Volume 6, Issue 7, July 2016 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Focussing on Quality Improvement with Theory of Constraint (TOC)

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Abstract: This study assesses penetration of Theory Of Constraint principles into quality for maximization of profit. Considering the various types of organizations (viz. production, service and project industries), quality has various dimensions – reliability, maintainability, integrity, safety, responsiveness, assurance, tangibility, psychology and empathy. Theory of constraint is a management philosophy which focuses on system improvement by identifying and exploiting number of constraints or one constraint of any manageable system. Whenever we talk of quality improvement, TQM, Six Sigma, Lean Manufacturing, TPM, International quality standards come in picture. It appears attractive to make quality improvements wherever it is needed, although economic reality indicates limited availability of resources. Even efforts to improve all organization processes in a single go, actually detriment your ability to meet customer's need and provide your product at lower cost. TOC focuses on one specific constraint at a time requires localized efforts on the basis of logical thinking and communication tools. However quality improvements with the help of TOC reinforce strong positive change in the process and it becomes continuous on going improvement. It establishes truly systematic entity in operation.

Keywords: Theory of constraint(TOC), Quality improvement, Constraint

I. THE EXPANDING VALUE OF QUALITY

For companies that manufacture or operate high value capital equipment, quality is a fact of life. Equipment requires quality. Parts wear out & break & need to be replaced or repaired. The more expensive the product & its capital function, the more important is service in its life cycle.

Today, companies are beginning to view quality as a means to generate value, rather than just a necessary expense. Quality offers untapped potential for competitive differentiation & profitability. Companies that deliver the best quality at the lowest cost will benefit from near term saving as well as improved customer loyalty in the long run. As the word 'quality control' indicate the discipline's objective to reduce defects clearly, but at the time its methods were obscure & it was not clear what had to be done in order to achieve the objective. It has developed into systematic method of improving quality from product planning thro' design, production & sales to after sale service.

Quality control is regarded as a management method centered on quality & many people are even calling it a resolution in business management. The word revolution is used for following reason. Quality control is management technique that originated in US & was introduced into Japan after Second World War. However there is a difference between Western style & Japanese style quality control. Western style aims to control quality & Japanese focuses quality thro systematic, continuous improvement activities.

The quality of a company's quality control program is judged from the following two viewpoint.

- **Product Quality**:: Whether the products or services satisfy customer requirements i.e. degree of customer satisfaction.
- **Process Quality**:: Whether the products or services are supplied economically with process efficiency.

In quality control from the purchaser's standpoint, the first question is how to inspect product quality. Various sampling plans & inspection methods may be devised, but it is impossible to assure the quality of sophisticated technical products by inspection alone, to achieve reliable quality, the supplier must be required to build in quality thro' the process. This means that purchase contracts not only have standards for a final product but also have to stipulate design methods, production methods & control methods in the form of quality control requirements. As a part of business management, quality control is a management tool with tremendous potential & superb results can be obtained if suppliers take the lead

& implement it on their own initiative. It's full potential can not be realized if it is practiced simply in accordance with purchaser's requirements because it then becomes static & lacks development potential.

As value of quality expands, quality itself is being redefined. It's no longer considered a single business function, but rather a web of interconnected processes that integrate with other enterprise systems at many points. Quality is not merely about having the right part at right place at right time with right service, but also about deploying it to the best field location, scheduling the right engineer to install it & repairing or refurbishing or remanufacturing the part replaced.

> ***Constraints are neither good nor bad.***
> ***They are fact of life.***

Managing today's expanding quality enterprise requires a new approach to quality management. **Theory Of Constraint** can be the answer to it.

TOC:: Theory Of Constraint

TOC is a management philosophy that has been effectively applied to manufacturing & service industry in terms of processes & procedures to improve organizational effectiveness. TOC emphasizes that any manageable system is limited in achieving more of its goal by a very small number of constraint & that there is always at least one constraint.

> ***There is really no choice in the matter.***
> ***Either you manage the constraints or the constraints will manage you.***
> ***The constraint will determine the output of the system whether they are acknowledged & managed or not.***

TOC's Intervention In Production Sector

TOC focuses improvement efforts where it will have the greatest immediate impact on bottom line & provides a reliable process that insures Follow Through.

According to **Dr Eliyahu M Goldratt**, TOC is applicable to all those organizations who can be measured & controlled by varying three measures VIZ. **Throughput, Operating Expense & Investment.**

II. ORGANIZATION AS A CHAIN

An organization can be compared to a chain. The activities that constitute a business chain of dependent events. For eg. We do not ship parts unless they are packed & we do not pack parts until they are manufactured. The output of organization is achieved thro' the synchronized efforts of various functions. The output is limited by weakest area. The strength of the chain is determined by the strength of weakest link. What should be done to improve the output of an organization?

- Improve all functions or all links?
- Strengthen the weakest function or weakest link?
- Common sense solutions?
- Impact on overall organizational effectiveness by improving performance in one department?

The global improvement is not the sum total of all the local improvements. Often organizations spread their energies thin in all areas in order to improve the output. In the TOC world optimizing a sub system would sub optimize the whole process.

A PROCESS OF ONGOING IMPROVEMENT [POOGI]

1. **Identify The Constraint.**
   - The constraint can be internal or external to your organization. Internal constraint is preferable.
   - The constraint can be tangible or intangible. For eg. It could be an equipment or a policy.
   - Invariably (>95%) the constraint is a policy.
2. **Exploit The Constraint.**
   - Get the most possible out of the existing capacity of the constraint.
   - Utilization at the constraint is critical.
   - The step is often treated indistinguishable from **Step 4** (Elevating), but it is vital to *Exploit* before elevating.
3. **Subordinate All Policies, Decisions & Procedures To Exploiting The Constraint.**
   - The focus is on being a high quality, reliable supplier to, or customer of the constraint.
   - Utilization & efficiency at the con-critical resources must not be measured.
   - This step is often missed. And thereby the majority of financial benefits of TOC is lost. This is the toughest step.
4. **Elevate The Constraint For More Output.**
   - If more capacity is required after steps 2 & 3 to meet the market requirements, increase it through capital investment, outsourcing, or off-load the constraint by defining alternative routings, processes or design.

- Often times, exploitation & subordination are sufficient to reach sufficient to reach the needed output. Do not increase the investment too soon.

5. **Avoid Inertia. If In A Previous Step Constraint Shifts, Start The Cysle Once Again.**
   - If in a previous step the constraint is broken, go back to step 1. Do not let inertia be the system constraint.
   - Often times when a new constraint is identified, it is necessary to change the policies you have just made!
   - The long term strategic application of TOC does not call for continuous removal of constraints, rather, the idea is *to choose where the constraint should be* in order to best exploit the market opportunities, and *then keep it there!*

CONSTRAINT IDENTIFICATION

CASE 1::MARKET CONSTRAINT

- Do you have more than 50% of world market?
- Yes. You do have a market constraint. Solution-New Product Development
- No. you do not have market constraint. However you may have order constraint.

CASE 2::ORDER CONSTRAINT

- Do you deliver 95% of the orders on time in full?
- Yes. You do have order constraint.
- No. you do not have order constraint.

CASE 3::SUPPLY CONSTRAINT 1

- Do you get 95% of the time the raw material & components on time?
- Yes. You do not have supply constraint. **The constraint is in your opinions.** Solution-implement *Drum Buffer Rope*.
- No. You may have a constraint in supply.

CASE 4::SUPPLY CONSTRAINT 2

- Do you pay 95% of the time your suppliers on time?
- No. You have cash constraint.
- Yes. Your constraint could be in supply.

CASE 5::SUPPLY CONSTRAINT 3

- Do you buy more than 50% of the world buying?
- No. You do not have a supply constraint. **The constraint is in your supplier management.**
- Yes. **You have a supply constraint.** Solution- develop new suppliers.

TOC'S MEASURING PARAMETERS

Once we have identified our Goal, we need to define the measures for its progress, goal of making money now & in future. Generally accepted measures are efficiency, machine utilization, Net Profit(NP), Return On Investment(ROI), Cash Flow etc.TOC does not question the validity of these measures. However it does question the usefulness of these measures as operational measures. For the average employee, seeing the effect that any given action has on NP or ROI is almost impossible. As a result we have created local measures like efficiency & utilization because we believe that they are linked to NP or ROI.

TOC operational measures are

1. **Throughput ("T").** The rate at which *Contribution Rupees* are coming into organization.
   - Only Rupees generated by the system are counted ,eg. Rupees spent on purchasing raw material or services do not count as they are passed on to your suppliers.
   - T = (Net Selling Price – all truly variable costs)
   - **Producing to stock is not Throughput.**
2. **Investment("I")** All the money currently tied up inside the system.
   - All the inventory in raw material, WIP, or in Finished Goods.
   - Money blocked in plant & machinery.
   - Receivables are also part of "I"
   - All inventories are *not a liability.* Of course the entire inventory is also *not an asset.*
3. **Operating expense("OE")** All the *money* that system spends on converting inventory into throughput.
   - All the expenses are clubbed together as "OE" and are thought as fixed.
   - All employee expenses are part of "OE".
   - Allocation of fixed costs often leads to local optimization that in turn leads to global sub-optimization.

Is there any link between TOC Operational Measures "T", "I", "OE", & conventional measures as "NP", "ROI" & "Cash Flow"?

- NP = T – OE
- ROI = NP / I = (T – OE)/I

Effect on NP, ROI & Cash Flow when we improve either "T", "I" or "OE", keeping other two as constant

- If we increase T, keeping I & OE constant, NP = (T – OE) improves, ROI = NP / I improves & so does the cash flow.
- If we decrease I, keeping T & OE constant, NP improves due to reducing cost, ROI improves & of course cash flow improves.
- When we reduce OE keeping T & I constant, NP, ROI & cash flow improve.
- Improving Throughput, Investment & Operating Expense has a positive co-relation with improving NP, ROI & cash flow.
- Throughput, Investment & Operating Expense are valuable operational measures that can guide our day to day actions to making money now & in future.

Focussing areas

- Increasing Throughput
- Decreasing Investment OR
- Reducing Operating Expense

III. THE QUALITY VALUE PROPOSITION

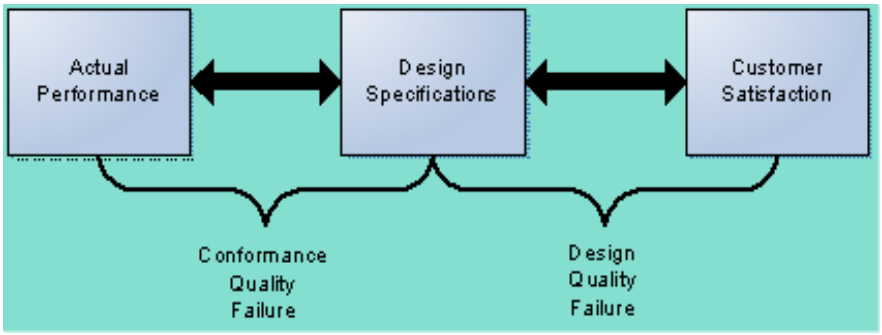
The total features and characteristics of a product or a service made or performed according to specifications to satisfy customers at the time of purchase and during use. A quality focus reduces costs and increases customer satisfaction.

> ***Cost reduction strategies have paid off for many…until now***
> From 1992 through mid 1996, 163 CEO's of the Fortune 500 must have been working on the wrong strategies, because of which they are fired.

Focusing on the quality of a product will generally build expertise in producing it, lower the costs of making it, create customer satisfaction for customers using it, and generate higher future revenues for the company selling it. Two basic aspects of quality is

- **Design Quality** – Refers to how closely the characteristics of a product or service meet the needs and wants of customers.
- **Conformance Quality** – Refers to the performance of a product or service relative to its design and product specifications.

Quality and Failure



Four Perspectives of the Balanced Scorecard

- Financial
- Customer
- Internal Business Process
- Learning and Growth

The Financial Perspective:

Costs of Quality (COQ)::Four Categories of Quality Costs:

- Prevention Costs – incurred to preclude the production of products that do not conform to specifications.
- Appraisal Costs – incurred to detect which of the individual units of products do not conform to specifications.
- Internal Failure Costs – incurred on defective products before they are shipped to customers.
- External Failure Costs – incurred on defective products after they are shipped to customers.

Elements of Costs of Quality Reports

Prevention Costs	Appraisal Costs	Internal Failure Costs	External Failure Costs
Design engineering	Inspection	Spoilage	Customer support
Process engineering	Online product manufacturing and process inspection	Rework	Manufacturing/ process engineering for external failures
Supplier evaluations	Product testing	Scrap	Warranty repair costs
Preventive equipment maintenance		Machine repairs	Liability claims
Quality training		Manufacturing/ process engineering on internal failures	
Testing of new materials			

Determining COQ using Activity Based Costing

- Identify the Chosen Product.
- Identify the Product's Direct Costs of Quality.
- Select the Cost-Allocation Bases to Use for Allocating Indirect Costs of Quality to the Product.
- Identify the Indirect Costs of Quality Associated with each Cost-Allocation Base.
- Compute the Rate per Unit of Each Cost-Allocation Base Used to Allocate Indirect Costs of Quality to the Product.
- Compute the Indirect Costs of Quality Allocated to the Product.
- Compute the Total Costs of Quality by Adding All Direct and Indirect Costs of Quality Assigned to the Product.

The Customer Perspective:

Nonfinancial Measures of Customer Satisfaction include:

- Surveys on satisfaction
- Market share
- Number of defective units shipped to customers
- Number of customer complaints
- Product fail rates
- Delivery delays / On-time deliveries

The Internal Business Process Perspective

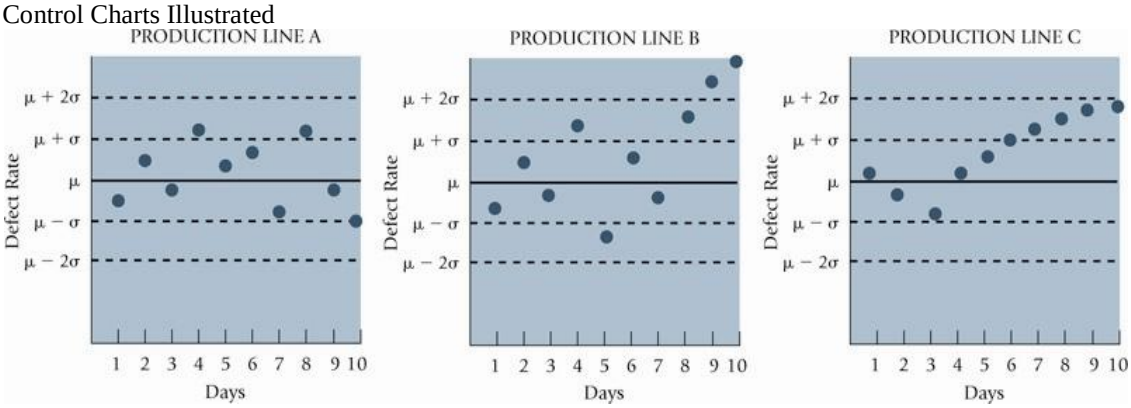
Three techniques for identifying and analyzing quality problems:

- **Control Charts**
- **Pareto Diagrams**
- **Cause-and-Effect Diagrams**

Control Charts

- Statistical Quality Control (SQC) is a formal means of distinguishing between random and nonrandom variations in an operating process
- Control Charts are a part of SQC.
- Control Charts
- Control Charts are a graph of a series of successive observations of a particular step, procedure, or operation taken at regular intervals of time.
- Each observation is plotted relative to specified ranges that represent the limits within which observations are expected to fall.
- Only those observations outside the control limits are ordinarily regarded as nonrandom and worth investigating

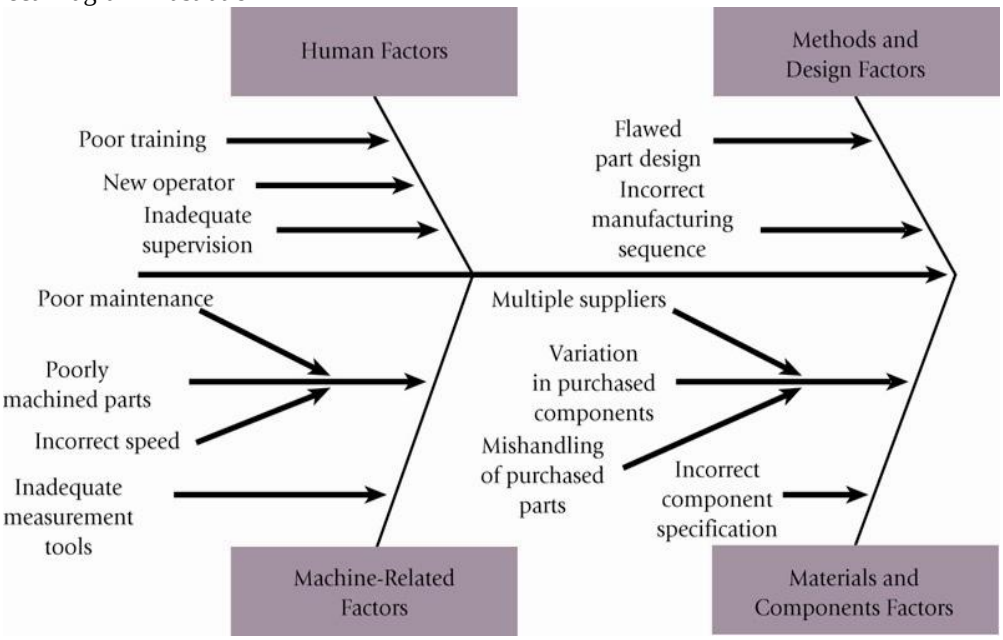
Quality Control Charts Illustrated



Pareto Diagrams

- Observations outside control limits serve as inputs for Pareto Diagram
- Pareto Diagram – a chart that indicates how frequently each type of defect occurs, ordered from the most frequent to the least frequent
- Identifies potential causes of defects
- Problems identified by the Pareto Diagram are analyzed using cause-and-effect diagrams
- Also called Fishbone Diagrams because they resemble the bone structure of a fish

Cause-and-Effect Diagram Illustration



Nonfinancial Measures of Internal Business Process Quality

- Percentage of defective products
- Average repair time at customer site
- Percentage of reworked products
- Number of different types of defects found
- Number of design and process changes made

The Learning & Growth Perspective for Quality

- Employee turnover ratio
- Employee empowerment – number of processes in which employees have the right to make decisions without consulting supervisors
- Employee Satisfaction
- Employee Training

Advantages of COQ (Financial) Measures

- COQ focuses managers' attention on the costs of poor quality
- COQ measures assist in problem solving by comparing costs and benefits of different quality-improvement programs and setting priorities for cost reduction
- COQ provides a single, summary measure of quality performance for evaluating tradeoffs among the costs of prevention, appraisal, internal failure and external failure

Advantages of Nonfinancial Measures of Quality

- Nonfinancial measures of quality are often easy to quantify and understand
- Nonfinancial measures direct attention to physical processes and to areas that need improvement
- Nonfinancial measures provide immediate short-run feedback on whether quality-improvement efforts have succeeded
- Nonfinancial measures are useful indicators of future long-run performance

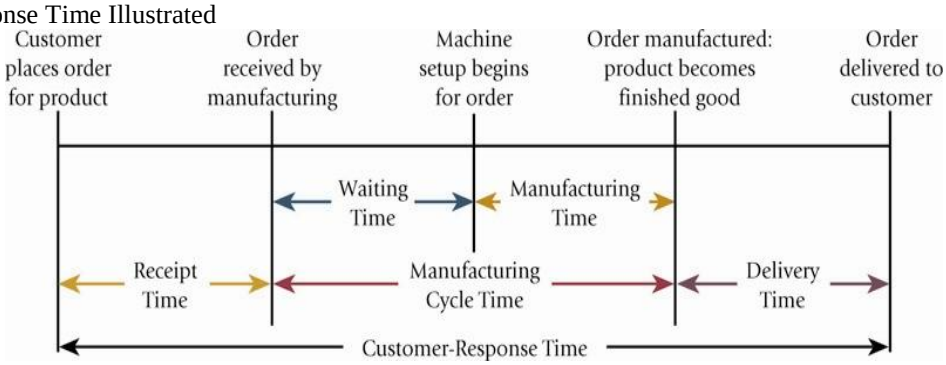
Time as a Competitive Tool

- Companies view time as a driver of strategy
- Operational measures of time: how quickly firms respond to customers' demand for their products and services, and their reliability in meeting scheduled delivery dates

Two Operational Measures of Time

- **Customer-Response Time** – how long it takes from the time a customer places an order for a product or service is delivered to the customer
- **On-Time Performance** – delivering a product or service by the time it was scheduled to be delivered

Customer-Response Time Illustrated



Time Drivers

- Time Driver is any factor in which a change in the factor causes a change in the speed of an activity.
- Two Time Drivers:
  - **Uncertainty about when customers will order products and services**
  - **Bottlenecks due to limited capacity. A bottleneck occurs in an operation when the work to be performed approaches or exceeds the capacity available to do it**

Simple Time Presumptions

- When demand uncertainty is high, some unused capacity is desirable.
- Increasing the capacity of a bottleneck resource reduces manufacturing lead times and delays.
- Reduce set-up times.
- Invest in new equipment to increase capacity.
- Careful scheduling of production.

IV. THEORY OF CONSTRAINTS AND THROUGHPUT- CONTRIBUTION ANALYSIS

The Theory of Constraints (TOC) describes methods to maximize operating income when faced with some bottleneck and some non bottleneck operations. TOC focuses on a short-run time horizon and assumes that operating costs are fixed costs. Throughput Contribution equals revenues minus the direct material cost of the goods sold.

If you choose the wrong projects it's possible to make big "improvements" in quality and productivity that have absolutely no impact on net profit. One approach uses the theory of constraints (TOC) to determine which project(s) to pursue.

Every organization has constraints, which come in many forms. When a production or service process has a resource constraint, the sequence of improvement projects should be identified using very specific rules. According to Eliyahu M. Goldratt, the rules are:

1. Identify the system's constraint(s). See if you can identify the system constraint in Figure 1. The answer is printed at the end of this column. This fictitious company produces only two products, P and Q. The market demand for P is 100 units per week, and P sells for $90 per unit. The market demand for Q is 50 units per week, and Q sells for $100 per unit. Assume that A, B, C and D are workers who have different, non interchangeable skills and that each worker is available for only 2,400 minutes per week (8 hours per day, 5 days per week). For simplicity, assume there's no variation, waste or similar problems in the process.

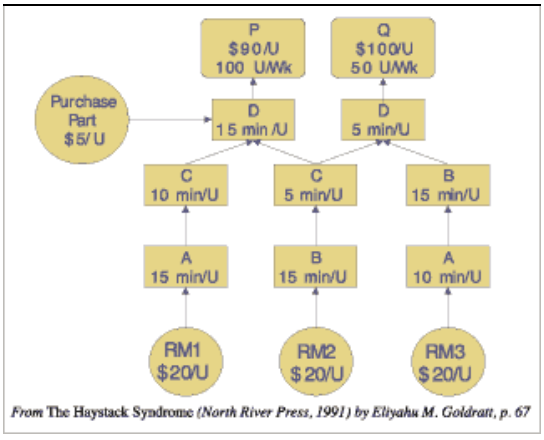


Figure 1: A Simple Process with a Constraint

2. Decide how to exploit the system's constraint(s). Look for quality projects that minimize waste of the constraints. For example, if the constraint is the market demand, we should look for quality projects that provide 100-percent on-time delivery. If the constraint is a machine, focus on reducing setup time, eliminating scrap and keeping the machine running as much as possible.

Improvement Strategies	***Realistic potential of bottom line improvement strategies***
Cost cutting	1-10%
Productivity	5-20%
Technology	10-50%
Throughput	50-5000%

Mac Ross, Ross & Company, from a speech at a public seminar, February 2, 1997.

3. Subordinate everything else to the decision made in step 2. Choose quality projects that maximize throughput of the constraint. First choose projects to eliminate waste from downstream processes; once the constraint has been utilized to create something, we don't want to lose it to some blunder downstream. Then choose projects to ensure that the constraint is always supplied with adequate non defective resources from upstream processes. We pursue upstream processes last because they have slack resources, so small amounts of waste upstream that are detected before reaching the constraint are *not* damaging to throughput.

4. Elevate the system's constraint(s) . Elevate means "Lift the restriction." Often the projects pursued in steps 2 and 3 will eliminate the constraint. If the constraint continues to exist after performing steps 2 and 3, look for quality projects that provide additional resources to the constraint. These might involve, for example, purchasing additional equipment or hiring additional workers with particular skills.

5. If, in the previous steps, a constraint has been broken, go back to step 1. If the constraint has been lifted, you must rethink the entire process. Returning to step 1 takes you back to the beginning of the cycle.

Table 1: Process Scrap rates

Process	Scrap Rate
A	8%
B	3%
C	5%
D	7%

The TOC approach is superior to traditional total quality management project selection. For example, consider the data in Table 1. If you apply Pareto analysis to scrap rates, you would begin with quality projects that reduced the scrap produced by Worker A. In fact, assuming the optimum product mix, Worker A has about 25-percent slack time, so the scrap loss can be made up without shutting down Worker B, who is the constraint. The TOC would suggest that the scrap loss of Worker B and the downstream processes C and D be addressed first, the exact opposite of what Pareto analysis recommends.

THE "THROUGHPUT WORLD"

- Increasing "T" is unquestionably #1 because it has the greatest potential impact on the bottom line.
- Decreasing "I" is the next priority as excess WIP & Finished Goods jeopardize future Throughput.
- Reducing "OE" is #3 as it often endangers protective capacity that in turn jeopardizes future Throughput.

FOUR STEPS IN MANAGING BOTTLENECK OPERATIONS

- Recognize that the bottleneck operation determines throughput contribution of the entire system.
- Identify the bottleneck operation by identifying operations with large quantities of inventory waiting to be worked on.
- Keep the bottleneck operation busy and subordinate all non bottleneck operations to the bottleneck operation.
- Take actions to increase the efficiency and capacity of the bottleneck operation. The objective is to increase the difference between throughput contribution and the incremental costs of increasing efficiency and capacity.

Methods to Relieve Bottlenecks

- Eliminate idle time at the bottleneck operation.
- Process only those parts or products that increase throughput contribution, not parts or products that will remain in finished goods or spare parts inventories.
- Shift products that do not have to be made on the bottleneck operation to non bottleneck processes, or to outside processing facilities.
- Reduce setup time and processing time at bottleneck operations.
- Improve the quality of parts or products manufactured at the bottleneck operation

THE BALANCED SCORECARD AND TIME-RELATED MEASURES

Financial Measures

- Revenue losses or price discounts attributable to delays
- Carrying costs of inventories
- Throughput contribution minus operating costs

Customer Measures

- Customer-response time
- On-time performance

Internal Business Process Measures

- Average manufacturing time for key products
- Idle time at bottleneck operations
- Defective units produced at bottleneck operations
- Average reduction in setup time and processing time at bottleneck operations

Learning and Growth Measures

- Employee satisfaction
- Number of employees trained in managing bottleneck operations

Comparison between routine quality projects & TOC based quality initiatives

QUALITY	TOC
Quality works primarily at the level of a local link of a system's chain, and it's interaction with it's immediate supplier and customer processes.	TOC works primarily at the level of the chain, driving focus to the weakest link and then to the linkages between that constraint and other aspects of the system.
Quality, with it's data-based philosophy is great for solving technical issues that are subject to quantitative analysis.	TOC, with it's logic-based tools, provides strength in dealing with what might be considered "qualitative" analysis, helpful for dealing with "rock and hard place" dilemmas.
Quality approaches root causes with traditional "quality tools" like the fishbone diagram, with searches for many possible root causes of a single problem. This is very appropriate for relatively simple (designed) systems, but is inappropriate for complex, evolved, or self-referencing organizational systems.	TOC's approach to root cause analysis, centered in the Thinking Process known as the Current Reality Tree, starts with a range of diverse problems with which the system suffers and then builds rigorous cause-and-effect logic to identify one or very few deep causes at the root of them all.
Quality focuses on minimizing variation associated with the processes that get put under it's microscope.	TOC first strives to build "logistical" processes that are robust enough to deal with current variation, and through concepts like the Five Focusing Steps and "buffer management," identify where attacks on variation will give us the biggest bang for the buck.
The Quality approach to value for the customer is closely tied to assuring that products and services delivered meet or exceed specifications or requirements of those outputs.	TOC extends its use of the constraint to define maximum value for a market segment or customer in terms of the constraint or core problem of their system. Having identified that, positioning one's product and offering in terms of assisting with that critical issue is the main route to increased value.

V. CONCLUSIONS

As a management philosophy, TOC has broad applicability & this work has explored its application to quality. Contributions have been made by exploring the penetration of TOC principles into quality & by developing & validating an instrument for that exploration. The instrument captured the principle underlying each of the three TOC paradigms—quality, global performance measures, and the thinking processes. Previously, no such instrument was available. It was felt that the more of those underlying principles that were used, the better an organization would function, resulting in higher customer service quality. The use of the principles underlying the problem solving paradigm lead to significantly increased customer service quality. By using the principles underlying this paradigm, problems encountered as a result of

incorporating new technology or problems with the assessment of proposed changes to the service system can be minimized or eliminated, leading to improved customer service quality. The use of the principles underlying the logistics paradigm was found to have a significant effect on each of the dimensions with the exception of tangibles. Under the logistics paradigm, a system-wide view must be taken. Having this broad perspective leads to better customer service quality. There are some limitations of this study. One may involve the measurement scales for improvement methods, especially those underlying the global performance measure paradigm. Global measures for quality are not as straightforward as they are for manufacturing. For example, in manufacturing, inventory is anything that can be sold. This leads to some creative definitions of inventory in services.

TOC Implementations in India

- Hari Machines Limited
- Salora International Limited
- Godrej & Boyce Mfg. Co. Limited
- Nat Steel Equipment Private Limited

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