Information technology in operations management: a theory-of-constraints approach

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The theory of constraints (TOC) has recently gained much success in its application to industrial and service organizations. This paper applies the TOC principles to the management of information technology (IT) in the organization. The paper creates a four tiered model for the application of the TOC to IT, starting with TOC's throughput-driven business policy; on with the seven step resource management methodology; through the cost/utilization capital investment technique; and concluding with the drum-buffer-rope production activity procedure. We draw a framework and a methodology showing how IT can be more effective using the TOC way of management. In order to systematically explore the location of the organization's constraints we adapt to the TOC a synthesis of three established management frameworks: stakeholder analysis, the value chain and Boston Consulting Group's portfolio analysis model.

1. Information technology, industrial engineering and the TOC

Management practices in industry as a whole are undergoing profound changes as the methodologies of total quality management (TQM), just-in-time (JIT), and the theory of constraints (TOC) are being absorbed. This revolution currently addresses the less studied domains of services and research and development (R&D). The information technology (IT) industry, intensive in R&D and with the profile of a services industry, is one of the more problematic to manage. Abdel-Hamid and Madnick (1991) indicate that '15% of all projects never deliver anything; that is, they fail utterly to achieve their established goals. Overruns of 100–200% are common. So many software projects fail in some major way that we have had to redefine 'success' to keep everyone from becoming despondent'.

Data from TRW, IBM and GTE (Pressman 1987) demonstrate that if the cost of fixing an error detected in the preliminary product definition stage is one unit, it costs three units to fix the same error during general design, six units during detailed design, ten units if the error is detected in the programming lifecycle stage, 60 units if detected in acceptance tests and 190 units if the error is detected while the system is operational. Though this data demonstrates the weaknesses of late error detection, a study by Daly (1977) states that 70% of design errors and 75% of programming errors are detected by the customer during the product acceptance and operation lifecycle stages. Considering the slow adoption of software engineering (IEEE 1990) and quality assurance standards (IEEE 1984), these figures demonstrate that the IT department needs a radical change in its management approach in order to improve the quality of its production process.

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The leading TQM thinkers differ in the scope set by their definitions of quality. Deming (1986) defines quality as: 'conformance to requirements'. This definition implies that requirements adequately describe the product or service. In many software applications written requirements fail to transmit the 'feel' of the system as well as other nonfunctional features. Juran's (1979) definition. 'Fitness to use' better reflects that the judge is the user and not the requirements. The distinction between satisfying the user and satisfying the requirements is a frequent stumbling block in supplier–customer relations. Taguchi's (1986) definition requires: 'correctness from the first time, uniformity, and user satisfaction'. This definition recognizes two entities: the supplier and the user. Correctness from the first time measures the volume of product rejects and rework required by the process. Uniformity of process output measures product related variables. User satisfaction measures the application of the product over time. Garvin's (1984) definition provides a list of eight dimensions: 'performance, features, reliability, conformance, durability, serviceability, aesthetics, perceived'. These attributes elaborate on the issue of user satisfaction. Garvin's definition is thus close to a marketing perspective of product quality from the customer's viewpoint, i.e. the value per dollar produced by the product.

While statistical quality control literature has a narrow focus on the measurement of tightly defined quantitative product attributes, TQM literature takes a 'total' perspective starting with the commitment of senior management, through customer perceptions of quality, on to the production or service process, finally focusing on the measurement of specific attributes. TQM thus spans from 'philosophical' guidelines on one extreme to 'pragmatic' statistical techniques on the other.

We suggest that insufficient interaction between general operations management professionals and IT management is a major obstacle in the rationalization of the IT industry. In this study we present a framework for the application of theory-of-constraints (TOC) principles (Goldratt 1988, Goldratt 1991, Fox 1988, Ronen and Starr 1990) to the management of information technology. The TOC methodology augments TQM principles by focusing TQM's across the board effort towards the organizational goal. Another contribution lies in TOC's specific heuristics for constraint management, capital investment and production scheduling. A partial application of TOC principles to IT was done by Floyd and Ronen (1989).

This study starts with the introduction of our hierarchical model of the TOC. A hierarchical model of IT activities is then presented, consistent with the TOC's top-down philosophy. We then use TOC methodologies to re-analyse case studies, operationalize TOC principles for the IT environment, and examine those areas of IT where the application of the TOC is particularly lucrative. The paper ends-up with a normative methodology of IT implementation according to TOC principles.

2. A hierarchical model of the TOC

The theory of constraints (TOC) is a top-down methodology that helps the manager to concentrate on those critical issues that constrain the corporation's throughput. We describe TOC applications at three levels in the organization. Constraint-focus is applied at the business policy level. Two TOC tools are applied at the production management level: cost/utilization for capital investment decision making and the constraint management cycle for production resource management. Finally, the drum/buffer/rope methodology is applied at the production floor operations level.

Constraint hierarchy	Constraint location		
	External supply	Internal production	External demand
Policy			
Capacity			
Dummy			

Figure 1. Constraint classification.

2.1. *Business constraint focus—TOC's business policy*

An established managerial policy is to focus efforts on a small number of critical success factors (CSF) (Rockart 1979). The TOC focuses on the localization of bottlenecks and other constraints in the business processes, with the objective of concentrating the managerial efforts of these bottlenecks. A constraint is any important entity that limits the system from achieving a better measure of performance versus its goal. In linear programming terminology it is a bounding constraint (Ronen and Starr 1990).

Policy makers determined to adopt the TOC philosophy make a long term commitment to a constraint management cycle (CMC) where they search for constraints, exploit the constraints identified, and elevate these constraints above other organizational resources. Constraint categories (Fig. 1) are classified by their location on the value chain (Porter and Millard 1985) and by their hierarchical level.

The first potential constraint on organizational throughput along the value chain is external supply—i.e. limitations on the availability of supplies. This is followed by the internal production constraint—i.e. limitations on the availability of production resources. Last along the value chain is the external demand constraint—i.e. limitations on the demand for products or services (Goldratt 1988, Ronen and Spector 1992).

Capacity is the most documented hierarchical constraint, reflecting actual limitations on supply, production or demand capacity. A raw material supplier who at the same time competes in other markets often creates a supply capacity constraint. Manufacturing resources or the number of tables in a restaurant are production capacity constraints. Market conditions frequently constrain the demand capacity.

Policy is a less documented hierarchical constraint, reflecting the outcome of management policy. The decision to purchase from local suppliers ignoring available international alternatives creates a policy supply constraint. The decision to eliminate extra hours across the board creates a policy production constraint, and deciding to reject small customers constitutes a policy demand constraint.

Dummy is the least documented hierarchical constraint, reflecting the outcome of petty problems. Economy in commission payments may result in a dummy supply constraint. Economy in the cleaning personnel employed by a major hospital, created a dummy production constraint on its operating rooms. Shortage in the number of incoming phone lines may create a dummy demand constraint.

Senior management is responsible for defining the system's goal at the organizational level, otherwise defined as the business mission. The next step is to translate the business mission into action at the operations management level. This is accomplished by TOC's seven step methodology.

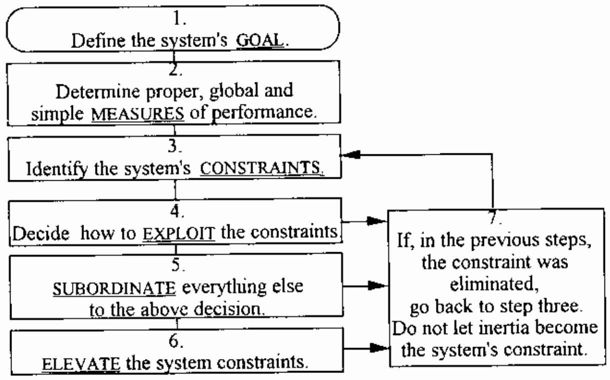

Figure 2. TOC's constraint management cycle.

2.2. *Constraint management cycle—TOC's resource management methodology*

The TOC business policy translates into a seven step methodology for the identification of business-unit constraints and their confrontation (Ronen and Starr 1990, Floyd and Ronen 1989). The methodology is verbalized as shown in Fig. 2.

This seven step methodology is performed at the frequency of short range planning–once or twice a year—by top and middle management. After the business mission is defined, the goal for each business unit is derived from it and defined explicitly. Measures of performance need to be proper measures of the actual throughput of the system. Measures should reflect the business unit's contribution to profits rather than some insignificant feature such as efficiency. Measures should take a global view of the business rather than a narrow sectarian perspective. Finally, performance measures should be simple enough to be applied by line workers in an intelligent mode. Simple measures provide the workers with information they can use, unlike sophisticated measures that produce accurate but useless data.

The first three steps—identification of the system goal; definition of measures; and identification of constraints, are the diagnostic part of the process. The next three steps—exploitation of the constraint resource, subordination of all other resources to it, and elevation of the constraint resource, provide the cure. The seventh step protects the business from the disastrous effects of inertia.

For example, one of Ford motor company's goals, as reflected by its annual report, is to make more money by achieving sustainable competitive advantage in the international automotive arena. Measures of performance include throughput, sales, market share, and after tax income. Ford's advertised statement 'quality is job one' reflects the company's recognition that quality constrains the achievement of sustainable competitive advantage. This implies that while other goals such as expanding production capacity, developing marketing networks, or reducing production costs are important, their importance is secondary. Ford exploits the quality constraint by focusing its restricted quality improvement resources on Taurus—Ford's flag product—where marginal profits would be maximized. Secondary goals such as the addition of new features to the Taurus are subordinated to the quality goal. They are undertaken only if they do not compete for resources with the quality goal and provided that their introduction will add to the product's quality. Ford's strategy is to focus its quality efforts on a different car every year. The quality constraint is elevated by training employees to focus on the quality issue, measure the quality of the tasks they perform, and improve the quality delivered by their system. TOC's techniques or the exploitation and elevation of the quality issue will, in the long term, remove quality from its status as the constraint to Ford and replace it by some other issue. Japanese manufacturers for example, consider that lack of customer excitement constrains the achievement of their long term strategic goals. Improving product quality, while still important, is of secondary importance to them. At some time in the future, Ford may achieve excellent quality, at the parts-per-billion (ppb) defect level, leaving its competition behind at the parts-per-million (ppm) defect level. Seeking better production quality, at that stage, would indicate that inertia has become the system's constraint. The seventh step, testing against inertia, is TOC's operationalization of Deming's (1986) process of on going improvement (POOGI) principle.

The TOC's constraint management cycle focuses on short term actions: the 'exploit' stage requires change of some machine operation practices; the 'subordinate' stage requires change of the operation practices of neighbour machines; the 'elevate' stage suggests the reintroduction of old equipment or the purchase of new machines. Cost/utilization is the TOC technique for facility layout design and for the prioritization of property, plant and equipment investments.

2.3. *Cost/utilization—TOC's capital investment technique*

Middle management determines the design of production lines and the business capital investment policy. Such decisions are taken in the medium to long range and demand major financial and organizational resources. The seven step methodology mentioned above institutes the cost/utilization technique (Borovits and Ein-Dor 1977, Ronen and Spector 1992) into the prioritization of production resource investments. The cost/utilization technique focuses on bottlenecks that constitute long term constraints rather than formulating the short-run decision problem. The TOC's cost/utilization technique bases capital investment decisions on the utilization of available resources vis-à-vis the marginal cost to increment resource capacity. The cost/utilization technique prescribes the optimal location of constraint resources in the production flow and helps policy makers to determine the location and size of buffers in the business flow.

After operations managers identify the constraints and determine the placement and capacity of buffers throughout the facility, a procedure is needed for the scheduling of production (or service) resources. Drum-buffer-rope (DBR) is TOC's production scheduling procedure.

2.4. *Drum-buffer-rope—TOC's production scheduling procedure*

DBR, the TOC resource scheduling procedure, is central for constraint management (Schragenheim and Ronen 1990, 1991). Scheduling decisions guarantee maximum exploitation of the constraint, protect the constraint from disruptions upstream and prevent non-constraint resources from exceeding their production limits. The constraint is the drum dictating the overall pace of the system. Buffers are used to protect the constraint from disruptions in preceding production systems caused by breakdowns, absenteeism, fluctuations in setup times, unreliable vendors, scrap or the unavailability of a certain resource while it is used for other jobs. Rope is the mechanism forcing all the parts of the system to work up to the pace set by the drum and no more.

3. TOC and IT

TOC and IT interact in three modes. First, IT-aiming applies TOC techniques to the organization. Constraints obstructing the organization's ability to accomplish its global goals are the objectives for IT to confront. Constraints in the organization's ability to produce timely information for decision makers, to communicate information about orders, and to retrieve stored data are particularly appropriate for IT to tackle. For example, interviews with Merrill-Lynch executives have suggested that the company uses information technology to elevate the communication bottleneck occurring between 9 am and 11 am between thousands of its clients (corporate and individual) communicating with forty account executives. Client trade instructions are communicated to the dozen traders on the trading floor for execution. The goal here is to take over as much trading business as possible. Merrill-Lynch will get more business when the communication between its account executives, its clients and its traders is improved. Even physical constraints such as machine capacity can be exploited better through the use of IT.

In the second type of interaction, IT-constraints, IT executives should apply TOC principles to expose the constraints of the IT function. These constraints restrict the application of IT to the organization's constraints. The typical IT department maintains a backlog of applications waiting to be developed. This backlog reflects the existence of bottlenecks in the application development process.

In the third type of interaction, computer-aided-TOC (CAT), information technology should be applied to facilitate utilization of TOC techniques in the organization. CAT includes computer monitoring of resource utilization rates, computerized resource scheduling according to the DBR technique, prioritization of purchasing decisions according to TOC's cost/utilization technique, and computer simulators training employees in the application of TOC principles.

In this article we deal with IT-aiming—how to identify the organization's constraints, and how to make information technology instrumental in tackling them.

3.1. *Constraints at the organizational level*

Coman's (1992) top-down methodology for the definition of an IT policy is consistent with the TOC top-down approach. We suggest that IT is an important tool towards the accomplishment of certain strategic objectives. The model identifies three dimensions: the organizational dimension spanning from a mission down to the individual IT project; the product lifecycle dimension beginning with the initiation of a project, through its development, all the way to maintenance and finally termination; and the professional IT dimension covering disciplines of hardware architecture, operating systems, knowledge and database management systems, telecommunications, user interface etc.

Executives applying the TOC to IT should start by defining a goal for the IT department. Since IT is an instrument subordinated to the organization, it is prerequisite to analyse the organization first. We start by stating the organization's mission, continue by defining measures of performance, and then locate the system's constraints. The next step is to implement TOC's seven step constraint identification and confrontation methodology. The role of information technology is to exploit the constraint, help subordinate non-constraint resources or elevate the constraint. Rockart (1979) in a similar approach prescribes the identification of critical success factors (CSF) that can be supported by IT. The issue facing practitioners is how to scan the organization for constraints in a systematic method. We hereby synthesize three techniques from the domains of organizational policy, systems theory and marketing, to produce a more specific constraint identification theorem under the paradigm that people create business processes to deliver products. Stakeholder analysis (Connolly *et al.* 1980) focuses on the groups of people influencing the system at the enterprise, corporate, strategic business unit or functional level; the value chain and value system models (Porter and Millard 1985) focus on business activities; and the Boston Consulting Group's model (Derek 1979) focuses on product and market types.

3.1.1. *Stakeholder analysis*

The stakeholder analysis (Fig. 3) model focuses on stakeholders—parties that influence the system's goal—such as customers, suppliers, unions, government agencies, stockholders and equity holders. It maps them on a two dimensional grid where the Y axis represents the stakeholder's influence over the system and the X axis represents the system's influence over the stakeholder. The model's objective is to identify those stakeholders that are a constraint to the system. Of particular interest are those stakeholders who influence the system and yet are not vulnerable to counter-measures available to the system. Such stakeholders are the system's present or future constraints. For example, ZIM (Coman 1993), an international shipping company, was a major client of a small British trucking company. The shipping company accounted for 40% of the trucking company's business, ultimately forcing a hostile takeover leveraged on its threat to take its business elsewhere. Stakeholder analysis performed by the trucking company maps the shipping company in the first quadrant—the stakeholder (the shipping company) has great influence over the system (the trucking company), but the system has little influence over the stakeholder. This example illustrates the importance of early identification of future constraints.

Stakeholder analysis scans the environment for potential constraints stemming from present instabilities. Looking forward extends the time horizon, adding a proactive attribute to the seven step methodology.

The manufacturing-automation-protocol (MAP) (1986) illustrates how purchasers of computerized production systems united to form a powerful and influential stakeholder group. General Motors (GM), General Dynamics (GD) and other major users of IT, realized from their analysis of Japanese industry, that work-in-process (WIP) was a constraint on the way to better quality and reduced cost. When headquarters got the complete picture of inventory and WIP levels at all facilities it became possible to exploit the WIP constraint. IT could elevate the communication bottleneck by

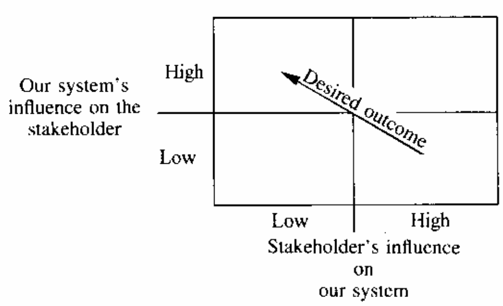

Figure 3. Stakeholder analysis.

networking facility computers together. The MAP was designed to bridge the current state of 'islands of automation'.

Up to that point, lack of connectivity between the products of different vendors did not constrain the market for data processing equipment. Vendors were therefore not motivated to create and adhere to a new universal standard. The solution was to organize a powerful user group committed to purchasing only MAP certified equipment. The user group applies its power to transfer its own communications constraint up the value system to its suppliers. IT vendors facing a new value-system where non-stardardization constrained their business, were induced to comply with the MAP standard.

From a vendor perspective the MAP users' group became a powerful stakeholder. The only way to exploit this constraint and stay in business with this stakeholder was to comply with the MAP standard.

A similar phenomenon occurred when the American Department of Defence (DOD) introduced the requirement that new software supplied to it should be written in ADA. This was the DOD's response to its inability to maintain applications written in a multitude of programming languages. The DOD took advantage of its position as a major stakeholder to defence contractors and created this policy constraint to reduce its maintenance expenses.

In recent years the DOD made one further step to require vendors to comply with its quality assurance standards (e.g. DOD-STD-2167A—Defence system software development and DOD-STD-2168—Defence software quality program). The Food and Drug Administration (FDA) uses its powerful stakeholder position to force suppliers to comply with its own software standards (FDA 1989). System vendors are constrained by these and other standards with which they have to comply, and must use stakeholder analysis to identify those stakeholders that restrict their business the most.

3.1.2. *The value chain*

The value chain model (Porter and Millard 1985) analyses the firm's business activities. The value chain creates a matrix listing primary activities that are directly associated with the product line on the X axis, and support activities that provide corporate support on the Y axis. Every cell describes the interaction between a primary and a support activity, as value is being added to the product being processed from left to right. In the example of a production firm (Fig. 4) the product flows from the engineering stage, through the manufacturing floor to the marketing distribution chain,

	Primary activities			
Support activities	Product engineering	Manufacturing and assembly	Marketing and distribution	Installation and service
Corporate planning				
Accounting and control				
Human resource management				
Technology development				

Figure 4. The value chain,

concluding with the service stage. Support activities include corporate planning in charge of strategy, accounting and control monitoring the product's flow through the system, human resource management responsible for quality trained and motivated staff, and technology development seeking and absorbing new technologies for the long term. Primary activities usually account for internal constraints while support activities account for policy constraints.

The value chain matrix identifies constraints and bottlenecks along the value added axis. The value system technique extends the axis to include supplier and customer value chains that are useful in the identification of external constraints. Consideration of supplier and customer value chains is consistent with Deming's (1986) prerogative to mobilize suppliers and distributors as part of the total quality effort, blurring the firm's boundaries. While the value chain targets what the TOC terms 'internal constraints' the value system targets 'external constraints'.

Two important performance measures of primary activities are lead time—the time from the moment the activity is initiated until its completion, and 'right-first-time'—the proportion of tasks that were correct from the first time. Long lead times constrain the system's responsiveness to customer demand and to changes in the market-place, constituting a bottleneck on the firm's competitiveness and profitability. A high proportion of defects requires rework, limiting the system's capacity and introducing internal bottlenecks. Many defects generate customer dissatisfaction and reduce demand, forming an external demand bottleneck. Digital Equipment Corporation (DEC) (Hayes-Roth *et al.* 1983) illustrates how expert system technology can reduce lead times and defect proportion. DEC sales personnel and order processing clerks registered customer orders for a wide variety of VAX system configurations, applying a broad range of information located in several manuals. Manually, it took up to three days to configure orders, only 80% of which were correctly configured. The configuration problem constrained DEC's ability to expand into the upper end of the market where systems were even more complex to configure. It also constrained DEC's ability to introduce new technology due to the long training lead times. The constraint was thus located at the intersection of marketing distribution on the primary activity dimension, and technology development on the support technology dimension. DEC's introduction of the expert-system-configurator (Xcon) reduced order configuration time to between three and five minutes, reducing rework by half to 10% of orders. Likewise, the service and human resource bottleneck is better exploited as clerks liberated from routine orders concentrate on more complex tasks.

Otis Elevator (Cash *et al.* 1988) is an example of a company supporting its product throughout the value chain from design and manufacturing to installation and service. By 1985 North American new elevator equipment sales represented $1 billion while service represented approximately $2 billion. Facing a competitive industry, Otis identified quality of service as the primary activity constraining its market share. It identified technology development as the secondary activity capable of exploiting that constraint. At the intersection of service and technology, Otis developed Otisline—a database used to monitor and control the service business, and remote elevator monitoring (REM) a microprocessor based elevator monitoring the elevator's control system and its performance statistics. 'REM could be enhanced by having the elevator communicate to a central computer that would interpret problems being experienced by the elevator, determine the cause of the problem, transmit a message to the Otisline system, and result in the dispatch of the service mechanic.' REM initiates preventive technician calls prior to the occurrence of actual problems, taking advantage of the customer's value chain where elevator failure in general and being 'trapped-in-an-elevator' in particular are very sensitive issues.

Intel Corporation is at the forefront of VLSI technology development. Incorrect management of its human resources would constrain its status as an industry leader. Human resource management is particularly complex at its research and development laboratories. Intel prescribes a set of managerial duties to support its corporate culture. These duties load R&D managers with daily, weekly, quarterly and annual tasks. The time bottleneck is identified at the intersection of product engineering—on the primary activity dimension, and human resource management—on the support activity dimension. Due to their time constraints, managers either comply with their human resource management responsibilities, at the expense of their technical duties, or reduce the quality of their managerial performance. Intel's managerial support information system (MSIS) (Gavish 1991) helps managers to plan, monitor and aggregate human resource management tasks. As the time constraint is exploited, the quality of managerial tasks rises.

While the value chain targets what the TOC terms 'internal constraints', the value system targets 'external constraints'. The analogous treatment of internal and external processes is consistent with TQM philosophy viewing the organization as a chain of suppliers and customers and treating supplies and customers as extensions of the organization.

3.1.3. *Product portfolio*

The Boston Consulting Group (BCG) (Derek 1979) model assists business units in their management of product portfolios to exploit the cash flow constraint. The core concern of the BCG model is that as the product goes through its life cycle its cash flow profile changes. In the earlier stages, the product is hungry for cash as it tries to gain market share. In contrast, mature products provide positive cash flow. The model refines the simplistic life cycle issue by introducing the corporate strategy dimension. Products are mapped on a two by two matrix where the X axis indicates the product's competitive position as measured by its relative market share and the Y axis represents the attractiveness of this market operationalized as the growth rate or maturity of the market. Four stereotypes represent the product's life cycle through the market: Question Mark, Star, Dog and Cash-cow (Fig. 5).

The BCG model prescribes a distinct top-down propagation of constraints for the business unit, treating cash flow as the supreme constraint. The business unit's product portfolio uses Cash-Cow products and liquidation of Dog products to elevate the cash flow constraint. Question-mark and Star products are selected to best exploit the

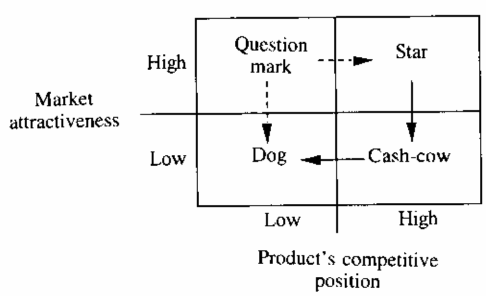

Figure 5. Boston Consulting Group—product portfolio matrix.

constraint and to produce the Cash-cows of the future. Once portfolio selection is complete, each product category has a different set of constraints and performance measures.

The performance of Question-mark products is measured in terms of market share growth. The constraint to gaining market share is the firm's ability to identify market needs and to adapt the product to these needs. IT exploits this constraint (Ahituv and Neumann, 1990) by permitting shorter response lead times through technologies such as computer-aided design, computer-aided manufacturing, and marketing databases. In general, software intensive products are easier to adapt to market demands than other products. For example, Fiat's new computer controlled automatic transmission was designed to provide no traction when the accelerator was not depressed. Realizing that customers accustomed with conventional automatic transmissions were expecting some traction, Fiat was able to replace the controller chip within months. Such a short response lead time is impossible and much more expensive with mechanical transmissions. The informal management style characteristic of Question-mark products is particularly amenable to end-user systems accessible throughout the organizational hierarchy. These are lightweight local applications that support specific production functions. The BCG portfolio model prescribes a certain quantity of Question-mark products. IT supporting collaborative work elevates the firm's creative process, facilitating the generation of new product ideas.

The performance of Star products is measured by sales growth. Distribution networks are the bottleneck constraining sales growth. Since information about prices, product features and market demand constitutes a major component of distribution networks, IT can elevate the distribution capacity constraint. By enabling distributors to place orders directly into the computer system and to monitor delivery status in a do-it-yourself mode, time lost to intermediary handling of orders is saved, the quality of service is improved and the distribution constraint is elevated. Question-mark product lines are not characterized by control applications of IT. Star products, constrained by the high sales growth rate, benefit from the introduction of control systems. This is the stage when production and sales applications are introduced to exploit the control constraint.

Cash-cow products are measured by the sales income that they produce for the business. The Cash-cow is a market leader and profits are constrained by competing products. IT helps protect the market leader status by attaching the customer and by setting entry barriers for new competitors. Companies providing customers with information processing services may achieve longer term brand loyalty from the client to their Cash-cow product. Examples include banks providing small businesses with payroll processing services, telephone companies providing detailed cost information, etc. IT also increases the operational efficiency, to improve exploitation of the Cash-cow. Examples include MRPII, integrated accounting control systems, etc.

Dog products are measured by their liquidation value. Loss of exploitable resources as part of the liquidation constrains the profitability of the transaction. IT helps test for interaction effects between the Dog product and other products to test whether the Dog can be liquidated without damaging the firm's overall product offering. This is the case in service markets where a Dog service is an integral part of the firm's operation. For example, third party collision insurance, not very profitable in itself, opens the potential for the client's other insurance business. Likewise, a supermarket allocates some shelf space to not very profitable products, just to maintain a full product offering. Decision support systems can provide information to better assess the value of the business to prospect buyers and thus elevate the sale values to the firm.

4. Conclusions

The TOC offers a comprehensive methodology for the harnessing of IT to the organization's goals. This article linked three domains: TOC, strategic models and IT.

We describe the TOC at four levels from business policy at the top, through the seven step operations management focusing methodology, and cost/utilization investment decision-making technique, down to the drum-buffer-rope production scheduling methodology.

We demonstrate how stakeholder analysis, the value chain and system and the BCG product portfolio model can be mobilized to produce a systematic search for constraint domains. These constraints are set as targets for the IT activity.

These tools extend the TOC to examine potential future constraints in addition to current constraints, suggest exploitation of competitor constraints to establish barriers for entry into the market, and offer a hierarchy of constraints starting from the cash flow constraint at the corporate level down to the constraints restricting the contribution of IT to the organizational mission.

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