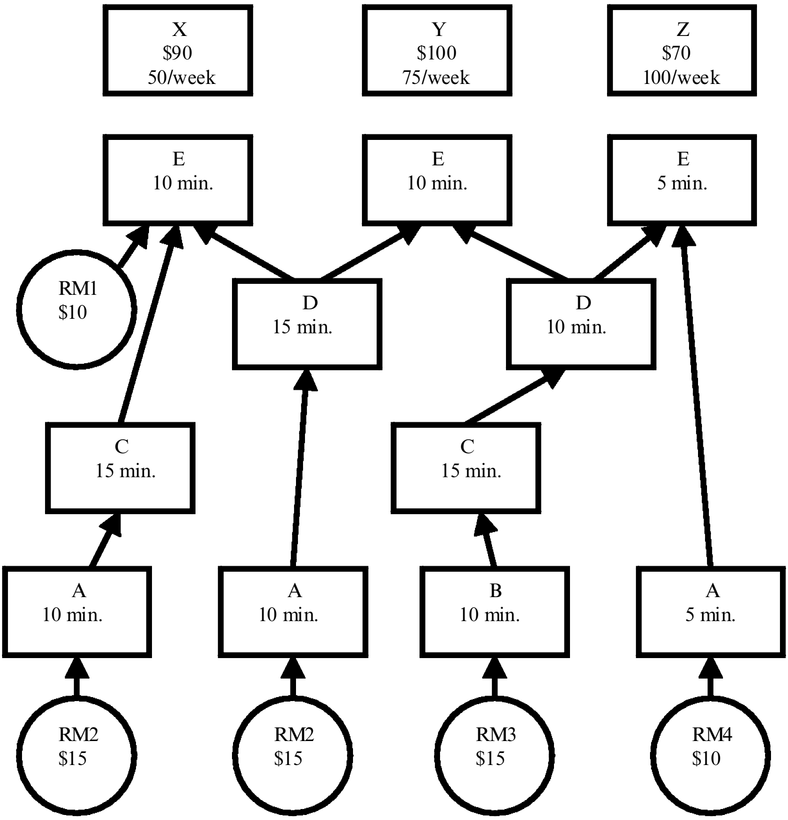

Figure 6. A hypothetical facility.

The first issue to address is whether the company can make all demand. To answer this we need to examine figure 6 to compare demand to productive capacity. From figure 6 we can determine how much time is spent at each workstation to make one unit of each product. This information is extracted into figure 7.

In the top part of figure 7 the capacity required by each workstation to complete its work on a single unit is listed. For example, station B requires 10 minutes to make a Y and so on. In the bottom of the figure, each product's demand is multiplied by the time per piece to get the total required to make a week's demand. For example, to make 75 Ys requires 750 minutes at station B. Then the capacity required to make each product is summed to get the capacity required at a workstation. For example, station B requires 1750 minutes to make all three products (B does not participate in making X).

Now we can compare the time required at each workstation to the time available, which is 2400 minutes. We see that station D, and only station D, needs more time than is available. Station D needs 3625 minutes if it is to make 50 Xs, 75 Ys, and 100 Zs. Because Widgets, Inc. cannot make all demand for all products, the question becomes which products should it make, how many of each, and how much profit can it make?

	X	Y	Z
A	20	10	5
B	0	10	10
C	15	5	5
D	15	25	10
E	5	10	5

Capacity required per unit

	X	Y	Z
Demand	50	75	100

	X	Y	Z	Total
A	1000	750	500	2250
B	0	750	1000	1750
C	750	375	500	1625
D	750	1875	1000	3625
E	250	750	500	1500

Capacity required per week

Figure 7. Calculation of capacity required.

3.1. *Traditional approach*

The traditional approach to deciding the product mix, that is, how much to make of each product, is to use a product margin as the decision rule. Product margin is shown in figure 8.

In figure 8, the selling prices and raw material costs are taken from figure 6. Labour cost is set at $10 per hour. Product X requires 60 minutes of labour, so its labour cost is set at $10 for a unit. The overhead to be allocated to a unit is 3 times the labour cost or $30 for a unit of X. (Total labour cost is $2000 for 5 stations at $400 per week each. Operating expense is $8000; OE minus labour is $6000 so overhead ($6000) is 3 times labour ($2000)). Thus, the product cost for a unit of X is $80 per unit and the margin is $10 per unit. Using similar logic figure 8 shows the product profit to be $30 per unit of Y and $25 per unit of Z. Thus, by traditional logic we much prefer to sell Ys and Zs rather than Xs. Let us see how many of each we can make and how much profit is there.

Figure 9 shows traditional product mix and profit calculations. The most preferred product is product Y, which has a $30 per unit product margin. There is demand for 75 units of Y so we choose to make all 75. Product Y requires 25 minutes of product D per unit or 1875 minutes to make all 75 Ys. This leaves 525 minutes to make other products, as there are 2400 minutes in a 40-hour week. The second most preferred product is product Z with a product margin of $25 per unit. Station D requires 10 minutes to make each Z so Widgets, Inc. can make 52 Zs in the 525 minutes remaining. (We assume nothing can be done with the 5 minutes remaining.) The dog product, Product X, is not produced at all.

	X	Y	Z
Selling Price	$90	$100	$70
Raw Material	$40	$30	$25
Labor	$10	$10	$5
Overhead	$30	$30	$15
Product Cost	$80	$70	$45
Product Margin	$10	$30	$25

Figure 8. Product cost and margin calculation.

Throughput per unit is defined as Selling Price minus Material cost. We can find Throughput per product by multiplying by units produced and sold. Finally, Total Throughput is found by summing Throughput per Product and Net Profit is found by subtracting Operating Expense from Total Throughput. In figure 9, Total Throughput is $7590 and Net Profit is –$410.

3.2. *Theory of Constraints Approach*

The single factor not considered in the traditional approach is time required at the constraint, in this case Station D. While Product Y has the highest product margin, $30 per unit, it also has the highest use of the constraint, 25 minutes per unit compared with 15 minutes per unit of X and 10 minutes per unit of Y. In the Theory of Constraints, the proper decision variable is Throughput per Constraint Minute (T/Cm), where Throughput (per unit) is defined as Selling Price minus Raw Material cost. For Product Y, T/Cm is 70/25 or 2 4/5. For Product X, T/Cm is 50/15 or 3 1/3. For Product Z, T/Cm is 45/10 or $4\frac{1}{2}$. Thus, the traditional star product, Y, is

	X	Y	Z	
Selling Price	$90	$100	$70	
Raw Material	$40	$30	$25	
Throughput/unit	$50	$70	$45	
Production	0	75	52	Totals
Throughput/product	0	$5,250	$2,340	$7,590
Operating Expense				$8,000
Plant Profit				($410)
Minutes of D per unit	15	25	10	
Minutes of D per product	0	1875	520	2395

Figure 9. Plant profit using traditionally preferred product mix.

the least preferred product to TOC. Product Z is first and Product X second. Figure 10 shows these calculations as well as the calculation of profit for a week.

Making 100 Zs requires 1000 minutes at Station D. Making 50 Xs requires 750 more minutes. There are 650 minutes remaining of the 2400 minutes available to Station D; these 650 minutes can be used to make 26 Ys at 25 minutes each. With this product mix, Total Throughput is $8820 and profit is $820 per week.

This example proves emphatically that products do not have profits, companies do. Making decisions based on 'product profit' while ignoring the impact of the product on the constraint is clearly suboptimal. The correct decision variable for determining product mix is Throughput per Constraint Minute.

Two related issues are local efficiency and Make/Buy decisions. Traditional managers use departmental utilization and efficiency as prime measures. Workstation B needs only 1260 minutes to make 100 Zs and 26 Ys. What happens if station B tries to work 2400 minutes in order to have high utilization? Raw Material 3 is purchased early to keep B busy and unneeded work-in-progress inventory builds up at station D. This causes inventory, and holding costs to go up while cash flow is negatively impacted by the early purchases of RM3. Clearly, trying to run station B above the 1260 minutes required to support the constraint schedule results in wastes. Station B and the other non-constraints must be subordinated to the constraint schedule and judged by their ability to move material into the constraint buffer as needed.

The second issue is the Make/Buy decision. Suppose someone suggests that instead of buying RM1 for $10, a less-processed item be purchased for $3 and the item be processed at station C for 15 minutes. Processing cost for this item (including overhead) would be $13 – 2.50 labour, $7.50 overhead, $3 purchase cost. The traditional decision would be to purchase the $10 item. However, from a TOC perspective, this decision is wrong. If the $3 item is processed internally, no additional time per week is required at Station C—it is still within the 2400 minutes available, even though 750 minutes would be added to its processing time. Thus, Total Throughput

	X	Y	Z	
Selling Price	$90	$100	$70	
Raw Material	$40	$30	$25	
Throughput/unit	$50	$70	$45	
Constraint Minutes	15	25	10	
Throughput/Constraint Min.	3.33	2.80	4.50	
Production	50	26	100	Totals
Throughput/product	$2,500	$1,820	$4,500	$8,820
Operating Expense				$8,000
Plant Profit				$820
Minutes of D per unit	15	25	10	
Minutes of D per product	750	650	1000	2400

Figure 10. Plant profit using Theory of Constraints.

would go up by \$350 per week (\$7 per unit times 50 Xs per week) while Operating Expense would not go up at all. Clearly, this part should be made rather than purchasing RM1.

We cannot leave the topic of product mix without addressing the sales function. Why does Product Y have demand of 75 per week while Product X has only 50? Could it be because Product Y has a higher commission based on a higher selling price? What is the best basis for sales commissions; that is, the one that will have the salespeople emphasizing the items that are most profitable to the company? If you said Throughput per Constraint Minute give yourself a gold star. But how many companies do you know which actually use it? Could it be that nearly every company can make more money by restructuring sales efforts as well as product mixes?

3.3. *Example*

Zycon is a California-based maker of printed circuit boards. Prior to using TOC it preferred to make boards for computers—involving many layers on each board and a high 'profit margin' per board. Zycon did not make boards for automobiles or consumer electronics, which have fewer, layers and have lower 'margins'. After beginning to apply TOC Zycon realized that its constraint was a very expensive machine needed only for boards having the highest number of layers. Boards for automobiles and consumer electronics used exclusively non-constraint machines. If these boards were made, Throughput would go up much faster than Operating Expense. Zycon began to make boards with low 'product margin' but high Throughput per Constraint Minute. The result: sales tripled in less than 5 years. Just as important, Zycon became diversified and was no longer so susceptible to a recession in the computer industry (which happened in the mid-1980s and caused Zycon to lay off half its staff).

3.4. *Summary of finance and measures*

What to Change? is the use of product costs and product margins (which are abstract concepts that do not exist in reality in any event).

To What to Change? is to the use of throughput per constraint minute as the primary decision variable in making product mix decisions and in paying marketing commissions.

How to Change? is again a difficult question because moving from product margin to throughput per constraint minute is a paradigm shift. One way to start may be to present the X, Y, Z problem as an exercise to company management.

4. Project management

Goldratt developed a technique called Critical Chain, which replaces PERT/CPM as a scheduling and control mechanism for projects. This subject is discussed in 'Project Scheduling using Critical Chain' (Blackstone *et al.* 2000, Goldratt 1997).

4.1. *Supply chains*

A supply chain is a set of entities that produce, distribute, and/or sell items along the path that a product takes from raw materials to delivery to the final consumer. A simplified supply chain is shown in figure 11.

If you interview managers within supply chains you find that there are two common complaints. On the one hand, they have too much inventory, as marked by few inventory turns per year and by frequent end-of-season sales. On the other

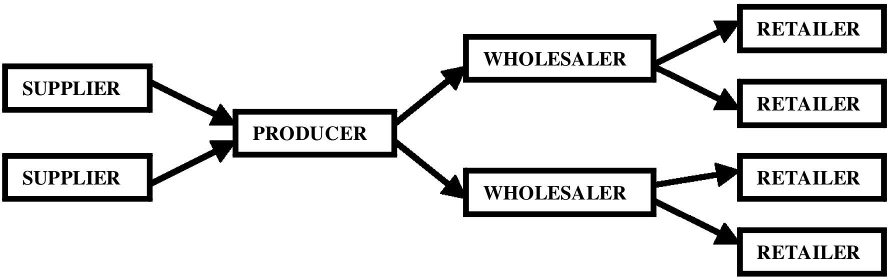

Figure 11. A simplified supply chain.

hand, they are all too frequently out of stock of items, particularly the ones that seem to be the most popular. For example, a president of a chain of 150 retail stores related that the chain had $1 billion in inventory while having only $2.5 billion in sales. At the same time, an internal study revealed that 20% of the customers who entered a store with the intent to buy left without buying because they could not find the item they wanted. This chain is not poorly managed. Rather, it typifies the generic dilemma of supply chains, as illustrated in figure 12.

I think you will agree that the objective of every manager is (a) to manage well. To do this, he or she must (b) reduce costs and (c) protect throughput. But to reduce costs requires (d) holding less inventory, while to protect throughput requires (d′) holding more inventory. Assumptions associated with holding more inventory include that replenishment times are long, vendors are unreliable, and forecasts are inaccurate. To illustrate this situation, we will continue our previous example, an apparel retailer owning a chain of 150 retail stores. Replenishment times in the apparel industry are so long that a retailer must place an order well before the season begins and must order for the entire season since re-supply during a season will not happen. Vendors have long lead times, which drive the retailer's actions. Retailers are therefore forced to forecast sales for items 6 months or so in advance, before they have a chance to see what will really be popular. The results are low turns and high stockouts, as previously mentioned. Does this have to occur?

Let us start by considering where inventory is held in a supply chain. Usually, you will find a lot of inventory held at the end of the supply chain — the retailers and the wholesalers. The producer tends to hold little inventory — shipping products out to retailers via the wholesalers as quickly as possible. Because the producer manufactures in large lots, several weeks are often required to return to an item that has just been produced. So if a wholesaler replaces an order for an item at the wrong time the lead time may well be several weeks. This phenomenon is what causes long lead times and unreliable vendors. Producing overseas to hold down labour costs also causes lead times to lengthen.

Now, consider a different mode of operation. The retailer holds only enough inventory to meet weekly operations with a buffer for high demand. Every week the retailer orders what was actually sold during the week. The wholesaler responds immediately by quickly delivering what was ordered and passing through the sales volume. The producer now holds a large buffer of inventory and delivers replacement stock weekly (or even daily depending on volume) to the wholesaler. The producer uses drum-buffer-rope to restock the buffer of inventory held locally so

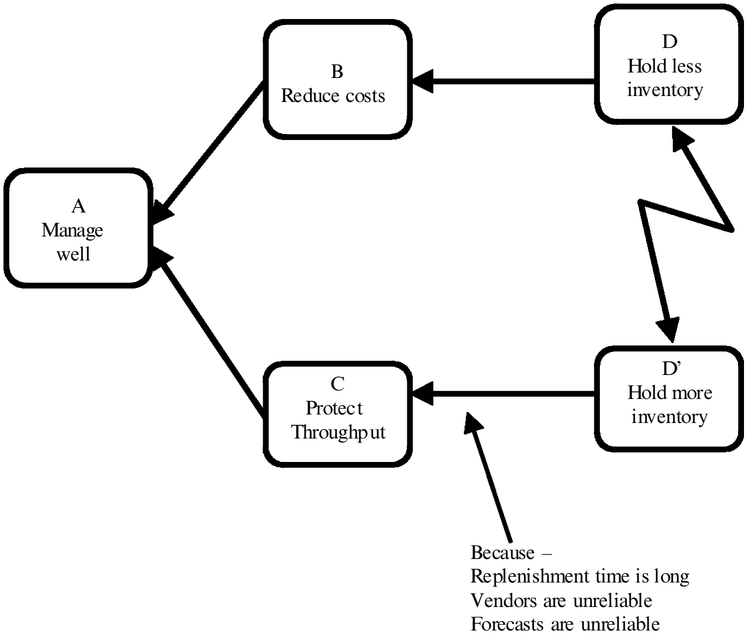

Figure 12. Generic evaporating cloud of a supply chain.

that it is never out of stock of any item. The result breaks the DD′ arc of the cloud. There is D′—more inventory relative to supply frequency—at the retailer while at the same time there is D—much less inventory in the entire system. Forecasts are virtually eliminated as production is related to actual sales rather than to forecast. Lead times are very short because of the buffer at the producer. Vendors are highly reliable because of this buffer.

It is significant to note that reliable weekly delivery is achieved *without* just-in-time manufacturing by keeping the buffer at the plant stocked. For many industries, such as the textile and apparel industry, long set-up times preclude movement to just-in-time in manufacturing. (It is hard to have single-digit set-up times when, for example, 10 000 threads have to be connected to set up a loom.) Of course, if the plant itself were able to adopt either drum-buffer-rope or just-in-time production it could replenish the buffer of each type item more frequently so the buffer at the plant could be reduced.

4.2. *Example*

I was fortunate enough to sit in on a Jonah Course,† taught by Eli Goldratt himself, which first developed the solutions to the supply chain problem presented

† A Jonah Course is a 10-day introduction (usually in three stretches) to the Theory of Constraints which is intended to allow a person to lead TOC introduction into his or her company. The course is taught by someone with tremendous experience, but is rarely ever taught by Eli Goldratt himself.

here. A fibre manufacturer, a textile (cloth) manufacturer, an apparel manufacturer, and a distributor (who owned warehouses and retail outlets) attended the course. A representative of the Department of Commerce to ensure that the details of the cooperation between links in the chain did not violate any antitrust regulation also attended the course. The apparel manufacturer, Warren Featherbone Co. of Gainesville, GA, USA, a maker of children's apparel, immediately implemented the solution with the retailer by holding inventory at the plant and frequently re-supplying in small quantities. Both parties were very happy with the arrangement. Featherbone has now extended this arrangement to 32 of its distributors. A point made by Gus Whalen, president of Featherbone, is that this solution gives a competitive advantage which, coupled with short lead times created by drum-buffer-rope, absolutely cannot be matched by competitors using cheap overseas labour.

4.3. *Summary of Supply Chain*

What to Change? is the practice of ordering in large quantities to long-range forecasts and holding the resulting production at the retailer.

To What to Change? is drum-buffer-rope feeding a buffer held at the producer with weekly or daily deliveries replenishing actual sales occurring at the retailer.

How to Change? is again difficult. Moving to drum-buffer-rope is a paradigm shift. It is so much of one that you probably feel like you have not completely followed this section. Unfortunately there are no books devoted to managing supply chains via Theory of Constraints, although Goldratt touches on the topic in *It's Not Luck* (Goldratt 1994).

5. Marketing

Eli Goldratt makes an interesting distinction between marketing and sales; he says that marketing's job is to spread the corn on the field so that ducks will come while sales' job is to shoot the sitting duck (Goldratt Satellite Program, Session 5, Marketing). What I think he means by this is that marketing is to understand what is important to the customer and, more than this, to understand how a company's products relate to problems the customer is experiencing. From this, understanding marketing can present the product in such a way that the customer immediately sees the advantage (such as Featherbone solving the distributor's problem in the previous section).

To understand the generic problem of marketing one must understand that there are always two perceptions of the value of a product. The supplier's perception of value is based on cost — the product must be valued in such a way as to cover the cost of producing it and to provide a profit to the company. The customer's perception of value is based on usefulness — how the product improves the customer's life. Different potential customers have different perceptions of value. Only those potential customers whose perception of value exceeds the price the company places on the product will become satisfied customers. This situation leads to the generic cloud of marketing, see figure 13.

The assumption on the conflict arrow (DD' arrow) of this evaporating cloud is that the supplier's perception of value, hence price, is very often higher than the client's perception of value. Since the supplier does not wish to lower the price, he or she must find a way to raise the client's perception of value. This is the best injection with which to break the conflict.

To explain this point we must first introduce logic trees as they are used in TOC.

In a logic tree, entities are linked by cause and effect relationships. A simple two-entity logic tree is shown in figure 14. Entity 10 states that my car's battery is dead. Entity 20 says that my car won't start. The arrow connecting Entity 10 to Entity 20 implies causality. My car won't start *because* its battery is dead. Logic trees can be used to describe the present (current reality trees), anticipated futures (future reality trees), or to plan how to implement a solution (transition trees). Figure 15 shows a future reality tree, first defined in *It's Not Luck*, that gives a generic approach to improving marketing (Goldratt 1994, pp 186–187).

Figure 15 is a future reality tree outlining a plan to improve marketing. In figure 15, Entity 10 says that the company studies its customers in order to construct a current reality tree (CRT) based on the customers' undesirable effects. The purpose of a current reality tree is to find a *core problem*, or underlying cause, of the customer such that the core problem is caused or influenced by the company's actions. (For example, my car not starting has an underlying problem that my battery is dead. Once I understand the underlying problem I can take actions to correct it, but acting on the symptom without understanding the underlying problem may be futile.)

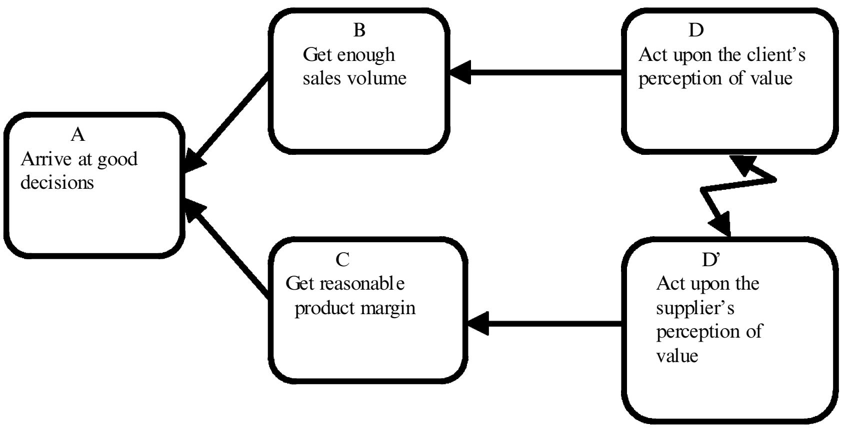

Figure 13. The generic evaporating cloud of marketing (*Goldratt Satellite Program Viewer Notebook,* p. 112).

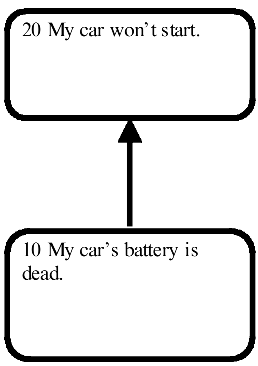

Figure 14. A simple logic tree.

Entity 20 states that a current reality tree is a very effective way to connect problems. That is, if the company uses a CRT it will be able to connect the customer's problems to causes it can influence. The arrows from Entities 10 and 20 indicate that Entity 30 is caused by them. The oval that connects the arrows indicates that Entities 10 and 20 must both be present for Entity 30 to exist.

Thus, Entity 30 says that 'The company can determine which are the deep causes in the Current Reality Tree that can be removed by the company's type of offering'. An example of this from the supply chain example is that the retailer has large quantities of some items and stockouts of others because of the long lead times at

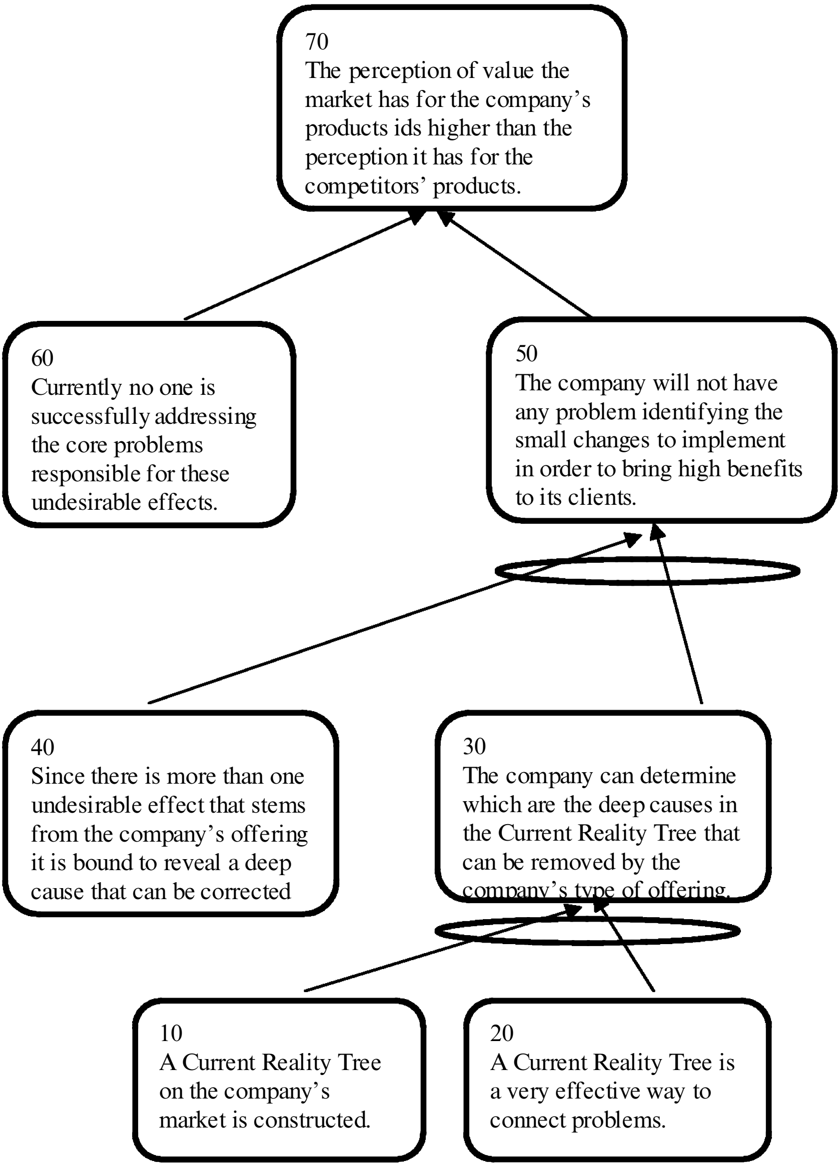

Figure 15. A generic future reality tree for marketing.

the manufacturer. By holding inventory at the plant the manufacturer can drastically reduce its lead time and solve the retailers' problem.

Entity 40 states that 'Since there is more than one undesirable effect that stems from the company's offering it is bound to reveal a deep cause that can be corrected'. A company competes on quality, lead time, price, payment terms, after-sales service, and other factors. There are bound to be aspects of one or more of these that the customer does not like. Taken together, Entities 30 and 40 cause Entity 50 — 'The company will not have any problem identifying the small changes to implement in order to bring high benefits to its clients'. With more than one core problem to choose from, the company can choose a problem to attack that will not be too difficult to correct. Continuing the supply chain example, holding inventory at the plant causes few or no problems for the manufacturer but the resulting shorter lead time is of great benefit to the distributors. (For one thing, more frequent deliveries mean more frequent payments so the cash flow at the manufacturer may improve when inventory is held at the plant.)

Entity 60 says that no one else is currently addressing the problem. This statement has to be true because if the competition had solved the problem the company would have already lost the business. From Entities 50 and 60 comes Entity 70, the company improves the perception the market has for its products. It will increase sales from implementing this solution.

5.1. *Example*

Zycon is a California-based maker of printed circuit boards.† Years ago their lead time was 4 weeks, which is the industry standard. By implementing drum-buffer-rope Zycon was able to reduce lead time to well under one week. It realized that a short lead time raised the market's perception of value of the product. It therefore advertised a standard four-week lead time for the standard market price, a higher price for a two-week lead time, and a still higher price for a one-week lead time. The one-week lead time does not really increase Zycon's cost, but it does significantly raise the client's perception of value. Zycon has received numerous orders for the one-week lead time. (Of course, if the client needs the part in one week it must have a significant problem that Zycon is solving so the customer is happy to pay the higher price.)

5.2. *Summary*

What to Change? is a client's core problem that is related to an aspect of our company's offering.

To What to Change? is a simple change for the company that gives it a significant competitive advantage. Goldratt calls this a 'mafia offer' — an offer that can't be refused (Goldratt Satellite Program, Session 5, Marketing).

How to Change? is the difficulty. It requires learning how properly to construct logic trees. Logic trees that are properly constructed are easy to read (they seem like common sense) but are devilishly difficult to construct. The best reference for learning logic trees (and evaporating clouds) is *Thinking for a Change* (Scheinkopf 1999).

† This example is taken from a presentation by Larry Shoemaker, then Executive Vice President of Zycon, Orlando, Florida, USA, April, 1991.

Workshops in logic trees are offered by several organizations, including the Goldratt Institute and Chesapeake Consulting.

6. Sales

Every improvement is a change. Every change is not an improvement. A salesperson's job is to induce a potential client to change from the competition's offering to his or her company's offering. Doing this requires overcoming several layers of resistance to change. For example, the first layer of resistance is agreement on the problem. Many salespeople make the mistake of skipping this layer and going straight to presenting the solution. The client is left wondering how the solution really meets his or her needs. The correct way to start is to show the CRT developed in the marketing stage. This CRT highlights the potential client's problem(s) and shows how the saleperson's company is contributing to that problem. An example of such a CRT is given in figure 16 (*Goldratt Satellite Program Viewer Notebook,* p. 120†).

In figure 16, 'Shops' refers to small retail outlets that offer several varieties of a consumer product. 'Brands' refers to an international company producing this consumer product. Entity 100 says that 'Brands' offers big discounts on large quantities. This causes (110) 'Shops' to order in large quantities, which causes 'Shops' (130) to be squeezed for cash when coupled with (105) the fact that 'Brands' will not offer products on consignment. Lack of cash leads to a death spiral in which (135) 'Shops' has difficulty making payments which (145) leads to less available merchandise, which leads to (150) less profitability, which leads to (155) less credit, which means that (back to 130) 'Shops' is even more squeezed for cash.

At the same time, if 'Shops' is ordering in large quantities it is ordering infrequently. 'Shops' must (165) rely on a forecast (forecasts are often unreliable). This causes 'Shops' to run out of some items which leads to (150) less profitability, which puts it back in the death spiral. On the other hand, 'Shops' inevitably over-forecasts for some items, which leads to (180) stocks of obsolete products that are (185) offered at discount prices, which (150) directly lowers profitability and (190) indirectly lowers profitability by hurting sales of new products.

All of the problems shown in figure 16 can be directly related to the fact that 'Brands' does not offer goods on consignment. 'Brands' therefore can construct a 'mafia offer' by presenting goods on consignment; payment to be made after each item is sold. Other terms of this offer are that the shop will carry only enough inventory for proper display; that payment will be made immediately upon sale; and that a replacement item will be delivered when payment is made. Note that 'Brands' is unlikely ever to come up with this solution without having first developed the CRT of 'Shops'. Of course, the competition can meet 'Brands' offer. However, without the CRT the competition is likely to view offering goods on consignment as an added cost and will probably refuse to do it. (Figure 16 is based on the actual and successful experience of the European division of a multinational company.)

† The Goldratt Satellite Program was 8 three hour sessions broadcast from the Netherlands worldwide via satellite March through May, 1999. Tapes of these sessions are distributed by the International Institute for Learning, Inc. under the title of the Holistic Approach Workshop. The same viewer notebook is used.

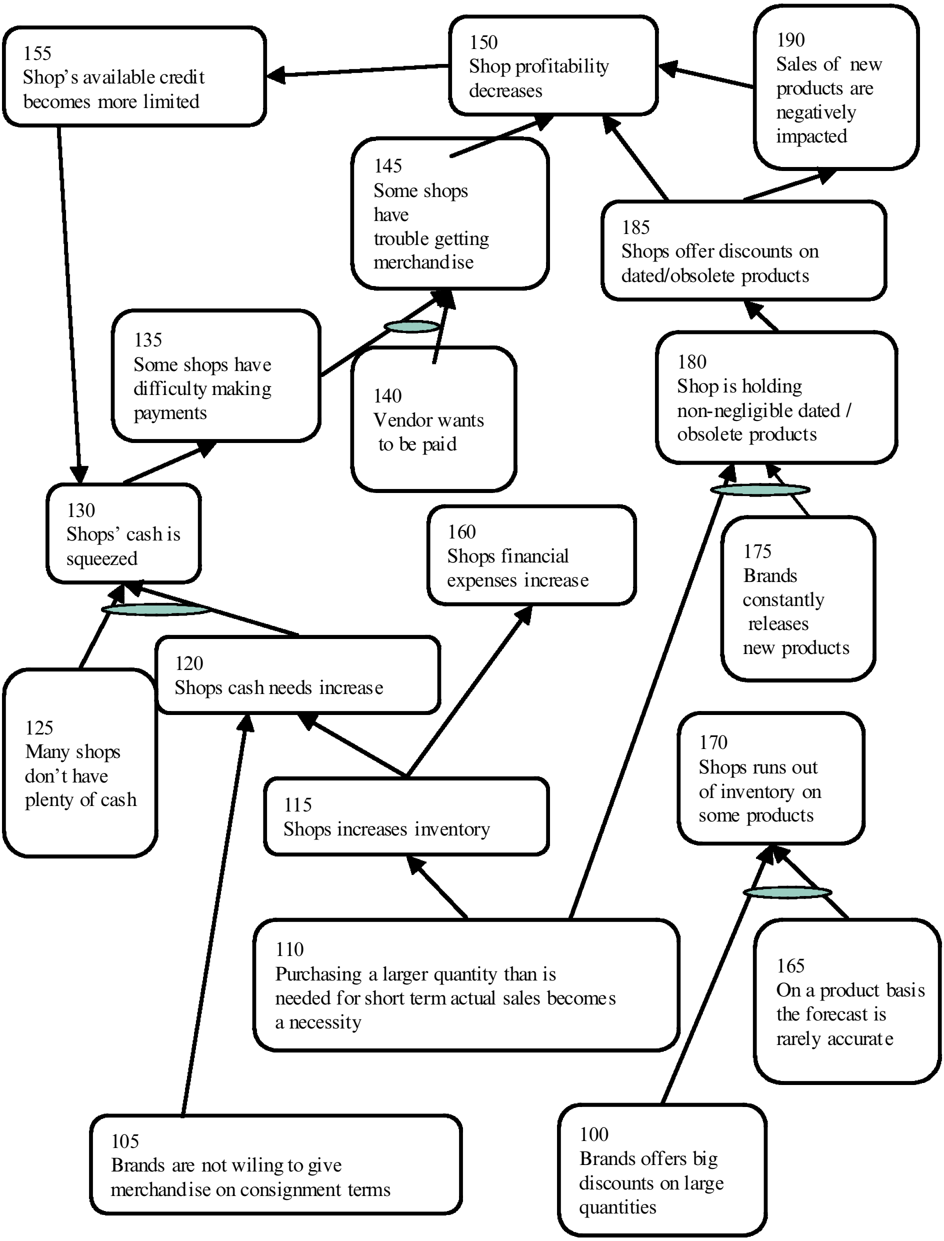

Figure 16. Current reality tree of 'shops'.

Another important aspect of Sales is to realize that different customers have different perceptions of the value of your product; some value it more than others. The trick is to extract the higher value from some customers without making them feel that they have been cheated, because they feel they received extra value. An example of this was given in the previous section. Zycon stratified its prices by the length of the lead time. The market segmented itself into those needing 1-week, 2-week, or 4-week lead times. Those paying higher prices for shorter lead times do not think that those with lower prices got a better deal. This is true even though Zycon goes to no extra effort or expense to produce the shorter lead times.

6.1. *Summary*

What to Change? is the tendency to present an offer without first having the client realize what problem is being solved.

To What to Change? is to the development of a 'mafia offer' built around a CRT of the client's problem.

How to Change? is to learn how to build the CRT and the 'mafia offer'. Some tools for this include *Thinking for a Change* (Scheinkopf 1999), which shows how to develop these thinking tools of TOC, and *It's Not Luck* (Goldratt 1994), which describes the development of some 'mafia offers'. There is also a workshop on marketing and sales offered by the Goldratt Institute.†

7. Managing people

At first glance it may seem that TOC has little to do with managing people and it certainly does not provide a comprehensive approach to the topic but there are some TOC tools that help with managing people—the Current Reality Tree, the Evaporating Cloud, and the Negative Branch.

Workers approach managers for a lot of reasons. Two of the most common are that they have a problem and that they have an idea for improvement. We will examine both.

7.1. *Problems*

Very often, when people have problems they are looking at symptoms, not at the underlying cause of the problem. Fixing the symptom leaves the underlying cause still there—like taking aspirin for a headache caused by a brain tumour. The symptom will pop up again. Just-in-time says 'ask why 5 times', which is its way of saying that you must find the underlying cause. For example: my car won't start. Why? The battery is dead. Why? It is really old and I haven't replaced it. Why? I don't have a lot of money. A short reflection on this problem leads to the realization that the least expensive solution is to get a new battery.

A more formal structure for finding underlying causes is the Current Reality Tree (CRT), such as the one in figure 16. Constructing CRTs is discussed at length in Cox, Blackstone and Schleier (unpublished). Here is a brief outline.

Step 1. List not more than 10 undesirable effects (UDEs).
Step 2. Find any two UDEs that you feel have a causal connection.
Step 3. Determine which UDE causes the other. Place each UDE as an entity in the diagram and insert a causal arrow from the cause to the effect.(
Step 4. Continue to add UDEs to the diagram, including effects that may not appear on the list of UDEs.
Step 5. Read the CRT from the bottom up, tightening the logic as necessary.

† Information on TOC workshops may be obtained from www.goldratt.com. Other organizations such as Chesapeake Consulting also offer workshops on TOC thinking processes.

7.2. *Example*

Suppose you are a manager of a retail outlet. An employee comes to you toward the end of the summer and points out that there are a lot of bathing suits left in inventory. She suggests that you hold an end-of-season sale for these suits that never caught on in popularity. You can simply hold a sale. That would get rid of the excess inventory. But what are the chances that you will have an excess inventory of bathing suits next year too (or an end-of-season excess of other products)? (Think of how many end-of-season sales you see in your reality.)

Now let us look at the CRT approach. Here are some possibly connected UDEs.

(1) We have an excess inventory of some bathing suits.
(2) We need to have an end-of-season sale.
(3) We need to order a large number of bathing suits to get the maximum quantity discount from our supplier.
(4) We have to forecast demand for bathing suits before the start of the season.
(5) Our forecasts for individual bathing suit demand are not very good when we forecast several months in advance.
(6) We run out of the most popular models of bathing suits.

We have completed step 1 of the instructions on completing a CRT. Now we need to connect two UDEs to begin our CRT diagram. Suppose we select the first two. It appears that UDE #1 causes UDE #2, yielding figure 17. Note that entities 1 and 2 are taken directly from the UDEs and that the arrow connecting them says that #1 causes #2. This logic might be tighter if we noted that people will buy out-of-season merchandise if they feel it is a bargain. Adding entity 10 (which is not on the list of UDEs but which is true for our reality) to the CRT tightens the logic. The oval connecting the two arrows says that entities 1 and 10 act in conjunction to cause entity 2.

We now need to ask *why* entity 1 exists. The excess inventory of some bathing suits did not simply appear. In many cases excess inventory occurs because of the conjunction of three things. We must buy a large quantity to get the quantity discount. We must order this large quantity before the season because of the long lead time. Because we must order in advance, we must forecast demand before we see what the seasonal trends will be so our forecasts are not terribly accurate. These three effects are shown as entities in figure 18.

We might improve our logic leading to Entity 1 if we note that our forecast may be too high. When our forecasts are too high we end up with excess inventory and have to have an end-of-season sale. On the other hand, sometimes the forecast is too low in which case we run out of inventory. Several items are not on the CRT.

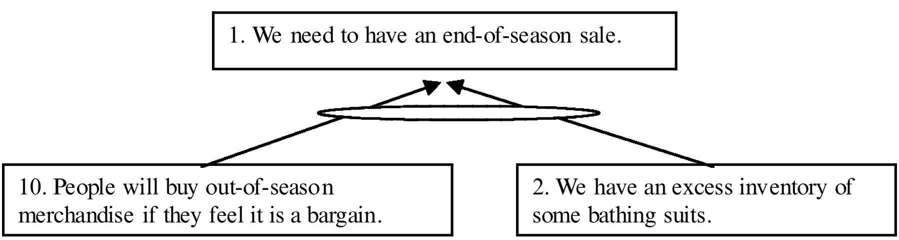

Figure 17. Beginning the current reality tree.

Because of long lead times we cannot get an order in for the overly popular items, so when forecasts are too low we lose sales. Both season ending sales and lost sales cause us to lose money. The reader may wish to try to polish the CRT to include these effects.

The reason for creating a CRT is to find and eliminate the underlying core problem. In figure 18, the core problem is that we have to order before the season starts and therefore have to forecast several months in advance. As long as we have to forecast we will always have some item forecasts that are too low and others that are too high, leading to end-of-season sales as well as lost sales. The solution to this is the supply chain solution presented earlier. Hold the inventory at the manufacturer with frequent replenishment of actual sales to the retailer. Then forecasts are eliminated as are the lost sales and the end of season sales.

This example illustrates how the CRT can help a manager move from a symptom to an underlying cause that can be corrected. In this case, we started with excess inventory and found that the solution was to hold the inventory at a different place in the supply chain. Note that in solving the excess inventory problem we also, simultaneously, solved the problem of lost sales. Solving a second problem is no coincidence. When an underlying cause is corrected, the solution usually eliminates more than one symptom.

7.3. *Aligning responsibility and authority*

Often, when a worker brings a problem to a manager, the underlying cause is a lack of alignment between what the worker is responsible for and what the worker has the authority to change. This problem is what Goldratt calls the *Lieutenant's Cloud*. Consider the following situation:

You are the manager of a distribution centre. A shipping clerk that works for you has a package to ship to a customer. His problem is that the customer has two

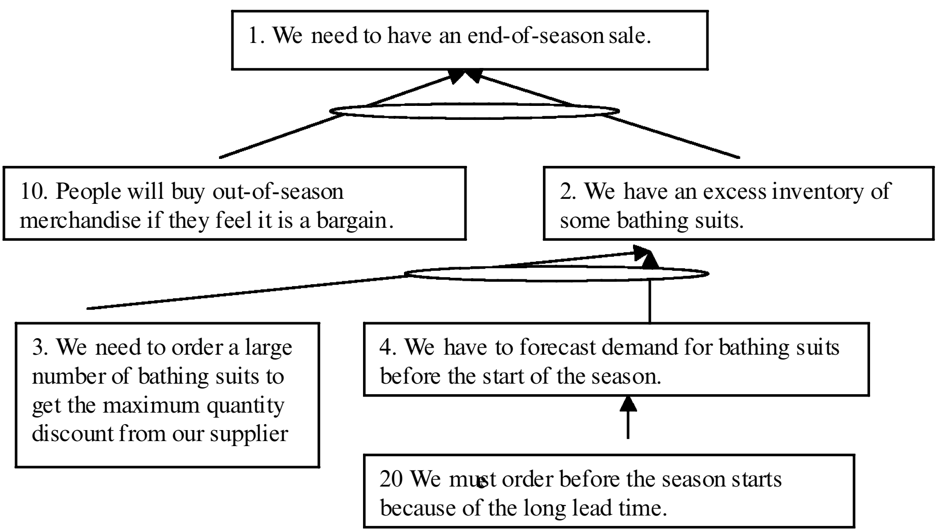

Figure 18. Further development of the CRT.

locations and he cannot tell from the paperwork, which of the two locations is to get the package. He has been trying for two days to get the company's contact for that customer but the contact is out of town and can't be reached. The company has a policy that says only one contact is to interact with each customer. The package must be shipped today to meet the customer's deadline. What can the shipping clerk do?

Figure 19 shows the lieutenant's cloud for this situation.†

This is a clear case of misalignment of responsibility and authority. The shipping clerk is responsible for the package getting to the customer on time but he lacks the information he needs to do this. He cannot call the customer because of the company policy. So he comes to you. The company policy is not a bad one. The company does not want the customer to be told different things by different people, so it created the policy of only one contact point. But this situation is really outside of what was anticipated by that policy. In this case it is not the customer who wants information it is you. You could simply call the customer yourself to get the information. (Goldratt calls this putting out the lieutenant's fire for him.) This would take care of this problem but the problem will happen again. Or you can give the lieutenant a new policy. If an order is to be shipped and the company contact for some reason cannot be reached then he can call the customer for the sole purpose of ascertaining the correct address to which to ship the package.

The generic form of the Lieutenant's cloud is given in figure 20.

Creating the generic lieutenant's cloud is done in the following sequence. First you formulate D′—what rule prevents the lieutenant from acting. Second, you state what action the lieutenant would take if he breaks the rule (D). Third you formulate the need of the system that is jeopardized by the lieutenant's problem (B). Fourth, you state what need of the system is protected by the rule (C). Fifth, you find the objective, which will be fulfilled, if needs B and C are met (A).

In general, a good way to build a cloud is to define the conflict (D and D′), then the needs (B and C), and finally the objective (A) (see Scheinkopf 1999, Goldratt 1994 and Cox, Blackstone and Schleier, unpublished).

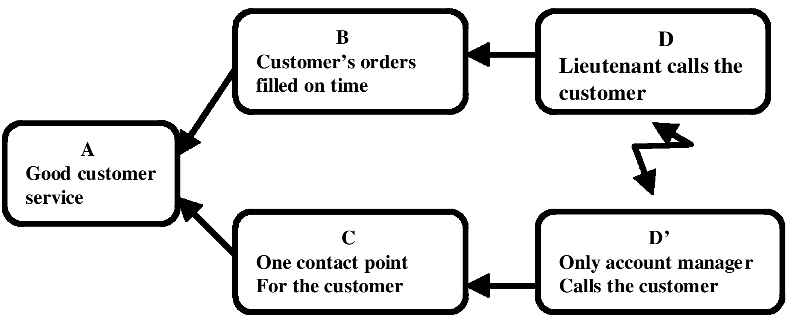

Figure 19. The shipping clerk's cloud.

† Figures 21 and 22 are taken from the Goldratt Satellite Program, pp. 170–171. This topic is also treated within the Management Skills Workshop.

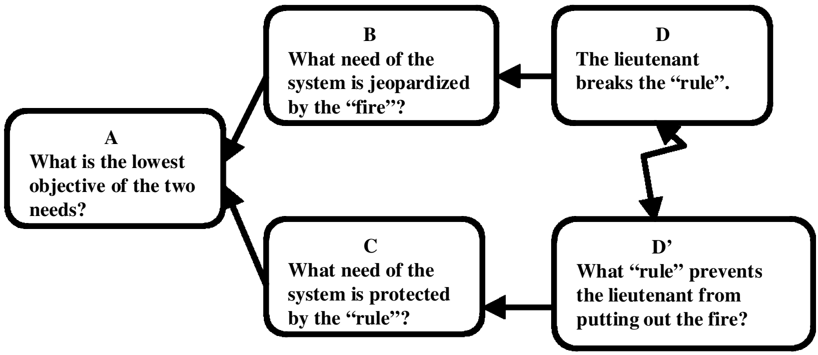

Figure 20. The generic lieutenant's cloud.

7.4. *Dealing with half-baked ideas — the negative branch*

Sometimes, someone may come to you with an idea for which you cannot immediately say yes or no. You need more time to think and you may have an issue or two to deal with before you can say yes. A form of a logic tree known as the negative branch can help with this problem. In a negative branch, one starts with the assumption that the idea is implemented and traces out possible negative consequences. The idea-bringer can then respond to the negatives, possibly amending his or her solution.

7.5. *Example of a negative branch*

I have a daughter who, at age 12, requested to go to London with part of her 7th grade English class on a sightseeing trip led by her teacher. This is a classic example of a half-baked idea. Emily (the daughter) had no idea how this trip could be paid for, nor did she have any real idea of the concerns her parents might have about her travelling abroad at such a young age. But she was so enthusiastic about the idea that we (her parents) did not wish to say no immediately. Our only recourse was to say we'd think about it. We then made enquiries as to how the trip would be chaperoned. When we were satisfied that the trip would be safe and would be a tremendous learning experience for Emily we began to lean toward her going on the trip. This still left the issue of expense, because with other children in college her parents could not simply write a cheque for the expenses. The solution to this situation was the negative branch outlining the issue to be addressed, as shown in figure 21.

The negative branch is presented to the idea-bringer and she is given the opportunity to solve the problem. Being 12, and not really understanding how much money the trip would cost, Emily's first suggestion was that she pay for most of the trip with money she would save in the interim from babysitting. Of course this situation was impractical. She eventually came up with two further suggestions. First, she would approach her grandmother for help and second she would use some of her educational fund for the purpose. Eventually, between her parents, her grandmother, her educational fund and her babysitting, the money was raised. In retrospect the trip was worth the expense.

The main point to take here is that the negative branch does not try to solve the problem. It merely shows to the idea-bringer why you cannot say yes *yet*. Ideally, the

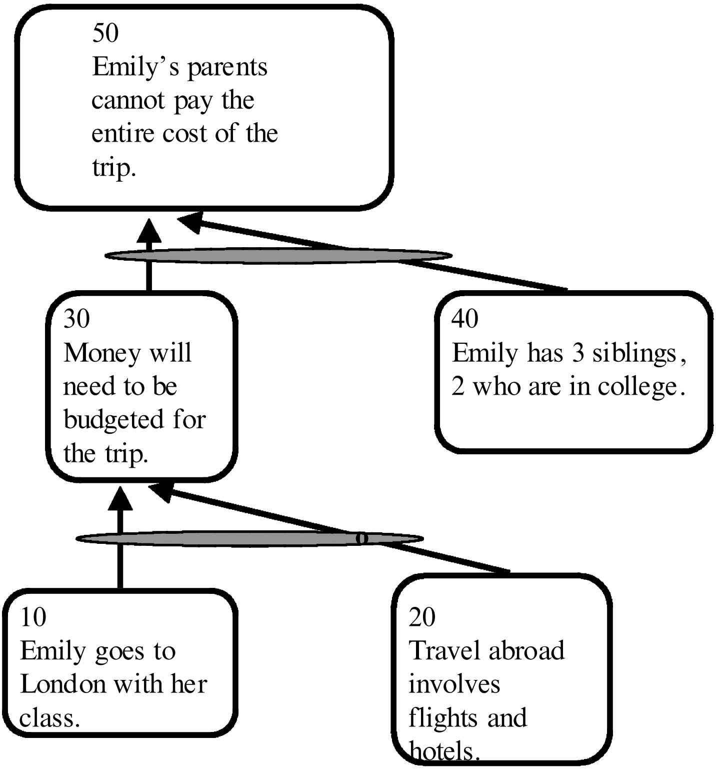

Figure 21. Negative branch on Emily's trip to London.

idea-bringer will come up with new ideas to overcome the problems that stand in the way.

7.6. *Summary*

What to Change? is dealing with subordinates' problems and ideas with off-the-cuff reactions that may solve symptoms but leave underlying problems intact.

To What to Change? is to the use of Theory of Constraints Thinking Process Tools (Current Reality Trees and Evaporating Clouds) to break the conflicts that hold core problems in place.

How to Change? involves learning these thinking process tools. Learning the tools is quite a bit harder than it looks and involves both practice and feedback from others as to how readable are the tools you produce. Several references for learning the tools have been provided.

8. Strategy and tactics

A strategy is a plan of action for winning a contest. In business, strategy may be aimed at overcoming the competition or otherwise winning a customer. Every business must have a strategy to improve continuously. Without improvement, any kind of competitive advantage eventually disappears and the company will soon follow it into oblivion.

Goldratt argues that every successful strategy involving continuous improvement must satisfy three necessary conditions—satisfying the owners (or stockholders), the employees, and the outside world (market, suppliers, and external environment). He further argues that to sustain a process of ongoing improvement (POOGI), there can be no conflict between these necessary conditions. A minimum profit level is necessary to pay dividends and to reinvest for future growth. An environment must exist to retain good employees for the long term. Both customers and suppliers must be happy or they will leave. Violating the environment or failing to obey laws will lead ultimately to a shutdown.

Every system has a constraint. If a business did not have a constraint it would have infinite profit. A strategy is a plan of action for winning a contest. In business, strategy may be aimed at overcoming the competition or otherwise winning a customer.

Eli Goldratt says that the first question of strategy is to determine where the constraint should be. Should it be internal to the company or should it be external (such as in the market)? Most people believe that the constraint should be in the market because internal constraints can be broken by adding more staff. Goldratt claims that it is best to have the constraint internal to the company. Goldratt argues as follows. If the market is the constraint, then employment must ride up and down with the market (and markets do eventually go down). Going up and down with markets means laying people off. But layoffs kill improvement efforts because employees are convinced that further improvement means further layoffs. Thus, if a POOGI is to be sustained in the long run, constraints must be internal so that market downturns do not lead to layoffs.

The issue of layoffs is the topic of a generic cloud for strategy as it relates to continuous improvement. This cloud is shown in figure 22.

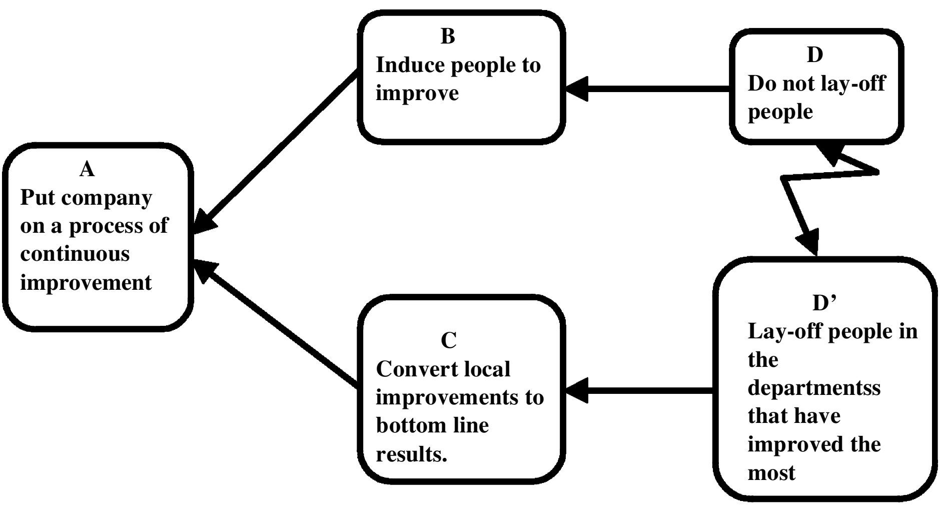

Figure 22. The generic cloud of a POOGI.

In figure 22, the objective is to put or keep the company on a process of continuous improvement. To do this a manager must induce people to improve and at the same time convert these improvements into bottom line results. For people to be willing to improve it is necessary never to lay people off because of an improvement. On the other hand, to convert improvements into bottom line results, layoffs may be necessary. This cloud may be attacked at the CD′ assumption, which is that the market is limited. The solution is to focus on improvements that can be translated into greater markets.

Notice how the strategy of never laying off differs from today's reality, which seems to idolize CEOs who come in and have large layoffs. A layoff may lead to a one-time improvement of the bottom line but never to a POOGI!

Goldratt recognizes that simply having an internal constraint does not mean that layoffs do not occur. Another aspect of strategy is then to diversify into segments that will not all be down simultaneously. For example, Zycon (a maker of printed circuit boards) once made boards only for computers. But after the computer recession in the 1980s they acted on Goldratt's recommendation and diversified into boards for automobiles and consumer electronics — markets that might not be down simply because computers took a temporary downturn.

The final aspect of strategy deals with marketing's 'mafia offer'. By creating a current reality tree of a customer's reality, we can determine small changes in our offering that will substantially improve our product from the customer's perspective (shorter lead time, more reliable delivery, higher quality, etc.). This change will lead to a substantial increase in throughput (and hence away from the necessity to lay off people in order to convert improvements into bottom line results). Very few companies have over a 2% market share of the world market — so there is always room for improvement there.

Ideally, markets should be segmented by how they value this improvement. For example, Zycon reduced lead time from 4 weeks down to 1. It then offered its product at three prices — one for 4-week delivery, higher for 2-week delivery, still higher for 1-week delivery. Those companies that were in a bind and had to have faster delivery were glad to pay the higher price. Notice that Zycon is segmenting the market but not the resources used to supply the market — the same resources were used regardless of the promised delivery date — 4-week promises were just inserted into the schedule at a later date while manufacturing lead time was always one week.

8.1. *Summary*

What to Change? is a strategy based on saving cost departmentally rather than maximizing flow throughout the system.

To What to Change? is to maximize throughput by exploiting the constraint and by finding products that have high throughput per constraint unit.

How to Change? is forever the question. Hopefully, this paper will help.

This paper draws heavily on the Goldratt Satellite Program (24 hours in 8 tapes delivered live between March and May of 1999) and the accompanying Viewer's Guide. Many thanks to Eli Goldratt for permission to use this material.

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