Solutions Manual to Accompany

FUNDAMENTALS OF QUALITY CONTROL AND IMPROVEMENT

Third Edition

AMITAVA MITRA

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AMITAVA MITRA
Auburn University
College of Business
Auburn, Alabama

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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.

CONTENTS

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.

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. 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, 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. It is quite possible to increase productivity, reduce costs, and improve market share at the same time. Through quality improvement activities, one could eliminate operations and thereby reduce production costs as well as production time. When production time is reduced, it leads to improved efficiency, which in effect increases capacity. Thus productivity is improved and costs are reduced. Additionally, with an improvement in quality, customer satisfaction is improved, which leads to an increase in market share through an expanded customer base.

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, 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. 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		
	C1	C2	M1	M2	Total
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 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.

b) In comparing the results of this problem with those in Problem 1-15, we note that unit costs, using the activity-based costing method, have increased for the monitors and have decreased for the CPUs. Observe that the setup and testing costs are higher for monitors than for CPUs, which could have caused this to happen.

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 1-3. 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

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.

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.

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

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

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
= $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.