SAMPLING PLANS FOR MONITORING QUALITY CONTROL PROCESS AT A PLASTIC MANUFACTURING FIRM IN NIGERIA: A CASE STUDY

By

E.A. Onyeagoro
School of Management Technology
Federal University of Technology, Owerri

Abstract
This paper explores the problem of high quality cost at a medium –sized firm manufacturing various types and sizes of plastic container, using a real life data. In pursuance of their quality objectives, the company established a policy that dictates and expensive and time-consuming post-manufacturing process. While the problem of the company's process control system was being studied, management considered other options that include sampling plans. The sampling plans were evaluated by considering the competing goals of decreasing the shipment of substandard goods, decreasing the percentage of acceptable lot that are erroneously labeled defective, and decreasing the sampling costs. The three sampling plans considered were the current sampling plan, minimum average total inspection (ATI) fixed average outgoing quality level (AOQL) plans, and a compromise plan. Comparison of the plans on a relative basis shows that the compromise plan is the best choice in term of cost.

1. Introduction

As more companies engage in international trade in goods and services, the process of managing these -activities in an intercultural environment will be of increasing importance. These intercultural activities not only are helping to reduce differences in technological and industrial process, but also are leading to adoption of new managerial concepts and .techniques among Societies around the world[3]. Unfortunately, most industries in the developing countries have not yet fully appreciated the importance of these new managerial concepts and techniques in manufacturing processes. The reason may be due to limitations in technical know-how or lack of competitive pressures amongst local companies or a combination of both. For instance, in Nigeria only a few industries manufacture similar products, so that each company enjoys a complete monopoly of the local market for -its product[6]. However, such a situation can result in substandard products flooding the market and, therefore, cannot prevail in international trade.

Cole[1] points out that the capacity of the Japanese to borrow, adopt, and institutionalize some of the methods, techniques, and ideas of Western organizational technology and behavioral science is nowhere more clearly evidenced than in the application of quality control techniques.

Quality control techniques are a means of seeing that quality standards are maintained. A more specific definition of quality control, simply state by juran[5], is that it is "the monitoring of production to maintain process control and produce goods that are fit for the intended purpose" integral to a quality control/statistical process control system is the concept of designing quality into product, with monitoring to maintain control, and acceptance sampling as a final check.

Sampling is a structured process for the selection of specified items from a population to obtain information about the product and the process. Traditionally, quality departments sample for both monitoring and quality control purposes. Prybrutok, et al[7] observed that the Japanese success with process control has led to acceptance sampling being relatively ignored in the literature, but acceptance sampling is a common tool in practice. A sampling plan gives management information on the production process after the process is completed and allows some regulation of the process.

Each plan contains a specific degree of certainty about the sampling results, as well as an average outgoing quality level (AOQL). Management is often presented with the dilemma of trying to understand the concepts of quality control and sampling, and of deciding

which of these systems,
or combination of systems, is appropriate for their production processes. The example discussed in this article illustrates that nonstandard procedures are at times more appropriate than accepted standard methods because of system constraints and competing objectives.

Experience has shown that system constraints and competing objectives are common in practice[7]. While process control and acceptance sampling are structured procedures in general, particular applications may require unstructured approaches. The extent and purpose of the involvement of management and customers in quality planning will be explored in the context of the case study described below.

2. Study background

This research was conducted in one manufacturing plant that manufactures different types and sizes of plastic containers for the storage and shipment of vegetable oil. The company is located in an urban area in Nigeria. Management's interest was in just-in-time (JIT) production, which combines the goals of making to order with off· the-line shipment. However, just-in-time must be preceded by absolute confidence in quality in-order to deliver the products economically. Management's quality motivation precipitated examination of both Process control and sampling policies. The managers knew that the production of high quality plastic containers not only increases customer satisfaction and good will but also fosters a positive corporate image. The investigation of the company's problem resulted in simultaneous experimentation with new and existing statistical process controls while sampling plans were being considered. Vardeman[8] argues that there are situations in which sampling and statistical process control work well simultaneously, but at other times one or the other is more appropriate than both. To choose the appropriate alternative therefore, management must consider the nature and extent of expected defects in the production' process. If the expected defect rate is near zero quality control by design is likely· to be the best choice, and sampling is probably inappropriate because of high Costs. On the other hand, if the expected defect rate is high, sampling may provide management with critical information about the state of the process.

Production of the container defects of concern at this farm (leakage of the joint and the covers) is extremely low, about 7 per 200,000, and current programmers will maintain but not improve this near-zero-defect rate. Nevertheless, management is interested in reducing the quantity of goods produced with this container defect. This quality improvement would then allow decreasing or elimination the associated inspection. In addition to management's desire to improve general quality is the desire to reduce the percentage of lots exceeding a specified defect rate. This means that management is not only interested in the shape of the distribution of the quality, but also in the average defect rate.

In pursuance of their quality objective the company established a policy that dictates an expensive and time-consuming post – manufacturing process to facilitate the elimination of container defects. The near-zero-defect rate, 7 per 200,000, coupled with almost impossible detection during manufacturing, renders process control relatively ineffective.

The company's existing sampling policy holds all container products for a five-day period awaiting a nondestructive examination. If the initial sampling of a lot is deemed substandard, 100% inspection and rectification is undertaken. Rectification requires extensive use of facilities and is extremely costly. Also, 100% inspection can result in an increased length of inspection time with all its in consequences. Jenkins[4] has stated that "decrease in inspector performance will occur with increases in length of inspection time". The company estimates the inventory holding cost associated with the 5-day hold at ₦120, 000.00 a year.

For the near-zero-defect process, the potential impact of the defect provides clues to management about the type of system to implement[7]. If a defect's impact has the potential to customer harm (e.g. if a manufacturing defect becomes contaminated with bacteria), then every applicable quality control technique control technique is required. When a serious consequence can result from a defect, it becomes vital to build in quality and

continually monitor the product in what should be a near-zero-defect situation. If the defect has the potential to cause customer great financial loss (e.g loss of good will and a corresponding market share), then a firm should strive for the best obtainable quality through design. For nonserious defects in a near-zero-defect process, additional and/or sampling would not be the best decision, but monitoring to establish long-term trends would be advisable.

While the problem of the company's process control system was being studied, management considered other options that included sampling plans. The sampling plans were evaluated by considering the completing goals of decreasing the shipment of substandard products, decreasing the percentage of acceptable lots that are incorrectly labeled defective, and decreasing sampling costs. The three sampling plans considered where current sampling plan, minimum average total inspection (ATI)/fixed average outgoing quality level (AOQL) plans, and compromise plan. The current plan is a fixed 1.37% sample that in a typical lot of 102,000 units would be a sample of approximately 1400 units. To make a comparison between the current plan and the minimum ATI/fixed AOQL plans, it is necessary to examine the inspection required and the quality that results. For the current plan, the average outgoing quality level is 0.00020 and the average total inspection is 2390, with the average long-run relative proportion defectives at 0.000035, the current plan has a less than 1% probability of holding a good lot for reinspection. But when the actual lot quality is as poor as a potential tolerance level of 0.0005, the probability of shipping this substandard lot is 0.40, which is unacceptably high.

3. Sampling plans and associated costs

Costs are associated with each aspect of a sampling plan and selecting items from the population, storing them in a separate location, and examining them for defects is often a substantial part of quality costs.

In the context of this case study alpha (a*)* is the probability that nondefective items are identified as defective by sampling and unnecessarily rectified. The costs associated with rectification sampling of these items will include the cost of selecting the items to be examined, the cost of examining selected items, and the cost of rectifying these items. Within the context of this example, beta (β) is the probability that a substandard lot is found acceptable and shipped. The costs associated with declaring a substandard lot acceptable must be assessed and must include the cost of replacing or repairing the goods, lost opportunities, customer dissatisfaction lost good will, and potential legal actions. .

These two sampling risks *(*α and *β)* complete with each other in the formulation of a sampling Plan, and are used to determine the number of items to be selected from the population for examination. In general, there is an inverse relationship between α and β in a sampling plan.

If α is decreased, it will be at the expense of higher β, while lower βincreases α. Similarly, to lower one risk and keep the other constant, or to lower both risks simultaneously, sample size must be increased.

In deciding on an appropriate mix of statistical process control and sampling plan, managers often find themselves faced with resistance to new ideas and techniques. Persons within the organization with vested interests in the current system may oppose any suggestion for change. While the implications of this resistance to change are difficult to quantify in the risk-benefit analysis, it may prove to be overriding factor in the final decision. Managers must, therefore, concern themselves with finding methods of compromise that balance the desire to attain positive change with maintaining current system.

4. Procedure

The first step was to discuss with management the appropriate risks and costs to be considered' and their acceptable limits· in the evaluation of potential sampling plans. To this end, managers were asked to make an assessment of the highest permissible proportion of lots within tolerances (i.e. good product) that can be; held as a result of incorrect sampling decision. Also, managers were asked to asses the maximum permissible proportion of lots that are just over tolerance (i.e. defective product) that can be shipped. In addition, managers were required to identify the goal for the "'worst" long run average

quality shipped out.

1n this way an acceptable α, maximum acceptable β and an AOQL were identified. Estimated costs of sampling, rectifying, and shipping bad products (including lost good will and public liability) were then discussed. Many of these costs, which can be described as indirect costs, were difficult to specify, and management's estimated costs were used; although qualitative estimates such as "prohibitive", "low" etc., were sometimes given.

The cost of sampling was considered from different perspectives. First, the cost associated with the initial sample size was considered; it is the most obvious .front-end cost. As the initial sample size increases, inspection. and storage costs also increase. Second, the cost associated with reinspection was a factor Reinspection has further complications Chat include involving the entire lot and requiring additional storage: capacity,

In this process, cost considerations alone would dictate that no sampling be earned out, but other factors make post-manufacturing inspection desirable. For instance, data can be simultaneously obtained and accumulated with respect to other quality variables which are useful for process monitoring and process capability analysis. Also, quality objectives are high and this firm was willing to incur additional cost to maintain their quality image with customers. Furthermore, the difficulty of detection until after production makes post-production sampling a viable alternative.

The required sample sizes for the sampling strategies varied with initial assumptions. In minimum ATI/fixed AOQL plans, AOQLs were set after discussions with the firm's planning task force. These plans both fix AOQL at a desired level and have low α and β risks. The plans were prepared using the standard procedures developed by Duncan[2], as described below.

Type B operating characteristic (OC) curves were obtained for comparison of these sampling plans. Type B OC curves give the probability of acceptance (P_a) and. a function of the process quality (P'). The average outgoing quality (AOQ) can then be calculated using P_a and P' When nonconforming items are discarded without repair or replacement

$$AOQ = [p_a p'(N-n)/[n - p'n - (1-p_a)p'(N-n)],$$

where n is the sample size from a population of size N. However, it is often easier to think of AOQ as the ordinate times the abscissa from the OC curve:

$$AOQ = P_a P'$$

This approximation is most accurate when defective items are replaced and n is small in comparison to N (one rule of thumb is that the sample size be less than 5% of the population).

The average outgoing quality curve shows AOQ as a function of the process quality. The maximum ordinate of this curve is the worst possible quality of material turned out by the plan and is termed the average outgoing quality level (AOQL). Using the Poisson approximation for the hypergeometric distribution, the average total inspection is estimated, as.

$$ATI = n + (N-n)[p\left(\times > \frac{C}{\lambda} = P'n\right)],$$

where P(X > C/λ = P'n) is the probability of getting more than C defect given a Poisson process where the average rate (λ) is p'n

5 Discussions

The results show that a prohibitively large sample is required from an average lot of 102,000 to assure management of $\alpha\beta$ and AOQL The AOQL plans varied the number of ·defects in the sample required to make a reinspection decision as well as varying the average outgoing quality level AOQL The initial inspection for the AOQL plans varied from about 35 x 10^3 to 35x10^4 but the average total inspection, which considers reinspection, was consistently in the 35 x 10^4 range. The consistency in the average total inspection result from the fact that, when a smaller initial sample is taken more rectification is required, and when initial inspection size is large, less rectification is needed. Obviously, there are some combinations that result in the lowest average total inspection. This lowest A TI does not result in a usable plan, because the total inspection required is prohibitive with A TI at almost one-third of production.

The compromise plan balances the advantage' and disadvantages of the AOQL and the current plans. These plans were designed to control reinspection and to fixα at 0.01 or

0.02. Associated with this goal was the reduction of both β and AOQL over the current system. A comparison of the compromise plans to the minimum ATI/fixed AOQL plans shows a 6 to 8 times reduction in the ATI for the compromise plans.

Computations for the plans summarized in Table 1 under the headings of AOQL, maximum number of defects per sample to conclude that the lot is within tolerance (c), initial sample size (n), α, β with 0.0005 as the true proportion defective, and ATI.

The desired AOQL can only be achieved at the expense of high sample size, and the minimum initial sample size for the AOQL system is 4901, more than three times the sample size for the current system. The average total inspection (ATI) for the minimum ATI/fixed AOQL plans has a 4·to 6 times increase in rectification. The probability of shipping above-tolerance lots is reduced over the current plan for both the AOGL and compromise sampling plans. The compromise plan shows AOQLs two to four times higher than desired, but the initial sample size (n) is low compared to most of the AOQL plans, and ATI at two to three times the current system.

Table1: Sampling plans (N=102, 000)

AOQL	c	n	α	β	ATI
Current plan					
0.0002	1	1400	0.01	0.41	2390
Min. ATI/fixed AOQL plans					
0.000025	0	4901	0.40	0.001	43673
0.000025	3	21413	0.19	0	36758
0.000025	7	35120	0.00	0	42116
0.000035	7	30977	0.02	0	32304
Compromise plan					
0.00011	2	4162	0.01	0.06	5152
0.00009	2	5202	0.02	0.02	6967

Examination of the three sampling plans shows the current plan has little effect on outgoing quality, and may only be suitable for maintaining a data base. In developing the compromise plans both costs and quality were taken into consideration. The resulting plans increased the initial inspection sample size, kept reinspection frequency near that of the current plan; and increased quality of shipped goods. The traditional AOQL plans are cost-prohibitive and mechanically unmanageable because of the initial sample size and reinspection storage requirements. Comparison of the plans on a relative basis shows that the compromise plan is in the middle of the AOQL and current plans in terms of all attributes, but is closer to the latter than the former in terms of cost. The compromise sampling plan is the best choice to obtain an optimal solution in the short term with a view to maintaining and improving the process controls as the long-term objective. This short-term use of the compromise plan is not only consistent with the concept of quality by design, but also makes the most efficient use of total resources.

6. Conclusion

This case study illustrates that there exists a common problem in the design and implementation of quality assurance systems. This includes the existence of competing objectives, systems constraints, and non-quantifiable cost and system parameters. In these situations, unstructured approaches must be chosen. One such attractive approach is the development of alternative plans for quality assurance and the discussion of these plans with management. Nonstandard solutions are sometimes required; although, they are not optimal from an economic, statistical, or behavioural perspective. They are, however, good in all dimensions and preferred overall.

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