International Journal of Production Research,
Vol. 45, No. 4, 15 February 2007, 779–788

Taylor & Francis
Taylor & Francis Group

Managing strategic and tactical constraints in the hi-tech industry

A. COMAN† and B. RONEN*‡

†The Academic College of Tel Aviv Jaffa, Israel
‡Tel Aviv University, Faculty of Management, Israel

(*Revision received September 2005*)

This paper addresses the issue of constraint management in the hi-tech industry, from the vantage point of the theory of constraints (TOC). First, we argue that the hi-tech industry faces a market constraint in operations, and resource constraints in both research and development (R&D) and marketing and sales (M&S). We then make the distinction between strategic and tactical constraints, and build a methodology to identify and manage them.

While the TOC enables tactical treatment of the organization's internal resource constraints, we consider the prevailing constraint to be in the external business arena. In the short term, organizations apply the TOC methodology to increase their throughput, usually by focusing on the internal constraints. This is defined as tactical constraint management. In the long term, they navigate to position themselves in relation to the business arena's constraint. This is defined as strategic constraint management.

In the paper we address the strategic dilemma of where the constraints should be in the hi-tech industry and how to reposition them there. In so doing, we bear in mind the relatively high frequency at which the hi-tech industry constraints change their position, and provide examples of disruptive change.

Keywords: Theory of constraints; Hi-tech; Permanent bottlenecks; Strategic constraint; Tactical constraint

1. Introduction

This paper addresses the issues of constraint management in the hi-tech industry, from the vantage point of the theory of constraints (TOC). First introduced by Goldratt in the mid-1980s (Goldratt and Cox 1992) as a comprehensive managerial tool, TOC's theoretical roots lie in linear programming and other operations research methodologies (Ronen and Starr 1990). Much research has been published on the application of TOC in manufacturing and industry (Cox and Spencer 1998, Coman *et al*. 1996, Blackstone *et al*. 1997). TOC-based methodologies and tools have also been developed in the areas of marketing and sales (Goldratt 1994), information systems (e.g. Goldratt 1990), decision-making processes for costing and pricing (e.g. Holmen 1995, Coman and Ronen 2000), project management (Goldratt 1997, Raz *et al*. 2003) and the management of human resources. A comprehensive review study has found hundreds of refereed papers on the subject of TOC in the various business

*Corresponding author. Email: boazr@post.tau.ac.il

International Journal of Production Research
ISSN 0020–7543 print/ISSN 1366–588X online © 2007 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/00207540600597237

areas (Mabin and Balderstone 2000). Work has also been done on the theoretical background of constraint management (e.g. Grosfeld-Nir and Ronen 1993, Plenert 1993). Pass and Ronen (2003) developed a methodology for addressing the issue of managing the market constraint in the hi-tech industry, but no comprehensive model has been developed for managing all its constraints. In an effort to fill this gap, the present paper focuses on constraint management in the hi-tech environment, building a comprehensive model to better manage and align both tactical and strategic constraints.

- *Tactical constraints* are identified through introspective processes using techniques such as cost-utilization (CUT) and the current-reality-tree (CRT).
- *Strategic constraints* are defined as the constraints influencing the organization's business arena, and their management consists of:

  (a) Identifying the arena constraint and its migration path,
  (b) Creating a vision for navigating the organization towards an advantageous position in the business arena, and
  (c) Translating that vision into a program for realigning the organization's structure and priorities.

Tactical constraints are under the responsibility of mid-management, and focusing on them may increase the organization's value without major structural changes. They may be immediate bottlenecks to be exploited, subordinated to, and offloaded; they may be 'dummy' constraints to be broken (Pass and Ronen 2003), etc. Strategic constraints are to be dealt with and managed by top and senior management. They are 'policy' constraints involving marketing offerings, measures of performance, costing, pricing, organizational structure and most of the organization's core problems. Table 1 distinguishes between tactical and strategic constraints.

Though the concepts presented in this paper are applicable to a broad variety of businesses they are more salient in the hi-tech industry. We thus limit the scope of this article to the hi-tech industry.

Section 2 of this paper presents the generic resource model of a hi-tech organization. Application of the cost-utilization (CUT) diagram (Ronen and Spector 1992) defines the marketing and sales (M&S) and research and development (R&D) departments as permanent bottlenecks in hi-tech organizations, as was suggested by Pass and Ronen (2003). Section 3 presents a methodology for the alignment of the organization's competencies with the business arena's strategic constraints.

Table 1. Tactical and strategic constraint management.

	Tactical constraints	Strategic constraints
Additional cash flow	Derives from the same position and business structure	Derives from change in positioning or business structure
Constraint management	By mid-management	By top management
Criticality to organization's survival	Usually not critical	Critical
Time horizon	Short	Long

Section 4 provides examples of using the strategic constraint management methodology, section 5 presents a case study, and section 6 concludes the paper.

2. The generic resource model and the permanent bottlenecks

A market constraint is defined as a situation in which the production/operations resource capacity exceeds market demand, and lack of profitable orders prevents the system from achieving higher value for its shareholders. As noted by Cox and Spencer (1998), a market-constrained organization is 'an organization that could produce more than it can sell'. However, although the capacity of production/operations and logistics resources in a hi-tech organization may be higher than the pertinent market demand, it always has two internal permanent bottlenecks: the R&D and the M&S departments. We define this two-bottleneck pattern in R&D and in M&S as the 'two-tower' constraint architecture.

The R&D department is necessarily a bottleneck since the demand for development always exceeds its capacity. There are more internal and external requests for development than resources to execute them. Whatever the size of the R&D work force, the potential demand will always be infinite with respect to the available resources. The M&S personnel are also an inevitable bottleneck since they could all bring in more sales if they had more hours available. The load on M&S includes processing ongoing orders, pursuing leads on potential customers, increasing sales to existing customers, participation in exhibitions and conventions, and tracking down all potential customers. Clearly, in such a situation the demand exceeds the supply, no matter how many new salespersons are recruited. In the case of M&S, as in the case of R&D, adding more resources will probably add some throughput to the organization at a substantial cost, but it will not change the fact that these departments will still remain bottlenecks, and should be managed as such.

A 'two-tower' constrained hi-tech organization is presented in figure 1 using a CUT (cost-utilization) diagram (Ronen and Spector 1992) depicting the various resources in the system as bars. The height of the bar represents the load on the resource (department, in our case) while the width represents the relative cost of the resource (department). As can be seen in the CUT diagram, operations are under-loaded and can take an extra load of at least 20% without adding extra resources. The same holds for logistics.

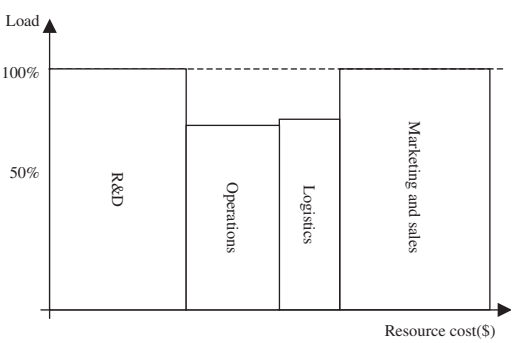

Figure 1. CUT diagram for a 'two-tower' constrained hi-tech organization.

The diagram shows that even in a market-constraint environment we have two internal permanent bottlenecks, which should be treated accordingly. As the permanent bottlenecks can be controlled, management can influence and improve the organization's shareholder value tactically. An organization should periodically review the capacity of its resources:

- If its R&D and M&S are bottlenecks and operations and logistics have some protective excess capacity then we manage the constraints tactically according to TOC's seven focusing steps (for details see Pass and Ronen 2003).
- If R&D or M&S are not fully utilized then the organization is facing a serious strategic problem. The authors' experience shows that in about 5% of hi-tech organizations the bottleneck is not correctly positioned, for reasons that may include improper tactical management or disruptive change in market conditions.
- Having operations or logistics as bottlenecks is acceptable only when their resources are particularly expensive, critical or scarce. If this is not the case then management should take measures to reposition the constraint in the right place.

3. The core competencies alignment process

We prescribe the following five-step process for aligning the organization's core competencies with the business arena's key success factors:

Step 1: Identify the organization's constraints.

Step 2: Identify the business arena's strategic constraints.

Step 3: Analyse the gap between the organization's and the arena's constraints.

Step 4.: Outline an action plan aligning the organization to its business arena.

Step 5: Execute the action plan and monitor its effectiveness.

Is the arena constraint a threat or an opportunity? If the firm is in an advantageous position to take over the arena constraint (e.g. you own the semiconductor fab or control the point-of-sale of computer games) then the opportunity is to leverage the arena constraint in order to take control over other profitable parts of the arena. If, however, the firm is in no such position then the arena constraint becomes a threat.

The recent oil crisis provides an example of the constraint in the energy arena shifting to the oil refinery resource. Constellation Energy Group leveraged its strong position in the refinery business to expand down market and sell its products directly to the end-consumer in its own gas stations. Similarly, Microsoft leveraged its control over the PC operating system to expand into the software application (Microsoft Office) and internet markets. This was an opportunity for Microsoft and a lethal threat to the incumbent players—Lotus 123, Word Perfect, etc.

Step 1 applies the cost-utilization (CUT) diagram (Ronen and Spector 1992) and load analysis methods (Pass and Ronen 2003) to identify the organization's constraints.

Step 2 focuses on understanding the business arena using the same methods as above. As the following examples show, different industries display constraints at different positions of the business arena.

- In the ethical drug manufacturing arena, dominated by 'Big Pharma' the constraint lies in the funding of new drug discovery: the bottleneck is capital investment in R&D. Typically, drugs require between $700 million and $1 billion per new blockbuster drug authorized by the FDA.
- In the semiconductor arena the bottleneck is capital investment in the fabs used to manufacture new chips.
- In the software arena the bottleneck is located in access to the consumer. Few companies are capable of providing full suite solutions and integration.
- In the 'edutainment' market, providing education and entertaining applications, the entry barriers are low (development of new applications ranges between $100 000 and $10 million), distribution is simple, and the bottleneck resides at the retailer level. Retailers can physically display around 1% of the new products launched each year. As a result, by controlling the market constraint retailers get to keep 80% of revenues while developers and distributors share the remaining 20%.

The business arena constraint can be identified using one or more of the following methods:

- *Cost of the resource and its utilization*. In most cases the most expensive resource is the most utilized one and becomes the arena constraint. For instance, when the hi-tech cycle peaks, the fab becomes the scarce resource. The price per fab is in the multi-billion dollar range.
- *Supply/demand gap*. When the demand for a given resource rises abruptly we encounter a shortage. For example in the edutainment business, the attractive sales and low investment required created excess supply, moving the constraint to the point-of-sale.
- *The margin test*. Sometimes analysing the profit margins along the arena helps identify the constraint. The constraint will usually be located where the highest margins are.

Step 3 is analysis of the gap between the organization's core competencies and the core competencies required to generate value in the constraint dominating the business arena. Gaps identified can be bridged in three ways:

1. Organic development of missing competencies.
2. Mergers or acquisition of organizations with complementary competencies.
3. Joint ventures with complementary players in the arena.

In Step 4 we translate each gap element into an action project aimed at acquiring the required competence. Resources allocated include dedicated executives and budgets, taking care to ensure that the project timetable matches the window of opportunity applicable in the particular arena.

Step 5 consists of monitoring progress and identifying future changes in the location of the arena's bottleneck.

4. Examples of the strategic-constraint-management methodology

Consider the following examples

1. Sony's well documented failure with its superior Beta format versus the inferior VHS format resulted in the realization that the bottleneck resided in content creation. The affordability of home entertainment equipment resulted in a tremendous growth in the demand for video titles far exceeding the available supply. This moved the arena constraint to the content level. Sony's core competencies were positioned around new electronic product development, attractive design and reliable performance. It was totally unequipped to compete in the content production arena, concentrated as it is around the Hollywood cluster in which core competences are highly specific to the geographic culture of southern California and alien to Sony's Japanese management culture. In an effort to bridge the gap between the frugal, lean-management philosophy of Japan and Hollywood's lavish style, Sony acquired Columbia and subsequently MGM. Integrating the two cultures was painful and extremely costly but eventually achieved its goals.
2. Acer's core competence was in the assembly of computer systems. Given the commoditization in the PC industry and its ready supply of assembly workers, supply far exceeded the industry's demand. The low margins in the assembly business indicate that this is not the arena constraint. Realizing that the electronics arena replicated the two-tower constraint architecture on a macro-strategic scale, Acer identified the arena constraints upstream—in global component manufacturing, and downstream—in the local distribution competition. Organizations that controlled the arena constraints enjoyed significantly higher profit margins. Acer's upstream margins in the over-capacity zone of 'local assembly' were 2.5% while they equalled 35% for CPU manufacturers, 20% for ASIC, LCD and DRAM manufacturers, 15% for software manufacturers, and 10% for monitor and motherboard manufacturers. Similarly, margins for organizations controlling the downstream market constraint, including local sourcing, marketing and distribution, were significantly higher. Developers of e-commerce applications enjoyed margins of 15%. Acer's core competencies centred on the low-cost manufacturing of computer systems and peripherals and, as aiming to navigate the organization upstream required technological intellectual properties that it did not possess, it therefore created a joint venture with Texas Instruments. When the business took off Acer acquired Texas Instruments' share. Migrating downstream towards providing customer-focused solutions required the creation of a brand and the discipline to provide services. Acer has entered into several partnerships and recently created the Benq brand.
3. Philips faced a similar two-tower constraint structure in the electronics arena, where high profits correlated with control over the technology and marketing. As the gap between its core competencies and those required to generate value at the arena-constraint level was not perceived as unbridgeable, Philips selected an organic strategy consisting of entry into semiconductors with a focus on the chip level, the integration of speakers and displays where core competencies include components, semiconductors, IP, process technology and intensive

investment in R&D. Philips also moved downstream where core competencies included brand, distribution and services. It divested its tuner manufacturing activity, and refocused its competencies away from analogue to digital technology.

4. Microsoft abandoned its focus on software for micro computers to start manufacturing the X-Box, when it realized that the constraint in the home market lay around set-top box technology. Set-top boxes are perceived to be the gateway controlling all data entry into the house, including cable, internet and telephone connections, and are expected to evolve into becoming the controller of the home entertainment zone and eventually the server of the home network. Microsoft correctly estimated that it could bridge its core competence gap, that is, its lack of presence in the hardware business, by using external contractors to manufacture the product.
5. Facing a stagnant PC chip market, which it controlled with its Pentium brand, Intel's vision was to create a new market around portable PCs using Wi-Fi and later Xmax communications technologies. By changing the focus from work-stations to mobile PCs the constraint became battery operation hours, and the performance measure of processor GHz was replaced by energy consumption. The downstream constraint in the communications arena was a market constraint—convincing users to demand and use Wi-Fi technology. Though its Pentium chips were ensconced in the majority of functioning PCs, Intel had no core competencies in direct contact with downstream entities such as small businesses and end-users. In order to bridge the core-competence gap Intel joined forces with 'direct marketing resellers' (DMRs), and initiated a program that provided DMRs with a Centrino evaluation kit which included a Centrino-based notebook PC to be shipped to potential small- and medium-sized business customers.

5. A case study

The case study described in this section demonstrates the application of the five-step strategic and tactical constraint management process in a real-life international hi-tech firm. The presentation has been modified to disguise the firm and its market.

Company profile

- $40 million sales per year.
- 200 employees.
- Operates in the hi-tech electronics defence arena.
- Two product lines:
  1. Components for the electronics defence industry; and
  2. Subsystems for first-tier customers in the electronics defence industry.
- Strong marketing and sales department, active mainly in the USA.
- Rapid time-to-market R&D expertise.
- Strong influence on major standardisation committees.
- Excellent human resource management and atmosphere.
- Subcontracting of production activities.

- Sales to original equipment manufacturers (OEMs).
- In common with the electronics defence industry as a whole, the firm was concerned by the possibility of declining demand, which might have posed a threat to its cash flow.

Following multiple interview sessions with senior managers, reviews of financial, operational and marketing reports, and field observations, the following strengths, weaknesses, opportunities and threats were identified:

Strengths

- High sales growth rate.
- Sales to market leaders.
- Rapid multidisciplinary product development.
- Influence on standards committee.
- Strong sales department.
- Technological innovation and professionalism.
- Good engineering and production.
- Good interdisciplinary communications.
- High employee motivation.
- Sales and partnership with leading firms.
- Choice people working in a creative atmosphere.
- Technological leadership.

Weaknesses

- Insufficient R&D strategic gating.
- Product not differentiated enough.
- New markets require 'education'.
- The firm is losing money.
- No awareness of mergers and acquisition (M&A) potential.
- Excessive technological orientation.
- No access to the end-user.
- Small player in giants' playground.
- Product over-specification and over-design.
- High burn rate.

Opportunities

- The firm recognized four growth scenarios attainable by expanding into new markets and by developing new products for existing markets. For reasons of business confidentiality, we cannot disclose the actual markets.

Threats

- Component market in decline.
- Subsystem market delayed growth.
- Major customers may develop their own products.
- Unfavourable standard attributes.
- Unfavourable alliances between customers and competitors.

We now apply the five-step methodology to the case study:

1. *Identify the firm's constraints*. The firm operated in the hi-tech market and had the characteristic two-tower constraint architecture in R&D and in M&S.
2. *Identify the business arena's strategic constraint*. The firm's arena consisted of four basic players:

   - Fabs—manufacturing the components;
   - Component suppliers—designing and distributing components;
   - Systems manufacturers—assembling components into systems;
   - Integrators—providing the customer with a solution consisting of acquiring, installing and servicing several systems at the customer's site.

   The firm was a small component supplier that pioneered the technology in question. Its arena had a constraint at the integrator level. The customer seeks a low-cost solution and the integrator selects the systems that will reduce the overall costs of systems and installation.
3. *Perform the gap analysis between the firm's and the arena's constraints*. Given the firm's small size it stood no chance of controlling or acquiring a significant integrator. Another option considered was to be acquired by a large integrator. This option too did not materialize. The eventual solution was derived from the realization that the firm's supplier of manufacturing facilities—its fab, was a large international company, selling to the integrator level of the arena.
4. *Outline an action plan aligning the firm to its business arena*. One of the firm's two owners was assigned to the position of 'VP of business development' with the sole responsibility of leveraging the supplier's position in order to generate 'pull' from the arena's constraint level. The lead time for this strategy to bear fruit was estimated to exceed 24 months, which presented the need to raise cash to finance the firm's activities during this time span. Considering the alternatives, the company realized that it had to go public and defined an action plan to carry this through.
5. *Execute the action plan and monitor its effectiveness*. The firm's IPO was successfully realized. The firm's products were successfully incorporated into the fab owner's product catalogue. Integrators were exposed to the technology's unique contribution to their bottom line and trained in its operation.

6. Conclusions

TOC has a proven track record of success in manufacturing, marketing, R&D and project management, though its success derives mostly from tactical rather than strategic applications.

In the hi-tech industry we recognize two permanent bottlenecks: in research and development (R&D) and in sales and marketing (S&M). Exploiting these constraints will clearly increase shareholders' value in the short run. However, if the organization

wishes to continuously improve its position in the market it should look at strategic goals and strategic positioning.

This paper developed a framework to increase shareholder value by navigating the organization toward the business arena's constraints, a strategic change that requires bridging the gap between the firm's current core competencies and those required to generate value at the constraints.

References

Blackstone, J.H., Gardiner, L.R. and Gardiner, S.C., A framework for the systemic control of organizations. *Int. J. Prod. Res*, 1997, **35**(3), 597–610.

Coman, A., Koller, G. and Ronen, B., The application of focused management in the electronics industry—a case study. *Prod. Invent. Manage.*, 1996, **Second Quarter**, 65–70.

Coman, A. and Ronen, B., Production outsourcing: a linear programming model for the theory of constraints. *Int. J. Prod. Res.*, 2000, **38**(7), 1631–1639.

Cox III, J.F. and Spencer, M.S., The Constraints Management Handbook. In *APICS Series on Constraints Management*, 1998 (St. Lucie Press: Boca Raton, FL).

Goldratt, E.M., *The Haystack Syndrome: Sifting Information out of the Data Ocean*, 1990 (North River Press: Croton-on-Hudson, NY).

Goldratt, E.M., *It's Not Luck*, 1994 (North River Press: Great Barrington, MA).

Goldratt, E.M., *Critical Chain*, 1997 (North River Press: Great Barrington, MA).

Goldratt, E.M. and Cox, J., *The Goal*, 2nd revised edition, 1992 (North River Press: Croton-on-Hudson, NY).

Grosfeld-Nir, A. and Ronen, B., A single bottleneck system with binomial yields and rigid demand. *Manage. Sci.*, 1993, **39**(5), 650–653.

Holmen, J., ABC vs. TOC: It's a matter of time. *Manage. Acc.*, 1995, **76**(7), 37–40.

Mabin, V.J. and Balderstone, S.J., The World of the Theory of Constraints: A Review of the International Literature. In *APICS Series on Constraints Management*, 2000 (St. Lucie Press: Boca Raton, FL).

Pass, S. and Ronen, B., Management by the market constraint in the hi-tech industry. *Int. J. Prod. Res.*, 2003, **41**(4), 713–724.

Plenert, G., Optimising theory of constraints when multiple constrained resources exist. *Euro. J. Op. Res.*, 1993, **70**, 126–133.

Raz, T., Barnes, R. and Dvir, D., A critical look at critical chain project management. *Proj. Manage. J.*, 2003, **34**(4), 24–32.

Ronen, B. and Spector, Y., Managing system constraints: a cost/utilization approach. *Int. J. Prod. Res.*, 1992, **30**, 2045–2061.

Ronen, B. and Starr, M.K., Synchronised manufacturing as in OPT: from practice to theory. *Comp. Indust. Eng.*, 1990, **18**, 585–600.