INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Mid-Autumn Semester Examination 2024-25

Date of Examination: 23-09-2024 **Session: (FN/AN)** AN **Duration:** 2 Hrs **Full Marks:** 50

Subject No. : RE30003 **Subject :** INTRODUCTION TO QUALITY

Department/Center/School: Subir Chowdhury School of Quality and Reliability

Specific charts, graph paper, log book etc., required No

Special Instructions (if any) : Answer all questions. Non-programmable digital calculator can be used for calculations. Clearly mention reasonable assumption(s), if any, while answering the questions.

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1) Name and explain three quality standards and describe the process of quality certification. Draw and explain the structure of the Malcolm Baldrige National Quality Award (MBNQA) assessment criteria. **[10]**

2) Draw and explain the Shewhart (PDCA) cycle. Name and describe the four main types of quality costs. **[10]**

3) A manufacturing company recorded the time (in minutes) taken to inspect 16 different batches of products. The data collected is as follows: 12, 15, 18, 20, 23, 25, 28, 30, 32, 34, 36, 38, 40, 42, 45, 46. **[10]**

a) Using the data above, create a stem-and-leaf plot to display the distribution of inspection times. Can you identify the stem with the highest concentration of data points? **(5)**

b) Construct a box-and-whisker plot for the data. Based on the plot, briefly comment on the symmetry and any potential outliers in the data. **(5)**

4) A pharmaceutical company is testing the effectiveness of a new drug. The effectiveness (in %) of the drug on individual patients is uniformly distributed between 60% and 80%. For regulatory approval, the company needs to ensure that at least 85% of patients experience an effectiveness level within a specific acceptable range. In addition, the company conducted a small-scale clinical trial with 25 patients, where effectiveness is defined as a level above 65%. The number of patients for whom the drug was effective follows a binomial distribution. The company also wants to determine how many patients must be tested until they observe 3 patients with an effectiveness level above 70%. This scenario is modeled using a negative binomial distribution. The binomial PMF can be written as: **[10]**

$$P(X = x) = {}^{n}C_{x}\, p^{x}(1-p)^{n-x}, \quad x = 0, 1, \cdots, n$$

The negative binomial PMF can be written as:

$$P(Y = y) = {}^{y-1}C_{r-1}\, p^{r}(1-p)^{y-r}, \quad y = \mathrm{r}, r+1, r+2, \cdots$$

a) Determine the central lower and upper thresholds such that at least 85% of the patients experience an effectiveness level within this range. **(3)**

b) What is the probability that exactly 20 out of 25 patients experience an effectiveness level above 65%? **(3)**

c) What is the probability that it will take exactly 5 patients to observe 3 patients with an effectiveness level above 70%? **(4)**

5) A satellite communication system relies on various components to maintain signal integrity and performance. Each component's capacity is crucial, and the company wants to ensure that all components meet a certain minimum standard to avoid system failures. The capacity C of each component follows a normal distribution with a mean of 50 Mbps (megabits per second) and a standard deviation of 5 Mbps. The demand D placed on these components varies due to fluctuating operational conditions and follows a normal distribution with a mean of 35 Mbps and a standard deviation of 5 Mbps. **[10]**

The total system performance P is modeled by a linear combination of the capacities of three randomly selected components. The overall system performance is given by:

$$P = 0.4C_1 + 0.3C_2 + 0.3C_3$$

where C_1, C_2, and C_3 are the capacities of the three components. The company defines non-conformance as any scenario where the demand exceeds the capacity, or the overall system performance falls below a threshold value of 45 Mbps.

a) Calculate the probability that a randomly selected component has non-conforming capacity (i.e., the demand D exceeds the capacity C). Use $\Phi(z = 2.12) = 0.9830$. **(3)**

b) Using the given linear combination for overall performance, calculate the mean and variance of P, assuming the capacities C_1, C_2, and C_3 are independent normal random variables with the same distribution as C. What is the probability that the overall performance P falls below the threshold value of 45 Mbps? Use $\Phi(z = 1.71) = 0.9564$. **(4)**

c) Given that the company requires at least 98% of components to conform (i.e., demand does not exceed capacity) and the overall performance to meet the threshold 95% of the time, discuss whether the current setup meets the quality standards. If not, suggest possible adjustments to either the component capacities or system setup to improve conformance. **(3)**