MODELING TOTAL QUALITY ELEMENTS INTO A STRATEGY-ORIENTED SIMULATION

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ABSTRACT

It has only been in recent years that quality -- as a strategic concept -- has truly moved into the management arena. Quality is now the prime focus of management for many companies in this country. The business sector, however, and not academia has lead the paradigm shift to a focus on total quality management (TOM). Academia needs to integrate TOM into its curriculum and teaching methods. The use of strategy-oriented simulations, that embody TQM concepts, is one method of ensuring our future managers are prepared to work in a TOM environment and to meet the demands of world-class competition.

This paper reviews the rudiments of TOM and describes algorithms for integrating many of the key elements into a strategy-oriented simulation. Specifically, the modeling of three key TOM components is described in detail. These include (i) an increased focus on customer need and satisfaction. The increased focus involves altering the demand equation in the model to include product failures and developing a quality-focused customer survey; (ii) continuous improvement and process capability modeling. This entails integrating quality prevention activities, statistical quality control procedures, and Taguchi Loss Function into the model; and (iii) adding competitive benchmarking options. Teams can assess who is “best’ in the industry and use this information to aid in goal-setting and continuous improvement activities.

INTRODUCTION

Quality has been the prime focus of the management of many companies in the U.S. ever since the competition from overseas showed that quality products and services give companies a strategic advantage in the global marketplace. Today quality is defined from the customers’ (internal or external) point of view: customer satisfaction. Quality control activities are no longer defect detection oriented, but geared towards defect prevention, referred to as ‘continuous quality improvement.’ This continuous improvement is accomplished by emphasizing design, raw materials and process; working closely with vendors; getting the workers involved in quality control and improvement activities; focusing on finding root causes of problems; applying statistical process control techniques; relying less on final inspection; and measuring the total cost of quality.

Quality is no longer seen as the responsibility of only the inspection or manufacturing department. It carries functional responsibilities in areas such as finance, operations, and marketing. This new quality philosophy is known as Total Quality Management (TOM) and can be defined as continuous process improvement activities involving everyone in an organization - managers and workers - in a totally integrated effort toward improving performance at every level" (Latzko, 1990).

It is important to educate the managers (present/future) in this new quality management philosophy. Edward Deming, internationally known authority on quality, refers to this change process as the ‘Transformation of Western Style of Management. In fact, he believes that this is the only way that U.S. companies can meet the challenge from abroad. Jack Grayson, Chairman of the American Productivity and Quality Center, states that the U.S. has less than two decades to improve quality and productivity in order to maintain the economic strength enjoyed during this past century (Talley, 1991).

We believe that strategy-oriented simulations should be a tool to educate managers and students in this new quality philosophy.

PURPOSE

The purpose of this article is twofold: (I) to review the development and the principal elements that embody the Total Ouality Management philosophy and (ii) to demonstrate how some of these elements can be built into a business simulation game.

TQM - EVOLUTION AND KEY ELEMENTS

For years quality was defined from the manufacturer's point of view, such as meeting some technical specifications. Ouality control activities were merely inspection functions (incoming material inspection/final product inspection) to sort the "bad" products from the "good ones, i.e., defect detection. This was the common practice in the industrialized West for many years, and even today it is not uncommon to find some companies still operating under this approach, though the numbers are declining.

During the 1920's, Dr. Walter Shewhart of Bell Laboratories introduced the idea of statistical quality control (SQC). SQC can be described as the use of statistical methods to study the characteristics of a process in order to make it behave the way we want it to behave (Statistical Quality Control Handbook, AT&T), i.e., control process variation. SQC is process-oriented, unlike inspection which is product-oriented. It controls and helps reduce the process variation so that the final products will be of desired quality (defect prevention). These methods are being effectively used today both in manufacturing and service companies as part of TOM.

During the 1950's and 1960's we saw the addition of reliability engineering techniques and other problem-solving tools (e.g., Pareto analysis, check sheets, cause and effect diagram, etc.) to the methods available to quality professionals. Concepts of "zero defect," "total quality control,' quality control circles' were introduced for the first time. Total quality control, which was introduced by Feigenbaum (1983), was the first step to getting people in all the functional areas and management involved in quality control and improvement activities.

The crucial step in quality management evolution was to establish that management must understand its role in achieving quality. Without management's understanding of its role, management's commitment to quality, and its effort to provide a supporting environment, those tools and methods would not be fully effective. As Latzko (1990) states. TOM consists of the synergism of people, methods and management concepts. Ouality needs to be managed at the strategic level like other key functions, e.g., finance, marketing.

TOM is process-oriented. In a typical organization there are several processes, e.g., marketing, design, manufacturing, purchasing, customer service, etc., and they are all interrelated. Thus errors committed in one process will be carried out through the whole system. Therefore, 'owner(s)' of the processes need to know how they affect and relate to one another. This helps break down the barriers between apartments, (functional areas), and encourages communication between departments to uncover the areas that need improvement.

TQM focuses on the customers' (both internal and external) needs. For example, one process may be the customer (internal) for another one and yet at the same time be a supplier (internal) for a third one (supplier/customer focus). It is important to know who the customer(s) is, what the needs are. Ouality-focused customer surveys and competitive benchmark studies are being used today in the design, control and the continuous improvement of product and processes.

TOM requires a top management commitment. Talley (1991) summarizes these key activities:

- o Top management must steer the quality improvement process toward excellence.
- o Education in quality management should be provided for all levels of management and for employees.
- o An overall strategy for TOM should be developed. This should include developing a vision, defining the mission, and postulating the strategic objectives and key performance indicators.
- o People, at all levels, should be involved and rewards provided to encourage commitment to continuous improvement.

For business students to be prepared for world-class competition, they need to be able to quickly move into this TQM work environment. One way to ensure this is to introduce lower-division students to the TOM philosophy and to the problem solving tools commonly used in industry. Then, have upper-division student's play a strategy-oriented business simulation which has TQM elements integrated throughout it. However, there are currently no commercially available business simulations that embody the TOM philosophy.

INTRODUCING TOM INTO A COMPUTERIZED BUSINESS GAME

We will present some algorithm changes that can be made to policy-oriented simulations that will make them more quality-oriented. The simulation that we have adapted is a full-enterprise business simulation (Pray and Strang, 1980) with approximately 15 major decision options --ranging from purchase of raw materials, scheduling production, marketing and sales, to pricing of the finished product. The simulation has two raw materials and one finished product. The decision variables are interrelated in such a manner that participants quickly recognize the importance of systems thinking and strategic planning.

We added five more quality-based decision modules including: (i) a quality management budget, (ii) a competitive benchmark study, (iii) a quality-oriented customer survey, (iv) process capability and improvement options, and (v) two statistical quality control procedures.

PURPOSE AND COMPONENTS OF THE MODEL

The overall objective of the TOM simulation is to allow the participants to experience first-hand (i) the importance of focusing on customer satisfaction and (ii) the need for continuous improvement throughout simulation play. The model was designed so that teams need to consider quality as a key strategic variable.

Four unique aspects of the modified model include (i) a “quality-oriented’ focus on customer satisfaction, (ii) continuous improvement emphasis-- with prevention and appraisal quality control activities and process capability improvements, (iii) a competitive benchmarking data bank, and (iv) optional levels of game play. In this and the following sections we will describe each aspect and detail the modeling procedures.

An Increased Focus On The Customer

Most business simulations are driven by a multivariate demand function. This demand equation is comprised of economic and marketing decision variables such as price, promotion, R&D, economic indices, etc. With such a demand equation, teams have to focus on the customer by finding the appropriate level and mix of these variables. If the mix is “too rich,” the firm has excessive demand (i.e. stockouts). If the mix is “too lean’ then sales potential will be insufficient and profits will be low. Most games supply teams with period-by-period market research data on the market mix of the competition.

To make the customer focus more “quality-oriented,’ two more demand & elements are added to the model. First, product failures are introduced. These failures cost the company money through warranty claims and have a negative impact on customer demand. By including failures as a demand component, firms that fail to reduce product failure rates will find themselves with a decreasing market share.

The second addition is a quality-oriented customer survey. The survey is made up of six factors that the hypothetical customer has determined to be important. These include price, company visibility and awareness of the product, service from the company, reliability of the product, modifications and new features of the product, as well as supply and availability. The survey normalizes the firm’s position, relative to the competition, and shows the firm’s status. The survey is composed of the (I) most current period results and a (ii) longer time series-based study.

Continuous Improvement - Prevention and Process Capability

To focus attention on “continuous improvement activities’ the simulation includes two additional sets of decisions. The first deals with budgeting funds for prevention and appraisal of quality activities. To reduce failures, teams can allocate monies to prevention activities (e.g. supplier education and certification, on-the-job TOM training, etc.) designed to keep mistakes from happening in the first place. Teams may also spend money on appraisal activities (e.g. inspection, testing, and other statistical QC procedures designed to assure conformance with quality standards).

A firm’s strategy should be to direct its attack on failure costs[1] with the ultimate goal to drive of driving them to zero and to securing a reputation in the industry for high-quality, reliable products.

The second decision focuses on reducing variability in the production process. Once a team has improved its production quality to the point where its process has been deemed ‘statistically in control,” (i.e. process is repeating itself with a stable mean and variance), then it may opt for process capability improvements.

Five different process improvement options are made available to team members. Raw data sets are presented along with descriptive statistics via MINITAB. Teams should study the process improvement options and apply the appropriate process capability tools (e.g. C (p) and C (pk) statistics[2], and Taguchi Loss Function) to lower their warranty/adjustment costs and process variability.

Competitive Benchmarking

Teams can purchase an industry-wide competitive benchmark data. The data bank shows the industry “best and worst” for: average cost of goods sold, average total costs, operating efficiencies including waste and downtime percentages, quality budgets, failure rates, cost of quality, etc.

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[1] Failure cost is defined as “the cost required to evaluate and either correct of replace products or services not conforming to requirements or customer/user needs’ (ASQC Ouality Cost Committee, 1986)

[2] Cp. index is used to compare the actual spread of the process (i.e. 6 sigma) to the desired spread which is defined as USL-LSL: Cp. = [USL-LSL]/6 sigma. LSL and USL represent the lower and upper specification limits respectively. The Cpk statistic deals with the question of where the process average with respect to the desired nominal: Cpk = Cp. -ABS [nominal - process average]/ 3 sigma.

These data help a team establish realistic and obtainable goals, and to find out how well it is performing relative to the competition.

Multiple Levels of Game Play

Adding all these new modules may cause some of the participants to be overwhelmed. Thus, many of the decisions are considered “optional” and the model is set up to override them. The override option allows for different levels of game play. For instance, if the participants are not familiar with statistical process control (SPC) procedures, or if the instructor does not want to focus on that area, then it can be played at Level I --where the appraisal activities are overridden by the model. Some of the TOM decisions can be introduced later during game play. As an example, process capability improvements will only come into consideration after the team has mastered the other quality decision areas.

MODELING THE KEY TOM COMPONENTS

This section is more technical in nature because it describes many of the nuances and underpinnings of modeling the elements described above into the strategy game.

Modeling Nonconformance and Failures --Prevention Allocations

One of the important lessons of the simulation is to demonstrate that a well designed and implemented total quality plan can actually lower the total quality cost. Decision variables have been created that permit teams to allocate money toward prevention activities and these can be apportioned to either the input side (i.e. working with the supplier to improve raw material) or process side (i.e. working to improve the firm’s in-house operations). The quality metric chosen is fraction defective (input side) and/or rate of failure (product side). The dollar allocations are then used to determine the underlying rate of nonconformance for raw materials received and the failure rate for products made.

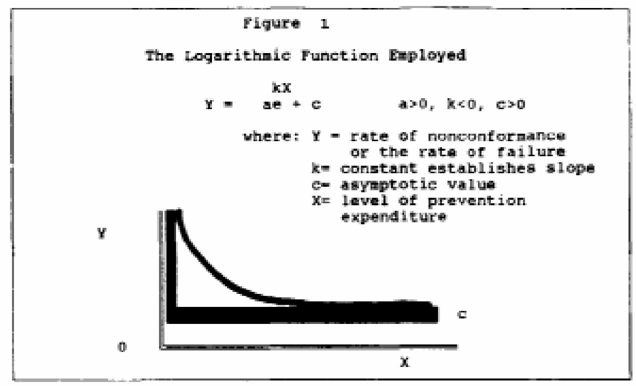
This is accomplished by using a stable logarithmic function shown in Figure 1. The rate of nonconformance of raw materials is then linked to the final product failure rate.

A firm that substantially lowers its raw material defective rate (i.e. representing supplier certification) will also reap additional benefits with a further reduction in the rate of failures for its finished product.

Appraisal Activities-- Input Side

On the input side, the rate of raw material defective can be further reduced, after prevention expenditures, by employing traditional acceptance sampling procedures. This is simulated by using a random number generator and then modeling a binomial probability process. Firms establish an acceptance sampling plan specifying the sample size (n) and the acceptance number (c). The computer then simulates the statistical sampling process and reports on the results of the plan. Figure 2 shows the outcomes of a typical acceptance-sampling plan. In this example the firm reduces the raw material defective rate from 5.71% to 1.66%.

As in the example, acceptance sampling will initially help reduce raw material defectives, but firms that trade off a prevention emphasis for a reliance on acceptance sampling will learn about the shortcomings of acceptance sampling as a total quality control procedure.



Appraisal Activities-- Process Side

Using the same procedure as the input side, along with the rate of product failure and the binomial probability process simulator, statistical process control can be simulated. P-charts can be applied to aid in reducing the number of failures reaching the market.

On the process side, the computer simulates the statistical sampling results and reports the results. Figure 3 shows the results of a plan in which the team chose 35 samples of size 35 and set its p-chart control limits at .02 and .00 respectively.

The plan provided sufficient quality control by readjusting its production process 17 times and reducing the failure rate from 5% to 3.3%.

Participants can become acquainted with the use of statistical tools -- acceptance sampling and p-charts. Over the simulation play, however, they should come to see that an over reliance on such procedures is not an effective way to become an industry leader in the quality arena.

Figure 3
INDUSTRY NO. 1
OUTPUT QUALITY CONTROL REPORT FOR FIRM NO. 1

DECISION SUMMARY

NUMBER OF SAMPLES = 35.
SAMPLE SIZE = 35.
UPPER CONTROL LIMIT = .020
CENTER LINE = .010
LOWER CONTROL LIMIT= .000

SAMPLING RESULTS

SAMPLE NO.	SAMPLE SIZE	NO. OF DEFECTIVES	FRACTIONAL DEFECTIVE	COMMENTS
1	35.	4	.114	PROCESS READJUSTED
2	35.	4	.114	PROCESS READJUSTED
3	35.	3	.086	PROCESS READJUSTED
4	35.	2	.057	PROCESS READJUSTED
5	35.	0	.000	
6	35.	0	.000	
.	.	.	.	. . .
.	.	.	.	. . .
.	.	.	.	. . .
24	35.	0	.000	
25	35.	3	.086	PROCESS READJUSTED
26	35.	0	.000	
27	35.	5	.143	PROCESS READJUSTED
28	35.	0	.000	
29	35.	0	.000	
30	35.	0	.000	
31	35.	2	.057	PROCESS READJUSTED
32	35.	1	.029	FALSE ADJUSTMENT
33	35.	6	.171	PROCESS READJUSTED
34	35.	1	.029	PROCESS READJUSTED
35	35.	0	.000	

OUTPUT QUALITY CONTROL ANALYSIS

TOTAL PRODUCTION	405000.	SAMPLING COST	40613.
NO. OF DEFECTIVES REMOVED	61.	ADJUSTMENT COST	1700.
TOTAL NUMBER OF EFFECTIVES	404939.	FALSE ADJUSTMENT COST	300.

TOTAL OUTPUT QUALITY COST 42613.

FRACTIONAL DEFECTIVE WITHOUT PROCESS CONTROL .050
FRACTIONAL DEFECTIVE WITH PROCESS CONTROL .033
TOTAL NO. OF DEFECTIVES 13439.

Figure 2

INDUSTRY NO. 1
INPUT QUALITY CONTROL REPORT FOR FIRM NO. 1

DECISION SUMMARY - RAW MATERIAL 1

SAMPLE SIZE = 20
ACCEPTANCE NUMBER = 0
RAW MATERIAL PURCHASE = 1000000.
A.Q.L. = .02
L.T.P.D. = .10

SAMPLING RESULTS

NO. OF LOTS INSPECTED = 1000
NO. OF LOTS REJECTED = 450
NO. OF DEFECTIVES REMOVED = 630.
NO. OF CHARGES ALLOCATED TO FIRM = 190
NO. OF CHARGES ALLOCATED TO SUPPLIER = 260.

SAMPLING COST = $ 500.
TOTAL INPUT QUALITY CONTROL COST = $ 58500.

FRACTIONAL DEFECTIVE PRIOR TO SAMPLING = .0571
FRACTIONAL DEFECTIVE AFTER SAMPLING = .0166

OPERATING CHARACTERISTIC CURVE SAMPLE SIZE = 20 C = 0		AVERAGE OUTGOING QUALITY LIMIT SAMPLE SIZE = 20 C = 0	
PROBABILITY OF ACCEPTANCE	FRACTION DEFECTIVE	AVERAGE OUTGOING QUALITY	FRACTION DEFECTIVE
.8179	.0100	.0080	.0100
.6676	.0200	.0132	.0200
.5438	.0300	.0162	.0300
.4420	.0400	.0177	.0400
.3585	.0500	.0182	.0500
.2901	.0600	.0178	.0600
.2342	.0700	.0170	.0700
.1887	.0800	.0158	.0800
.1516	.0900	.0145	.0900
.1216	.1000	.0131	.1000
.0972	.1100	.0116	.1100

THE COST OF QUALITY AND CONTINUOUS IMPROVEMENT MODELING

Product failures are distributed between "internal and external failures' on the basis of dollar commitment to quality prevention. Costs are assigned as either internal or external failure cost[3] and presented in a Total Oualitv Report as illustrated in Figure 4. For the examples described earlier, it can be seen that the firm budgeted only $75,000 for prevention activities. The firm divided the budget evenly between supplier development (input side) and in-house quality improvement process side). The results of the period show that this firm spent substantially more on appraisal, failure, and warranty adjustment costs -- costing it over $400,000. A more effective TOM plan would be to allocate additional funds to prevention. This strategy, over time, would lead to a decreased number of failures and lower total quality costs.

Figure 4
INDUSTRY NO. 1
TOTAL QUALITY REPORT FOR PERIOD 1 FOR FIRM NO. 1

		INPUT	PROCESS
APPRAISAL COSTS	$ 101113.	$ 58500.	$ 42613.
PREVENTION COST	$ 75000.	$ 37500.	$ 37500.

CONTR. STUDY COST	$ 0.	PROCESS ADJ. COST	$ 0.
ADJUSTMENT CHARGES	$ 105705.		
FAILURE COSTS	$ 199570.	PERCENT OF TOTAL	41.5%
TOTAL QUALITY COST	$ 481388.	PERCENT OF REVENUE	4.8%

FAILURE ANALYSIS		INTERNAL	EXTERNAL
NO. OF FAILURES	13439	4614	8825
FAILURE COSTS	$ 199570.	11.6%	88.4%
TOTAL PRODUCTION	405000.	PERCENT FAILURE	3.3%

PROCESS CAPABILITY AND TAGUCHI LOSS FUNCTION MODELING

Once a firm improves the quality to the point where the process is statistically stable (i.e. in statistical control), then process capability analysis can be performed to see if the specification limits are satisfactorily met. Taguchi has extended the concept further by saying that meeting specifications is not enough. Firms should concentrate on continuous reduction in the process variation so that outputs from the process will form a distribution with mean on or near the desired nominal with very small variation. Furthermore, he introduced a new quality cost concept and function stating that the quality cost will increase as we deviate from the nominal (see Sullivan 1984).

To simulate the 'Taguchi Loss" concept, firms are given five data sets, along with summary descriptive statistics, which represent data from different processes. Figure 5 illustrates three different distributions that are represented by the data sets.

Adjustment 1 tends to increase the number of units outside specification limits (e.g. LSL and USL), but will actually reduce the variability as compared to the uniform distribution of adjustment 2 or the bimodal distribution of adjustment 3. Each firm should study the data set, use descriptive statistics and employ Cp and Cpk process capability measures to aid it in making a process improvement decision. The Taguchi loss

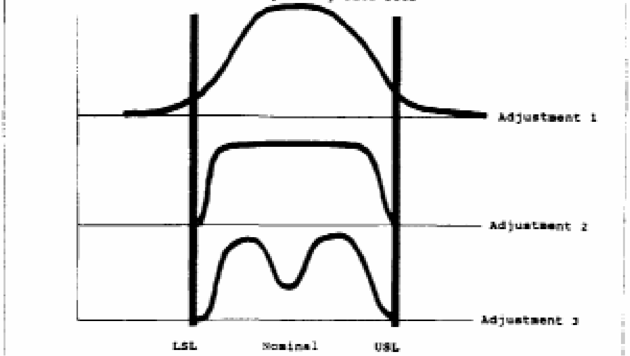
[3] Internal failure cost are the cost occurring prior to completion or shipment of the product, or furnishing a service; external failure costs are the costs occurring after shipment of the product, and during or after furnishing a service - (ASQC Oualitv Cost Committee, 1986).

function, Equation 1, determines the adjustment charges that the firm receives for each process.

$$\text{Loss} = c[s^2 + (X - \text{x-bar})^2] \qquad [1]$$

Where Loss = the adjustment charges
c = adjustment cost constant
s = standard deviation of process
X = nominal or desired center of specification
x-bar = center of process

Figure 5
Process Capability Data Sets



FAILURES AND THEIR IMPACT ON DEMAND

If a firm continues to supply the market with products that fail, its sales and market should suffer from such action. The Gold and Pray Demand System (1985) was used to model both the industry and the firm-level demand because of its versatility in introducing new demand variables and the controllable elasticities. Equations 2 and 3 show the calculation of the firm share calculation based upon four demand factors -- price, promotion, R&D, and failures.

FIRM-LEVEL DEMAND EQUATION

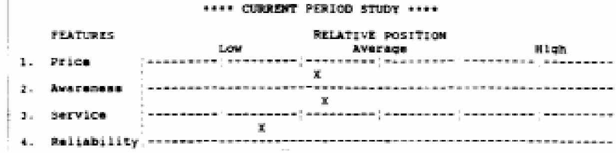
$$D_i = ng1\, P_i^{-(g2+g3P_i)}\, M_i^{+(g4-g5M_i)}\, R_i^{+(g6-g7R_i)}\, F_i^{-(g8+g9F_i)} \qquad [2]$$

$$shar_i = D_i / D_t \qquad [3]$$

Where P_i = firm i's price for the industry;
M_i = firm i's marketing expenditure for the industry;
R_i = firm i's R&D expenditure for the industry;
g_i = constants or parameters based on a priori specified elasticities or values for i = 1,9;
F_i = firm i's external failures reaching market
n = number of firms.

The failure elasticity parameters, g8 and g9 can be preset to establish the "power' of the failures in decreasing firm-level demand.

FIGURE 6
A MARKET RESEARCH FUNCTION FOR FIRM 1
CUSTOMER PERCEPTION



$$Z_i = \frac{X_i - \text{X-Bar}}{\text{St. Dev.}_i} \qquad [4]$$

Where: Z_i = the standardized value from -3 to +3;
X_i = is the ith independent variable;
X-bar = is the average for the industry;
St. Dev._i = the industry standard deviation.

MODELING CUSTOMER SURVEY

The modeling of the customer survey involves calculating standard Z scores for each of the independent variables in the firm-level demand function. Equation 4 reviews the calculation. The X_1 includes exponentially smoothed price, promotion, service, failures, R&D and stockouts.

The standardized Z scores were calculated for both the most recent data and for the time series data based on exponential smoothing of the variables.

Figure 6 illustrates an example customer survey for the most recent period. A Z-score of 0 represents average and each "-" denotes a change of .1 to the Z-value. The current period survey, along with the historical time series survey, provide valuable data to a firm. In this case Firm 1 found out that the customer feels they are below average on a number of key attributes including awareness, reliability, service, and new features.

MODELING COMPETITIVE BENCHMARKING

To aid the firms in establishing realistic goals and to let a firm know how its costs are relative to the competing firms, a competitive benchmark study can be purchased during the simulation play. The study reports on the industry best- and worst-performers. It covers three major areas of interest: (i) cost of production, (ii) operating efficiencies, and (iii) quality issues.

Figure 7 illustrates such a study. This study demonstrates that there is large difference among production costs. Firm 4 cost $27.08 where as Firm 1 is producing a competitive product for under $25.00. It is also apparent that Firm 3 has made a major commitment to quality prevention and some of the results indicate that it is working (i.e. Firm 3 is lowest in both internal and external failures).

Such a report can be purchased at any time during game play and aids firms in the strategic planning and the overall decision-making process.

Figure 7
COMPETITIVE BENCHMARKING STUDY
FOR FIRM NO. 1 IN PERIOD NO. 2
INDUSTRY BEST AND WORST

BENCHMARK ITEM	SMALLEST AMOUNT	Firm # ( )	LARGEST AMOUNT	Firm # ( )
COST OF OPERATIONS				
	Period 2 Average Costs:			
Average Cost of Goods Sold	$ 15.64	(1)	$ 17.29	(3)
Total Cost	$ 24.48	(1)	$ 27.08	(4)
OPERATING EFFICIENCIES	Period 2 Results:			
RM #1 Waste %	8.10 %	(4)	10.00 %	(1)
RM #2 Waste %	9.00 %	(4)	10.00 %	(1)
Downtime %	8.67 %	(3)	15.56 %	(2)
R&D $ (Ave)	$ 375050.	(1)	$ 549950.	(4)
Maintenance $	$ 375000.	(3)	$ 500000.	(4)
Capital Invest. $	$ 1000000.	(1)	$ 2075000.	(2)
TOTAL QUALITY BENCHMARKS				
Percentages:	Period 2 Results:			
RM # 1 Defective	1.98 %	(3)	4.56 %	(1)
Fin. Goods Defective	1.27 %	(3)	3.70 %	(1)
Qual $ as % Revenue	3.29 %	(1)	4.71 %	(3)
Number of Failures				
Ave. No. Ext. Fails.	9391.	(2)	11854.	(4)
Period 2 Ext. Fails	2097.	(3)	7778.	(1)
Period 2 Int. Fails	3100.	(3)	6044.	(1)
Costs:				
Total Failure Cost	$ 57440.	(3)	$ 185780.	(1)
Total Cost Quality	$ 285780.	(1)	$ 429765.	(3)
	Average Quarterly Expenditure:			
Prevention Input-$	$ 61750.	(1)	$ 110304.	(3)
Prevention Process-$	$ 56413.	(1)	$ 105203.	(2)
Appraisal Input-$	$ 0.	(4)	$ 31500.	(3)
Appraisal Process-$	$ 0.	(4)	$ 40825.	(3)

A THREE-FIRM ILLUSTRATION

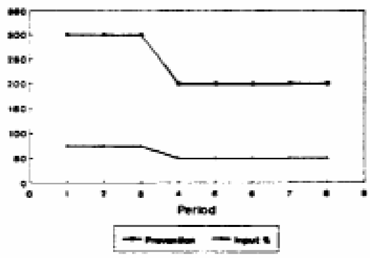
To demonstrate the impact of "quality' on the model, a mini simulation is presented. It has an industry composed of three firms competing against one another for eight periods. The simulation is set up with all firms starting with the same financial and operating positions. For the demonstration, the firms' decisions are limited to price, promotion, R&D, and quality-based decisions.

Strategies

Firm # 1 takes a conservative approach, budgeting only $75,000 per period for quality-prevention activities. Firm # 2 also allocates $75,000 per period for prevention activities, but uses statistical process control and acceptance sampling methods in an attempt to control the number of defectives.

Firm # 3 implements an aggressive total quality program. It spends $300,000 for three periods on prevention, allocating 75% to supplier development. It also uses statistical procedures until it achieved a significant reduction in the product failure rate. After seeing the benefits of the prevention plan, Firm 3 reduces its budget to $200,000 and divides it evenly between supplier development and in-house TOM activities. Figure 8 summarizes Firm 3's prevention allocations for the eight periods.

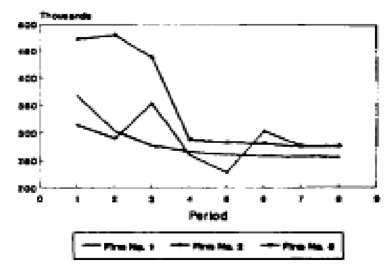
Figure 8
PREVENTION AND INPUT %



THE RESULTS - A FOCUS ON FIRM 3

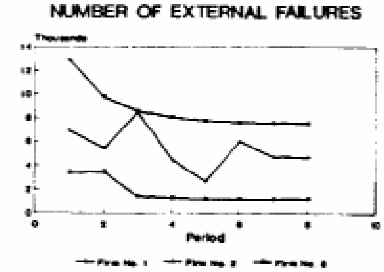
Firm 3's aggressive TOM program places them at a cost disadvantage, but as the game continues the benefits outweigh the initial cost. As shown in Figure 9, Firm 3 is able to lower its total quality cost after the fourth period. This is accomplished by cutting back on prevention allocations and by achieving a significant reduction in its failure cost.

Figure 9
TOTAL COST OF QUALITY



The immediate benefits of Firm 3's TOM program become apparent in Figure 10. With the smallest number of external failures, it becomes the industry leader in reliability.

Figure 10
NUMBER OF EXTERNAL FAILURES



As noted earlier, the model is designed to reward firms on the demand side when they reduced the product failure rate. In this illustration, Firm 3 finds that it did not need to advertise its product as much as the competition. In fact it finds that it can reach a desired sales level while reducing its promotion budget.

As shown in Figure 11, this lowers its average operating costs, as compared to those of the competition. The competition, however, finds that must increase advertising expenditures and cut prices to maintain market share and overall profitability.

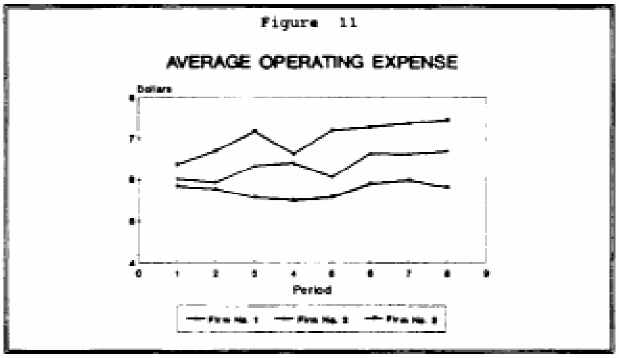


Figure 11
AVERAGE OPERATING EXPENSE

After the fourth period Firm 3 has significantly lowered its total quality cost, when expressed relative to its total revenue. Because of its quality-based competitive advantage, it is able to increase profits and ultimately become the dominant firm in the industry. Figures 12 and 13 summarize how the simulation played out.

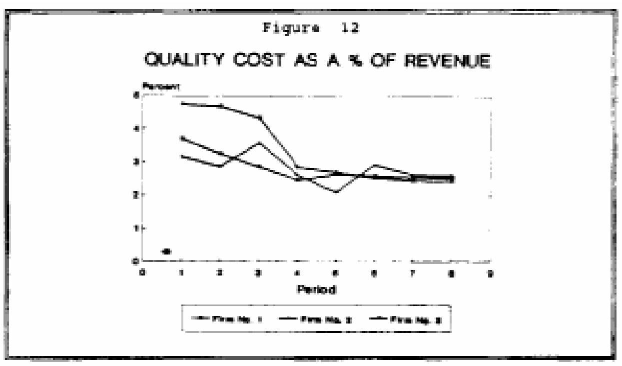


Figure 12
QUALITY COST AS A % OF REVENUE

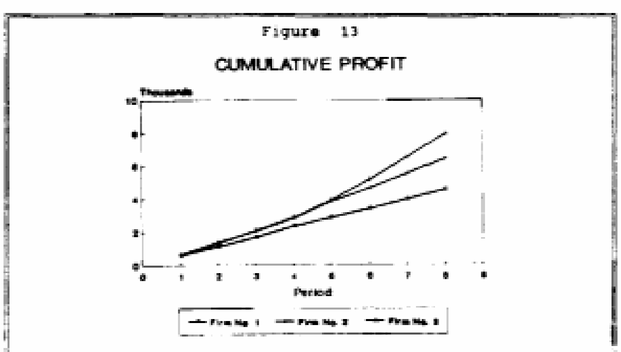


Figure 13
CUMULATIVE PROFIT

SUMMARY

The purpose of this article was to review the fundamentals of total quality management and to describe some methods of introducing the key elements of TOM into a strategy-oriented business simulation. As academics we need to work more closely with industry to ensure that we adequately prepare our future managers and business leaders for a new work environment. One method of better preparing students for a TOM environment is to teach them what quality is and to involve them in a TOM strategy simulation experience.

Lana J. Harris, Editor of the Xerox Ouality Forum II Proceedings (1990) noted in the summary section of the report:

> "To remain competitive in the next century, we must develop an educated, capable work force. Businesses have identified a need for recruits to understand statistical methods and teamwork as part of basic quality knowledge. Since quality begins and ends with education, the academics must act as the change agents to help businesses by providing graduates who understand TOM."

We hope this paper will encourage designers of simulations to develop new games that are consistent with the total quality movement and to share their algorithms and findings with the academic community -- for quality requires an attitude of sharing.

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