Solutions for Fundamentals of Quality Control and Improvement 4th Edition by Mitra

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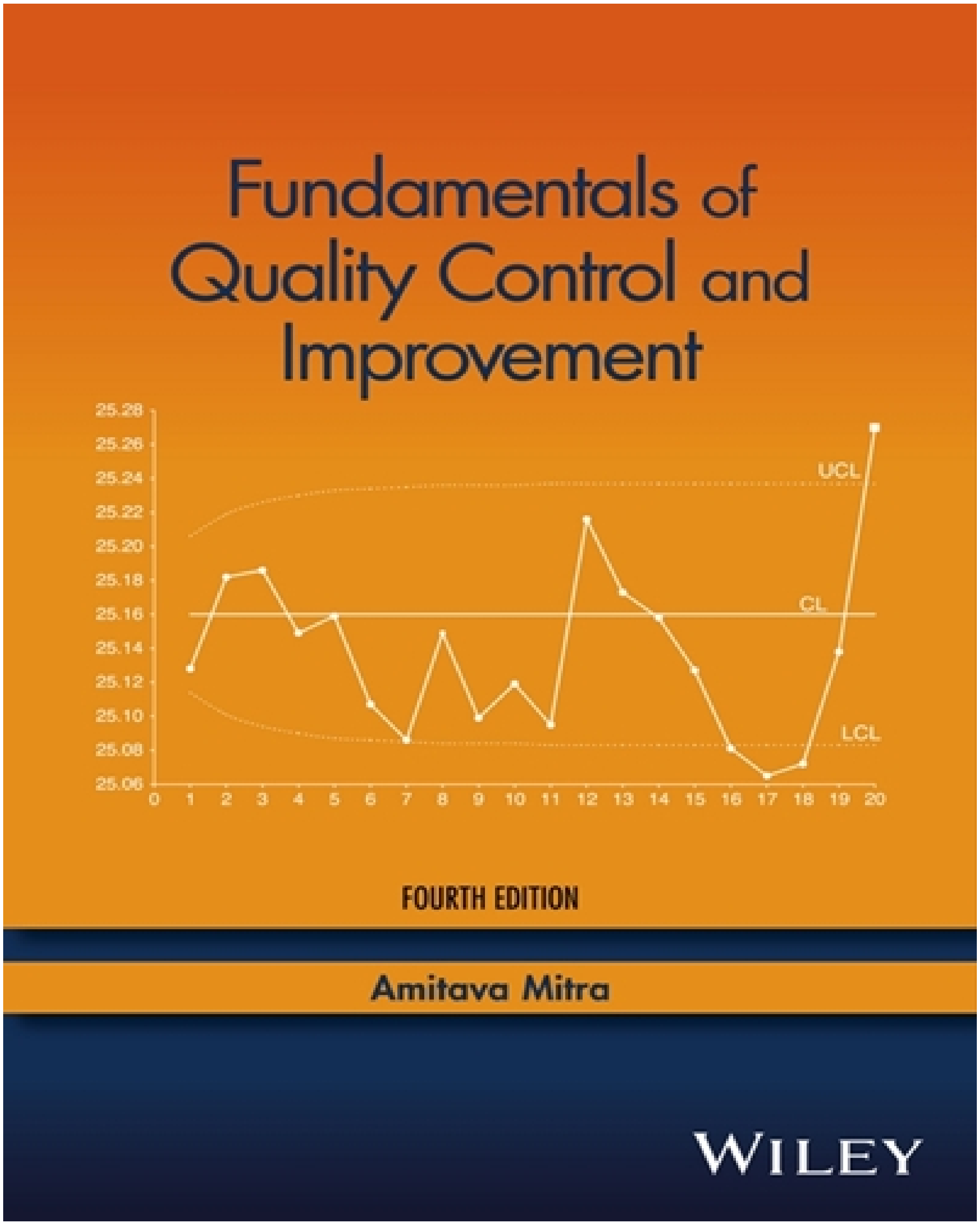

Solutions

FUNDAMENTALS OF QUALITY CONTROL AND IMPROVEMENT

SOLUTIONS MANUAL TO ACCOMPANY

FUNDAMENTALS OF QUALITY CONTROL AND IMPROVEMENT

Fourth Edition

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PREFACE

This solutions manual is designed to accompany the text, "Fundamentals of Quality Control and Improvement." To assist the student and the instructor in the teaching of the material, this manual includes solutions to the end-of-the chapter problems. The answers to the discussions questions are included too. Detailed explanation on the discussion questions may be found in the text and references. Associated figures and graphs on solutions to the problems are kept to a minimal. Most of the computations may be conducted using the Minitab software.

CHAPTER 1

INTRODUCTION TO QUALITY CONTROL AND THE TOTAL QUALITY SYSTEM

1-1. a) Call center that sells computers – possible definitions of quality that involve different variables/attributes could be as follows:

i) Time to process customer order for computers – Time measured in hours.
ii) Total turn over time (starting with customer placement of order to customer receipt of computer) – Time measured in hours.
iii) Proportion of delivered orders that do not match customer requirements exactly.
iv) Proportion of orders that are fulfilled later than promised date.

Integration of the various measures to one measure is not easily attainable. Individual measures, as proposed, should not be difficult to measure.

b) Emergency services for a city or municipality:

i) Time to respond to an emergency – Time measured in minutes.
ii) Time to process an emergency call – Measured in minutes and seconds.

Proposed measures readily obtainable.

c) Company making semiconductor chips:

i) Total manufacturing costs/10,000 chips.
ii) Parts per million of defective chips.
iii) Equipment and overhead costs/10,000 chips.

Measure iii) can be integrated into measure i). Measure ii) will influence manufacturing costs per conforming product. All of the measures should be easily obtainable.

d) A hospital: Variety of measures exist based on patient satisfaction, effectiveness of services, efficiency of operations, rate of return to investors, and employee/staff/nurse/physician satisfaction.

i) Proportion of in-patients satisfied with services.
ii) Length of stay of patients, by specified diagnosis related groups – Measured in days.
iii) Turn around time for laboratory tests, by type of test – Measured in hours/minutes.
iv) Annual or quarterly rate or return.

Most of the measures can be readily obtained. It may be difficult to integrate all such measures. However, some of these measures, such as annual rate of return, may serve as an integrated measure.

e) Deliver mail/packages on a rapid basis:

i) Total turn around time (from taking order to delivery) for packages – Measured in hours.
ii) Processing time of orders – Measured in minutes.
iii) Proportion of packages not delivered within promised time.
iv) Proportion of packages delivered to wrong address/person.

All of these measures should be easily obtainable. Measure ii) obviously is part of measure i). Measure i) may also influence measure iii). Measures iii) and iv) may involve causal analysis to identify reasons for errors or long delivery times. Measures i) and ii) could be analyzed for improving efficiency of the process.

f) A department store – Several forms of measures exist based on customer satisfaction, employee satisfaction, and rate of return to investors.

i) Proportion of customers satisfied with the store services.
ii) Time taken to service individual customers – Measured in minutes.
iii) Waiting time of customers before being serviced – Measured in minutes.
iv) Proportion of staff turnover.
v) Annual or quarterly rate of return to investors.

Majority of the proposed measures can be obtained with reasonable ease. Some serve as an integrated measure, for example, annual rate of return to investors.

g) A bank – Several forms of measure exist based on customer satisfaction, employee satisfaction, or rate of return to investors.

i) Proportion of customers satisfied with the bank services.
ii) Total time taken to serve the bank customer – Measured in minutes.
iii) Waiting time of customers before being serviced – Measured in minutes.
iv) Proportion of staff turnover.
v) Annual rate of return to investors.

Majority of the measures can be obtained with reasonable ease. Some of these serve as an integrated measure, for example, annual rate of return to investors.

h) A hydro-electric power plant – Several operational, effectiveness, and financial measures exist:

i) Cost per kilowatt-hour of electricity produced – Measured in dollars and cents.
ii) Total kilowatt-hours produced monthly – Influenced by demand.
iii) Proportion of total customer demand met by particular plant.
iv) Annual rate of return to investors.

Most of these measures can be obtained with reasonable ease. Some of these serve as an integrated measure, for example, annual rate of return to investors.

i) An insurance company – Several measures of customer satisfaction exist:

i) Proportion of customers highly satisfied or satisfied with service.
ii) Number of customers who discontinue their policy annually.
iii) Time, in days, to have claims processed and checks mailed to customer.
iv) Time taken for claims adjustor, in days, to view damage and submit report.

All of these measures can be obtained with reasonable ease. Measures iii) and iv) could be combined.

j) Internet service producer – Several measures of effectiveness of service and customer satisfaction exist:

i) Transmission speed, say in megabytes per second.
ii) Service downtime, in hours and minutes, per month.
iii) Time to respond, in hours, to a customer problem on site.
iv) Time to fix a problem, in minutes, via telephone/web communication.

All of these measures can be obtained with reasonable ease. Measures iii) and iv) could be integrated depending on the nature of the seriousness of the problem.

1-2. Quality of design – Ensure total service time to the customer or alternatively waiting time to the customer is minimized. Ensure a variety of services demanded by customers are provided. For example, such may include guidelines on investment, home mortgage loans, home improvement loans, automobile loans, financial management services for the elderly, availability of several locations that are of proximity to customers, etc. Quality of conformance should address the means to achieve the variety of features that are discussed in the design stage. Quality of performance will finally address and measure how the bank does in meeting the desired goals when it is operational. Some measures in this performance phase could be:

i) Percentage of customers satisfied with all services.
ii) Percentage of customers satisfied with financial management services.
iii) Dollar volume of loans processed per month.
iv) Time to respond to customer inquiry – Measured in minutes.

Basic needs in this context could consist of the following: Offer a variety of checking/savings accounts, safe deposit boxes, several ATM locations in convenient places easily accessible to customers, and internet banking services. Performance needs could be measured by time to respond to customer inquiry, waiting time of customers, time to process loan application, etc. Excitement needs could consist of special services for customers over the age of 50 years, investment planning assistance, attractive savings/investment promotions that become the benchmark in the industry, remote service locations in buildings with major employers/entertainment/shopping, cash advance with no interest for very short term periods, such as a week, birthday gifts for patrons, etc.

1-3. The travel agency should consider improving on the various performance needs, relative to the existing competitors, and possibly providing some of the excitement needs. Obviously, basic needs are assumed to be provided by the travel agency. Some performance needs could be measured by the following: Turn around time per customer, i.e., the total time to provide the customer with the requested service; cost of providing the service; time to respond to a telephone call from a customer; accuracy in fulfilling customer requirements. Some excitement needs could be measured by the following: Meeting with the customer in a convenient location (i.e., place of employment or home); delivery of travel documents to home personally; updating customer with additional promotional/savings features on travel packages even after packet has been delivered, etc.

Impact on the various costs will be as follows: For basic and performance needs, process costs will likely increase. To improve response time, more agents or more convenient locations might be necessary. To reduce external failure costs, which is equivalent to improving customer satisfaction with the provided services, either additional services will have to be provided through an increase in process investment costs (personnel, facilities, etc.) or the efficiency of services will have to be improved. This will also necessitate added process costs. Internal failure costs (detecting inaccurate travel documents before delivery to customers) can be reduced through additional training of existing staff, so that fewer errors are made or through automated error detection, where feasible, through audit of certain documents. Appraisal costs, thus, could go up initially.

1-4. In the hospitality industry, as in others, special causes could be detected by quality control procedures. On the other hand, common causes may be addressed through quality improvement procedures. Typically quality control methods involve the use of control charts, through selected variables or attributes. Quality improvement methods could involve Pareto analysis, flow chart analysis, cause-and-effect analysis, failure modes and effect analysis, and quality function deployment analysis of the process through cross-functional teams.

Some special causes are delay or long waiting time for customer to check-in due to admission staff not being trained in certain tasks, long time to respond to room requests to deliver food or other items, and conference or banquet rooms being unable due to lack of adequate scheduling processes. Some common causes, that are inherent to the process, whose remediation will require making corresponding process changes could be: Delay in responding to customer requests due to shortage of available staff on duty, inability to provide a reservation due to lack of availability of rooms, inability to meet customer expectations to provide information on tourist attractions in the neighborhood due to lack of training of concierge staff, and so forth.

1-5. For the OEM considering an improvement in its order processing system with its tier-one suppliers, some measures of quality are as follows: Time to process order by the supplier; lead time required by the supplier to deliver component or sub-assembly; proportion of time order is delivered on time; proportion of time order is error-free; and parts-per-million (ppm) of components or sub-assemblies that are nonconforming. Some special causes, in this context, could be: Increased time to process order due to malfunction in order approval process or downtime of computers; increased lead time due to longer lead time in delivery of components by tier-two supplier; increased downtime of certain machine/equipment in tier-one supplier; or wrong setting or equipment used causing increased nonconformance rate. Some common causes, in this environment, could be: Increased time to process order by supplier due to lack of adequate staff/ equipment; increased lead time to deliver sub-assembly due to lack of capacity in tier-one plant; or increased parts-per-million of nonconforming product due to poor quality in shipment of components from tier-two supplier.

1-6. For an inter-modal company, some examples of prevention costs are: Design of an effective tracking system that can locate the specific location of each container at any instant of time; design of a system that flags items once actual schedules deviate from expected schedules based on due dates; and projecting labor requirements based on varying demand. Examples of appraisal costs are: Determination of loading/unloading time from one mode (say, ship) to another (say, train); determination of transportation time of a container from one location to another; and determining percentage of shipments that are late. Examples of internal failure costs are: Rectification of a delayed movement between two stations in order to meet deadline on meeting the delivery time at final destination – such could be accomplished through additional operators and equipment (say, trucks). Examples of external failure costs are those due to not meeting delivery time of goods to final destination and thereby incurring a penalty (per contract). Other examples are loss of market share (or customers) due to goods being damaged on delivery at final destination and thereby having to pay a premium for these goods, incurring a loss in revenue. Customer dissatisfaction due to delivery beyond promised date or goods being damaged could lead to non-renewal of future orders or switching by the customer to a competitor. Such lost orders would be examples of external failure costs.

1-7. With the advent of a quality improvement program, typically prevention and appraisal costs will increase during the initial period. Usually, as quality improves with time, appraisal costs should decrease. As the impact of quality improvement activities becomes a reality, it will cause a reduction in internal failure and external failure costs, with time. In the long term, we would expect the total quality costs to decrease. The increase in the prevention and appraisal costs should, hopefully, be more than offset by the reduction in internal failure and external failure costs.

1-8. a) Vendor selection – Prevention.

b) Administrative salaries – Usually staff salaries are in the category of prevention. If there are administrative staffs dedicated to appraisal activities, such as processing of paperwork for audit activities, such salaries could be listed in the appraisal category.

c) Downgraded product – Internal failure.

d) Setup for inspection – Appraisal.

e) Supplier control – Appraisal.

f) External certification – Prevention.

g) Gage calibration – Appraisal.

h) Process audit – Prevention.

1-9. Labor base index – This index could measure quality costs per direct-labor hour or direct-labor dollar and is commonly used at the line management level. For products or services that are quite labor intensive (for example, transportation by truck, processing of income-tax forms), this could be an appropriate measure. In case there are major changes in wage-rates or inflation, quality costs per labor dollar would be monitored. The cost base index includes quality costs per dollar of manufacturing costs, where manufacturing costs include direct-labor, material, and overhead costs. Thus, in a laboratory in a hospital, processing of X-rays incur technical personnel time and major equipment costs. So, processing or internal failure costs, in such a setting, could be monitored through such an index. It could be used by the hospital administration coordinator. The sales base index, that measures quality costs per sales dollar, is used by senior management, for example the CEO or the COO of an organization. Hence, for a senior executive in the automobile industry, a measure of performance to be monitored could be quality costs as a percentage of sales. Quality costs, in this instance, should capture internal failure and external failure costs (due to customer dissatisfaction and warranty claims).

1-10. Examples of internal failure costs are long waiting time for patients to be assigned to a bed after registration, delays in obtaining a blood test or MRI report, and delays in a physician examining the patient. Examples of external failure costs are poor patient satisfaction level, errors in patient bill, and extended length of stay for the particular diagnosis. A review of the current procedures for bed allocation along with elimination of non-value added activities could reduce bed assignment time. Availability of laboratory equipment and technician could address delays in laboratory results. A study of the number of physicians available, along with patient volume for the day and time in question, could assist in reducing delays in physician time.

1-11. External failure costs are influenced by the degree of customer satisfaction with the product or service offered. Such influence is impacted not only by the level of operation of the selected organization, but also its competitors, and the dynamic nature of customer preferences. Hence, even if a company maintains its current level of efficiency, if it does not address the changing needs of the customer, external failure costs may go up since the company does not keep up with the dynamic customer needs. Furthermore, if the company begins to trail more and more relative to its competitors, even though it maintains its current level of first-pass quality, customer satisfaction will decrease, leading to increased external failure costs.

1-12. The impact of a technological breakthrough is to shift the location of the total prevention and appraisal cost function to the right, leading to a decrease in such total costs for the same level of quality. This cost function usually increases in a non linear fashion with the quality level q. Additionally, the slope of the function will also reduce at any given level of quality with a technological breakthrough. Such breakthroughs may eventually cause a change in the slope of the prevention and appraisal cost function from concave to convex in nature, beyond a certain level of quality. As indicated in a previous question, the failure cost function (internal and external failures) is influenced not only by the company, but also by its competitors and customer preferences. Assuming that, through the breakthroughs, the company is in a better position to meet customer needs and has improved its relative position with respect to its competitors and has approached (or become) the benchmark in its industry, the failure cost function will drop, for each quality level, and its slope may also decrease, at each point, relative to its former level. Such changes may lead to a target level of nonconformance to be zero.

1-13. Note that the goal of *ISO 14000* is to promote a social responsibility towards sustainability and the use of natural resources. It emphasizes a worldwide focus on environmental management. Thus, as natural resources become scarce, for example, the availability of fossil fuel, the adoption of such standards on a world-wide basis will create an environment for future operations in all manufacturing situations that make use of more renewable resources. Adoption of such standards will impact corporate culture and management ethics.

1-14. The monitoring of supply chain quality will be influenced by the type of configuration of the supply chain – dedicated supply chain or a tiered supply chain. In a dedicated supply chain, the supply chain consists of certain suppliers who provide the OEM with components or sub-assemblies. The OEM provides the finished product to certain distributors, that are responsible for meeting customer demand. The same distributor could serve more then one OEM, as also the same supplier. In this type of supply chain structure, different supply chains compete against each other. Thus, for a given supply chain, the quality of the supply chain could be monitored through the following functions: On-time shipment of components or sub-assemblies by suppliers to the OEM, maintaining short lead time by suppliers, maintaining or improving parts-per-million of nonconforming product by suppliers and maintaining or improving unit cost by suppliers. For the OEM, similar criteria could be: Assembly time per product unit, total lead time at the product level, total cost per unit at the product level, and nonconformance rate at the product level.

When the type of supply chain structure is a tiered type, several suppliers at a higher level (say tier 2) provide parts or components to the next level (say tier 1) where sub-assemblies are produced. Next, the various sub-assemblies are collected by an infomediary. The various OEMs draw from this common infomediary to make their final product. As in the other case, the finished product is provided by the OEM to various distributors. However, in this situation, each distributor serves only one OEM. Thus, in addition to some of the measures discussed in the previous context, here are some additional process measures in this context: For a given OEM, the effectiveness of its distributors as measured by proportion of customers satisfied, proportion of market share captured by a distributor, and total proportion conforming at the product level produced by the OEM. For the suppliers that feed their components and sub-assemblies to an infomediary, the quality measures adopted would apply to each of the OEMs, since the OEMs draw from this common infomediary.

1-15. a) Using the data provided, Table 1-1 shows the calculations for overhead rate using the unit-based allocation method.

Using the calculated overhead rate of 77.263%, the cost per unit of each product using the unit-based costing method is shown in Table 1-2.

b) Calculations of the cost per unit of each product using the activity-based costing method are shown in Table 1-3.

Product-unit related costs: Setup and testing: $1.1 million ÷ 63000 = $17.46/unit.
Product-line related costs: CPU C1: $0.5 million ÷ 10,000 = $50/unit.
CPU C2: $1.5 million ÷ 15,000 = $100/unit.
Monitor M1: $0.8 million ÷ 18,000 = $44.44/unit.
Monitor M2: $2.5 million ÷ 20,000 = $125/unit.
Production-sustaining costs: $0.6 million ÷ $9.06 million = 0.066225 = 6.6225% of direct labor costs.

TABLE 1-1. Overhead Rate Using Unit-Based Allocation

	CPU		Monitor		Total
	C1	C2	M1	M2	
Annual Volume	10,000	15,000	18,000	20,000	
Direct labor $/unit	80	140	120	200	
Total direct labor cost (million $)	0.80	2.10	2.16	4.00	9.06
Total overhead (million $)					7.0
Overhead rate					77.263%

c) As can be observed from a comparison of the unit costs from Table 1-2 and 1-3, here are some inferences. Complex products will typically require higher product-line costs. Thus, the activity-based costing method, that makes proportional allocations, will be a better representation compared to unit-based

TABLE 1-3. Unit Cost Using Activity-Based Allocation

Cost Components	CPU		Monitor	
	C1	C2	M1	M2
Director labor ($)	80	140	120	200
Direct material ($)	60	100	80	120
Assembly ($)	40	60	60	100
Overhead				
Product unit	17.46	17.46	17.46	17.46
Product-line related	50	100	44.44	125
Production-sustaining (6.6225%)	5.30	9.27	7.95	13.25
Total unit cost ($)	252.76	426.73	329.85	575.71

costing method. Note that among CPUs, model C2 is more complex relative to C1. The unit-based method estimates the unit cost for C2 as $408.17, which is quite less relative to $426.73, as estimated by the activity-based method. The unit-based method, in this situation, will under-cost complex products. A similar result is observed for monitor M2, the more complex of the two monitors. Here, however, the difference between the unit costs in using the unit-based method ($574.53) and the activity-based method ($575.71) is not as significant as that for the CPUs.

1-16. a) Since setup and testing costs are different for CPUs and monitors; we calculate these for each product type.

Product-unit related costs: Setup and testing:

CPU: $0.4 million ÷ 25,000 = $16/unit

Monitor: $0.7 million ÷ 38,000 = $18.42/unit

Table 1-4 shows the unit costs using the activity-based costing method.

1-17. a) We are assuming that the product-line cost ($2.5 million) associated with M2 no longer exists. Further, a corresponding reduction in the total setup and testing costs occur due to not producing M2. With the product-unit setup and testing cost remaining at $17.46/unit, since a total of 43000 units is produced, the total setup and testing cost is $750,780. We are assuming that the other company costs remains at $0.6 million annually.

TABLE 1-2. Cost Using Unit-Based Allocation

Cost Components	CPU		Monitor	
	C1	C2	M1	M2
Director labor ($)	80	140	120	200
Direct material ($)	60	100	80	120
Assembly ($)	40	60	60	100
Overhead (77.263% of direct labor)	61.81	108.17	92.72	154.53
Total unit cost ($)	241.81	408.17	352.72	574.53

TABLE 1-5. Unit Cost Using Activity-Based Costing Method

Cost Components	CPU		Monitor
	C1	C2	M1
Director labor ($)	80	140	120
Direct material ($)	60	100	80
Assembly ($)	40	60	60
Overhead			
Product unit	17.46	17.46	17.46
Product-line related	50	100	44.44
Production-sustaining (11.858% of direct labor)	9.49	16.60	14.23
Total unit cost ($)	256.95	434.06	336.13

The total direct labor costs are now $5.06 million. Hence, the overhead rate for production-sustaining costs is $0.6 million ÷ $5.06 million = 0.11858 = 11.858% of direct labor costs. Table 1-5 shows the unit cost of the products using activity-based costing method.

b) By not producing monitor M2, the annual overhead cost reduction to the company = Reduction in setup and testing + Reduction in product-line M2 cost.

Reduction = $(1.1 – 0.75078) million + $2.5 million
= $2.84922 million.

If the company chooses to outsource M2, the amount to be annually paid to the supplier = 20000 x 480 = $9.6 million. Hence, net outflow annually = $6.75078 million.

If the company produces monitor M2 (using the previous data), the added cost relative to not producing it:

Added Cost = Direct costs + added overhead
= $420 x 20,000 + ($0.34922 + $2.5) million

TABLE 1-4. Unit Cost Using Activity-Based Costing Method

Cost Components	CPU		Monitor	
	C1	C2	M1	M2
Director labor ($)	80	140	120	200
Direct material ($)	60	100	80	120
Assembly ($)	40	60	60	100
Overhead				
Product unit	16	16	18.42	18.42
Product-line related	50	100	44.44	125
Production-sustaining (6.6225% of direct labor)	5.30	9.27	7.95	13.25
Total unit cost ($)	251.30	425.27	330.81	576.67

= \$11.24922 million.

So, the decision is to outsource monitor M2.

1-18. a) Overhead costs (per 1000 tablets) = 0.4 x 250 = \$100.00. Process costs, that include material direct labor, energy, and overhead costs = \$400. With a process yield rate of 94%, the total cost per 1000 acceptable tablets = \$400/0.94 = \$425.53, which yields the cost/tablet of acceptable product = \$0.43.

b) With an improved yield of 96%, the cost/tablet of conforming product = \$400/0.96 = \$416.67/1000 tablets = \$0.42/tablet. The relative level in capacity = 0.96/0.94 = 1.0213, indicating a 2.13% increase in capacity.

c) New labor costs = \$85/1000 tablets, and new energy costs = \$40/1000 tablets. Total process costs now = \$150 + \$85 + \$40 + \$94 = \$369/1000 tablets. Assuming the process yield to be 96%, the cost per 1000 acceptable tables = \$369/0.96 = \$384.38, yielding a cost/tablet of conforming product = \$0.38. The percentage reduction in cost from the original process = (425.53 – 384.38)/425.53 = 9.67%.

1-19. a) Total cost of goods sold, including marketing costs, = \$(20 + 30 + 6 + 25 + 25 + 10) = \$116/m^3. Assuming a 100% first-pass yield, for a 10% profit margin over cost of goods sold, the selling price = \$127.6/m^3.

b) With a first-pass yield of 94%, cost of goods sold for conforming product = \$123.40/m^3. With the selling price being the same as in part a), the profit = \$(127.6 – 123.4) = \$4.20/m^3. So, profit margin as a proportion of cost of goods sold = 4.20/123.40 = 3.40%.

c) With a first-pass yield of 98%, cost of goods sold for conforming product = \$116/0.98 = \$118.37/m^3. If the sales price is kept at \$127.6/m^3, the unit profit = \$9.23/m^3. The profit margin as a percentage of cost of goods sold = 9.23/118.37 = 7.80%.

d) The additional capital expenditure = \$150,000 and the demand rate is 5000 m^3 monthly. With a profit of \$9.23/m^3, the volume of sales required to break even = 150000/9.23 = 16,251.35 m^3. Hence, the time to break even = 16251.35/5000 = 3.25 months.

e) The improved process has a first-pass yield of 98%, meaning that for 100 m^3 of production, 98 m^3 is conforming and 2 m^3 is of lower quality. For conforming product, profit = \$(127.60 – 116) = \$11.6/m^3. For lower quality product, profit = \$(120-116) = \$4/m^3. Using the concept of weighted average, profit = 11.6 (0.98)

+ 4.0 (0.02) = \$11.448/m^3. The break even volume now = 150000/11.448 = 13102.725 m^3. Thus, the time to break even = 13102.725/5000 = 2.62 months.

1-20. The flow chart of the four operations is shown in Figure 1-1, with the yield, unit processing cost, and unit inspection costs indicated:

a) The first-pass yield at the end of four operations = (0.95 (0.90) (0.95) (0.85) = 0.6904. Total processing costs per unit = 10 + 6 + 15 + 20 = \$51. Hence, the unit cost for conforming product = 51/0.6904 = \$73.87.

b) Inspection is now conducted after the first and second operation: It is assumed that the inspection process correctly identifies all parts and nonconforming parts are not forwarded to the next operation. Using the first-pass yields, processing costs per 1000 parts = 1000 (10) + 950 (6) + 855 (15) + 855 (20) = \$45,625. Inspection costs per 1000 parts = 1000 (0.50) + 950 (2) = \$2400. Hence, total costs for processing and inspection for 1000 parts = \$48,025. The number of conforming parts for 1000 parts produced = 1000 (0.6904) = 690.4. Hence, the unit cost per conforming part = 48025/690.4 = \$69.56.

c) We now consider the case where inspection is conducted only after the third operation: Using the first-pass yields, processing costs per 1000 parts = 1000 (10) + 1000 (6) + 1000 (15) + 1000 (.95) (.90) (.95) (20) = \$47,245. Inspection costs per 1000 parts = 1000 (3) = \$3000, yielding total processing and inspections costs per 1000 parts = \$50,245. Hence, the unit cost per conforming part = 50245/690.4 = \$72.78.

d) In general, it is desirable for inspections to be conducted in the early operations in the process, if one has to choose between locations of inspection. If inspection is conducted early on in the process, it will hopefully eliminate nonconforming product from going through subsequent processing and incurring these costs. Also, for operations that have expensive unit processing costs, it is desirable to conduct inspection before such processing so that nonconforming product can be eliminated prior to processing.

1-21. Total cost function is given by TC = $50q^2 + 10q + (5 + 85)(1-q) = 50q^2 - 80q + 90$. This function can be plotted as a function of the quality level, q, to determine the value of q where the total cost is minimized. Alternatively, taking the derivative of the total cost function with respect to q, we obtain, $(100q - 80)$. Equating this derivative to 0, yields the operational level of quality for this static situation as $q = 80/100 = 0.80$. It can be

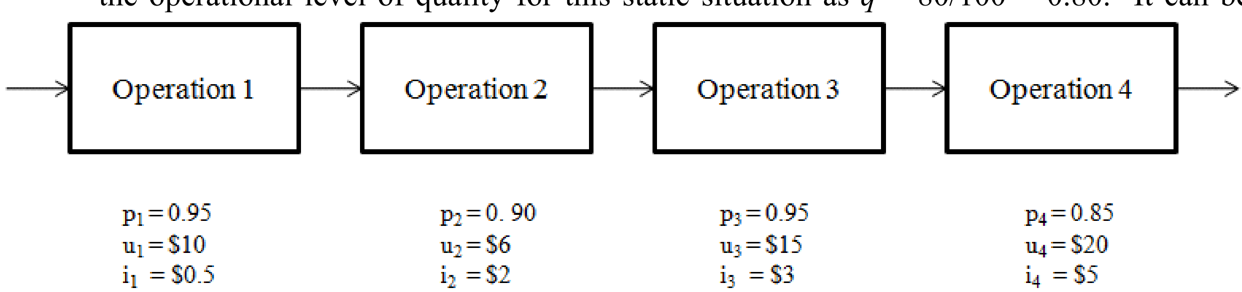

Figure 1-1. Operations Sequence and Unit Costs

seen that the total cost per unit at this level of quality is TC = $50\,(0.8)^2 - 80\,(0.8) + 90 =$ \$58.00.

The form of the cost functions assumed are as follows. Prevention costs increase y as a quadratic function of q, while appraisal costs increase linearly with q. It is possible that appraisal costs might actually decrease with the level of q. Further, it is possible that, beyond a certain level of quality, the combined prevention and appraisal costs might show a decrease in the rate of increase as a function of q. Internal failure and external failure costs are assumed to be linearly decreasing as a function of q. Here again, such cost functions might decrease as a non-linear function of q, with the rate of decrease diminishing with an increased level of q. When all such considerations are taken account, it is possible that the desirable operational level of quality is towards a goal of 100% conformance. In this situation, the total cost function may decrease as a function of q, rather than show the traditional u-shaped form.

1-22. The total cost function, per unit, as a function of the quality level, q, is given by:

$$TC = 50q^2 + 2\,(1-q) + 5\,\frac{(1-\ q)}{q} + 85\frac{(1-\ q)}{q}$$
$$= 50q^2 - 2q + \frac{90}{q} - 88.$$

Figure 1-2 shows a graph of the total cost function as a function of q.

From the total cost function, the level of q that minimizes the total cost can be identified. This is found to be approximately $q = 0.975$.

Alternatively, the derivative of the total cost function may be found and equated to zero. We have:

$$100\,q - 2 - \frac{90}{q^2} = 0$$

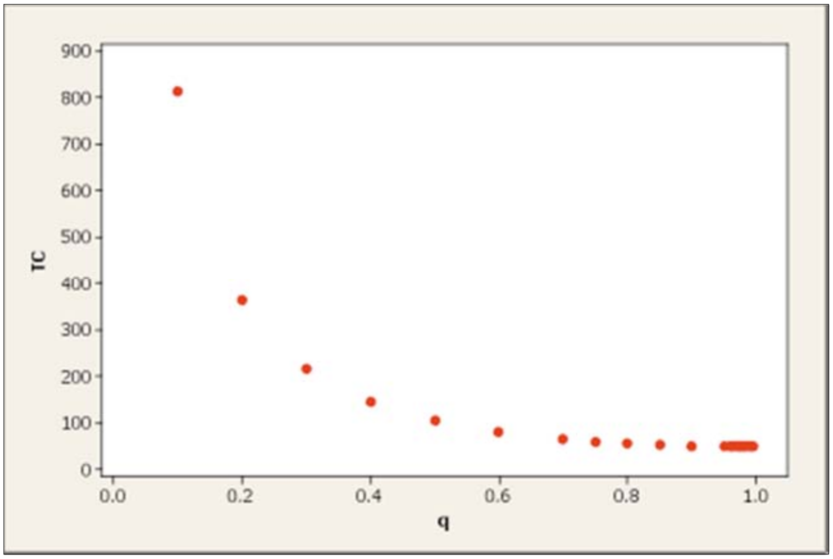

Figure 1-2. Plot of total cost versus quality level

or $100\, q^3 - 2q^2 - 90 = 0$, which yields $q \simeq 0.975$.

1-23. The revenue function is given by $90q^2$. So, the net profit function is expressed as:

$$NP = 90q^2 - (50q^2 - 2q + \frac{90}{q} - 88) = 40q^2 + 2q - \frac{90}{q} + 88.$$

This function may be plotted as a function of q, and the level of q that maximizes this function can be determined. Alternatively, the derivative of the net profit may be found and equated to zero. We have:

$80q + 2 + \frac{90}{q^2} = 0$ or $80q^3 + 2q^2 + 90 = 0$, which yields $q \simeq 1.000$, implying that total conformance is the desired option.

1-24 a) The net contribution to profit per patient, on average, due to an improved process = 400 + 40,000/500 = $480.

b) The reduction in market share due to the opening of a new facility may be viewed as an "external failure" cost. This is the cost associated with not being able to keep up with the competition. Hence, the net contribution to profit per month, on average, = 400 x 450 + 40,000 = $220,000, which is a reduction of $20,000 per month. The facility should re-vamp its operations and equipment to perform at a quality level that is better than its competitor and hope to recapture lost market share. Perhaps, it will even improve its market share at the improved quality level.

1-25 For the past month, reimbursement from CMS = 190 x 3000 = $570,000. Estimated costs = 80 x 2 x 600 + 50 x 3 x 600 + 60 x (1800 + 1500) = $384,000. Hence, monthly profitability per patient is $186,000/190 = $978.95, excluding other unusual costs. The lost opportunity cost for the patients that were released in 4 days (and not released in 3 days) = 60 x 1500 = $90,000. Obviously, the health care facility could continue its effective and efficient service through shorter stay of the patient. However, it needs to analyze the causes behind extended stay of some of its patients. For those causes that could be addressed, by preventing complications, for example, it must set up preventive means for doing so.