ASSIGNMENT

Course Code	**:**	**MMPC-005**
Course Title	**:**	**Quantitative Analysis for Managerial Applications**
Assignment Code	**:**	**MMPC-005/TMA/ JULY/2025**
Coverage	**:**	**All Blocks**

Note: Attempt all the questions and submit this assignment to the Coordinator of your study centre. Last date of submission for July 2025 Semester is 31st October, 2025 and for January 2026 Semester is 30th April 2026.

1. What is Statistical Decision Theory? Describe the four different states of decision environment in managerial applications. Which is the most prevalent state?

2. A certain manufacturing process yields electrical fuses of which, in the long run, 15% are defective. Find the probability that in a sample of 10 fuses selected at random there will be:
   a) No defective
   b) At least one defective

3. A manager at a drug manufacturing wants to estimate what proportion of the adult population of India has high blood pressure. He wants to be 99% sure that the error of his estimate will not exceed 0.02. Census reports indicate that about 0.20 of all adults have high blood pressure. What sample size shall he take?

4. For a set of 1000 observations known to be normally distributed, the mean is 534 cm and SD is 13.5 cm. How many observations are likely to exceed 561 cm? How many will be between 520.5 and 547.5 cm?

5. Write short notes on any three of the following:
   a) Level of significance
   b) Quartile Deviation
   c) Criterion of optimism
   d) Disproportional Stratified Sampling
   e) Least Square Criterion

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a) No defective

Probability Analysis in Manufacturing: A Case Study of Defective Electrical Fuses

In quality control and manufacturing, probability theory plays a crucial role in understanding and managing defects. Statistical tools enable businesses to estimate the likelihood of defects in production and to make data-driven decisions for improvement. In this context, we are given a scenario in which a manufacturing process yields electrical fuses, and 15% of them are defective in the long run. We are asked to determine the probability that a randomly selected sample of 10 fuses will contain **no defective** items.

Problem Restatement:

- Probability of a fuse being defective, $p = 0.15$
- Probability of a fuse being non-defective, $q = 1 - p = 0.85$
- Sample size, $n = 10$
- We are to find the probability of **no defective fuse**, i.e., 0 defective fuses in the sample.

This scenario follows a **binomial distribution**, where:

$$P(X = k) = \binom{n}{k} p^k (1 - p)^{n-k}$$

Where:

- $P(X = k)$ is the probability of getting exactly k defective fuses,
- $\binom{n}{k}$ is the number of combinations of k defectives from n,
- p is the probability of a fuse being defective,
- n is the total number of trials (fuses selected).

(a) Probability That There Are No Defective Fuses

We want the probability that all 10 selected fuses are **non-defective**, which is:

$$P(X = 0) = \binom{10}{0} (0.15)^0 (0.85)^{10}$$

Calculating step-by-step:

- $\binom{10}{0} = 1$
- $(0.15)^0 = 1$
- $(0.85)^{10} \approx 0.1969$ (Using a calculator or logarithmic table)

$$P(X = 0) = 1 \times 1 \times 0.1969 = 0.1969$$

Thus, the probability that all 10 fuses are non-defective is approximately **0.197** or **19.7%**.

Interpretation of the Result

The result shows that there is about a 19.7% chance that a random batch of 10 fuses will contain no defects. This information is valuable for quality assurance teams who need to set acceptable quality levels (AQLs) and for production managers evaluating process performance.

Managerial and Operational Implications

1. **Quality Control Planning:**

Knowing that there is only a 19.7% chance of zero defects helps managers understand the baseline risk. They might decide to implement additional inspections or revise manufacturing processes if higher quality is required.

2. **Batch Acceptance Sampling:**

In acceptance sampling, this probability would help determine whether to accept or reject a lot based on sample results. If zero defects is a strict requirement (as in high-reliability industries like aerospace or healthcare), the low probability would suggest that the current process is not sufficient.

3. **Risk Assessment:**

Managers can use such probability models to estimate failure rates and their financial or operational impacts. For instance, if a defective fuse leads to equipment failure, the cost implications can be assessed based on this 15% defect rate.

Generalization for Other Probabilities

Using the same binomial formula, we can calculate probabilities for other values (like exactly 1 defective, at most 2 defectives, etc.), which would provide a more complete view of the distribution and help develop better control strategies.

For example:

- Probability of **exactly 1** defective:

$$P(X=1)=\binom{10}{1}(0.15)^1(0.85)^9 \approx 10 \times 0.15 \times 0.2725 = 0.4087$$

- Probability of **at most 2** defectives:

$$P(X \leq 2) = P(0) + P(1) + P(2)$$

This cumulative approach would reveal the likelihood of acceptable quality thresholds being met.

Limitations and Assumptions

This model assumes:

- Each fuse is selected independently.
- The defect rate is constant (i.e., process stability).
- There is no inspection bias or sampling error.

In real-world scenarios, shifts in machine calibration, raw material quality, or human factors could affect these assumptions.

Conclusion

Statistical methods such as the binomial distribution provide essential insights into manufacturing quality control. In our case, with a 15% defect rate, the probability of selecting a sample of 10 fuses with no defects is approximately **19.7%**. This highlights that while the process produces mostly functional fuses, there is still a considerable chance of encountering defects. Understanding and acting on such probabilities supports data-driven decision-making, improved process control, and better customer satisfaction through enhanced product reliability.

b) At least one defective

Statistical analysis plays a central role in quality control within manufacturing industries. It enables decision-makers to assess the reliability of production processes and understand the likelihood of defects. In this case, we are given a manufacturing process where **15% of electrical fuses are defective**, and a sample of **10 fuses** is selected at random. We are to find the probability that the sample will contain **at least one defective fuse**.

Problem Overview

- **Defective rate (p)** = 0.15
- **Non-defective rate (q)** = 1 − p = 0.85
- **Sample size (n)** = 10 fuses
- **Required**: Probability that there is **at least one defective fuse** in the sample, i.e.,

$$P(\text{at least one defective}) = 1 - P(\text{no defective})$$

This is a **binomial probability** problem where each fuse has only two outcomes: defective or non-defective. The scenario is a classic example of **complement rule application** in probability.

Step-by-Step Calculation

Let X be the random variable representing the number of defective fuses in the sample. We are interested in:

$$P(X \geq 1) = 1 - P(X = 0)$$

Step 1: Calculate $P(X = 0)$

Using the binomial formula:

$$P(X = 0) = \binom{10}{0}(0.15)^0(0.85)^{10}$$

$$P(X = 0) = 1 \times 1 \times (0.85)^{10}$$

$$(0.85)^{10} \approx 0.1969$$

$$P(X = 0) \approx 0.1969$$

Step 2: Apply Complement Rule

$$P(X \geq 1) = 1 - P(X = 0)$$

$$P(X \geq 1) = 1 - 0.1969 = 0.8031$$

Final Answer:

$$\boxed{P(\text{At least one defective}) \approx 0.8031 \text{ or } 80.31\%}$$

Interpretation of the Result

The result indicates that there is approximately an **80.31%** chance that in any randomly selected batch of 10 fuses, **at least one fuse will be defective**. This probability is relatively high, especially if the acceptable defect rate for quality control is lower.

Managerial Implications

1. Quality Monitoring

The high probability of finding at least one defective fuse implies that defects are quite frequent. This should prompt quality control managers to examine:

- The production process for inefficiencies,
- Raw material quality, or
- Equipment calibration.

It also highlights the importance of random sample testing as part of the inspection process.

2. Inspection Planning

Knowing that more than 80% of the samples will likely contain a defect can influence how frequently and thoroughly batches are inspected. If the organization aims for Six Sigma or similar high-quality standards, this defect rate would be unacceptable.

3. Customer Satisfaction and Reliability

A high likelihood of encountering a defective product affects not only internal processes but also customer experience. If even a small batch of 10 fuses has an 80% chance of having a defect, the end-user reliability can be compromised.

4. Process Improvement Justification

This statistical evidence can justify investments in:

- Automated quality control systems,
- Staff training,
- Better machinery, or
- Lean manufacturing approaches.

Managers and engineers can use such probabilities to build a business case for continuous improvement initiatives.

Extending the Analysis

In addition to knowing the probability of at least one defective, managers may also want to calculate:

- The probability of **exactly one** defective,
- The probability of **two or more** defectives,
- The expected number of defective fuses in a batch of 10, i.e.,

$$E(X) = n \cdot p = 10 \cdot 0.15 = 1.5$$

This means that on average, **1.5 defective fuses** can be expected in every 10, further emphasizing the need for attention.

Limitations and Assumptions

- The calculation assumes **independent trials**, i.e., the defect status of one fuse does not affect another.
- The defect rate is assumed constant at 15%, which may not hold if process conditions vary over time.
- Sampling is done **without replacement**, but the sample size is small relative to the population, so binomial assumptions are still appropriate.

Conclusion

The probability of finding **at least one defective fuse** in a random sample of 10 from a process with a 15% defect rate is approximately **80.31%**. This high probability reflects the need for stringent quality controls in the manufacturing process. Managers can use this insight to evaluate the current quality level and implement strategies to reduce defects and enhance product reliability. Statistical decision-making like this forms a cornerstone of modern production and operations management.

3. A manager at a drug manufacturing wants to estimate what proportion of the adult population of India has high blood pressure. He wants to be 99% sure that the error of his estimate will not exceed 0.02. Census reports indicate that about 0.20 of all adults have high blood pressure. What sample size shall he take?

To estimate the proportion of adults in India with high blood pressure, the manager must determine the appropriate **sample size** to ensure a **99% confidence level** with a **maximum allowable error (margin of error) of 0.02**. This is a classic problem in **statistical estimation**, particularly involving **population proportion estimation using confidence intervals**.

1. Understanding the Problem

The goal is to estimate a population proportion, ppp, with a specific level of confidence and a defined margin of error.

- **Population proportion (ppp)**: 0.20 (from census data)
- **Confidence level**: 99%
- **Margin of error (EEE)**: 0.02

The manager wants the sample to be large enough so that the **estimate (sample proportion)** of adults with high blood pressure is within **±0.02** of the **true proportion** 99% of the time.

2. Formula for Sample Size Estimation (Proportion)

The standard formula for calculating the sample size for estimating a population proportion is:

$$n = \left(\frac{Z_{\alpha/2}^2 \cdot p \cdot (1-p)}{E^2} \right)$$

Where:

- n = required sample size
- $Z_{\alpha/2}$ = Z-score corresponding to the desired confidence level
- p = estimated population proportion
- E = margin of error

3. Determine the Z-Score for 99% Confidence Level

To find the Z-score corresponding to a 99% confidence level:

- Confidence level = 99%
- Significance level $\alpha = 1 - 0.99 = 0.01$
- $\alpha/2 = 0.005$ (two-tailed)

Using a **Z-table** or statistical software:

$$Z_{0.005} \approx 2.576$$

4. Substituting Values into the Formula

Given:

- $p = 0.20$
- $E = 0.02$
- $Z_{\alpha/2} = 2.576$

$$n = \left(\frac{(2.576)^2 \cdot 0.20 \cdot (1 - 0.20)}{(0.02)^2}\right)$$

$$n = \left(\frac{6.635 \cdot 0.20 \cdot 0.80}{0.0004}\right)$$

$$n = \left(\frac{6.635 \cdot 0.16}{0.0004}\right)$$

$$n = \left(\frac{1.0616}{0.0004}\right)$$

$$n = 2654$$

5. Final Answer

The manager should select a sample size of approximately **2,654 individuals** to be 99% confident that his estimate of the proportion of adults with high blood pressure is within ±0.02 of the true value.

6. Interpretation

With a sample size of **2,654**, the **sampling distribution** of the sample proportion will be **approximately normal** (due to the Central Limit Theorem), and the **sample**

proportion will lie within ±0.02 of the actual population proportion **99% of the time**. This ensures **high statistical reliability** in the estimate.

7. Why Use Prior Proportion (0.20)?

The use of $p = 0.20$ is based on **prior census data**, which helps to **reduce the required sample size** compared to using $p = 0.5$ (the most conservative estimate which yields the maximum required sample size).

However, if no prior estimate were available, we would use $p = 0.5$, leading to:

$$n = \left(\frac{(2.576)^2 \cdot 0.25}{(0.02)^2}\right) = \frac{6.635 \cdot 0.25}{0.0004} = \frac{1.65875}{0.0004} = 4147$$

Hence, using prior information (p = 0.20) reduces the sample size significantly from 4,147 to 2,654, which is both **cost-effective** and **efficient**.

8. Practical Considerations in Sampling

- **Random Sampling**: The sample must be randomly selected to ensure it is representative of the adult population.
- **Non-response Bias**: The manager must account for non-responses or incomplete data which may require **oversampling**.
- **Stratification**: If the population is diverse (e.g., urban vs rural, age groups, gender), **stratified sampling** might be used to ensure proportional representation.
- **Ethical Clearance**: Since it deals with health data, appropriate **ethical guidelines** must be followed in data collection.

9. Importance of Confidence Level and Margin of Error

- **Confidence level (99%)** implies **high assurance** in estimation but also **increases sample size**.
- **Margin of error (2%)** defines the precision. A smaller error requires a larger sample.

If the manager reduced the confidence level to 95% (Z = 1.96), the required sample would drop significantly:

$$n = \left(\frac{(1.96)^2 \cdot 0.20 \cdot 0.80}{(0.02)^2}\right) = \frac{3.8416 \cdot 0.16}{0.0004} = 1537$$

This trade-off between **accuracy**, **confidence**, and **cost** is crucial in statistical decision-making.

10. Conclusion

To estimate the proportion of adults in India with high blood pressure with a **99% confidence level** and a **margin of error not exceeding 2%**, the manager should sample **at least 2,654 adults**. This calculation ensures the estimate is **statistically reliable**, allowing for informed **health policy planning** or **drug manufacturing**

strategies. Thoughtful sampling methodology and awareness of practical constraints will further enhance the study's success.

4. For a set of 1000 observations known to be normally distributed, the mean is 534 cm and SD is 13.5 cm. How many observations are likely to exceed 561 cm? How many will be between 520.5 and 547.5 cm?

To solve this, we'll use **properties of the normal distribution** and the **Z-score formula**:

Given:

- Number of observations, $N = 1000$
- Mean, $\mu = 534$ cm
- Standard deviation, $\sigma = 13.5$ cm

(a) Number of observations likely to exceed 561 cm

First, calculate the **Z-score** for 561 cm:

$$Z = \frac{X - \mu}{\sigma} = \frac{561 - 534}{13.5} = \frac{27}{13.5} = 2$$

Now, using the standard normal distribution table:

- $P(Z > 2) = 1 - P(Z \leq 2) = 1 - 0.9772 = 0.0228$

So, the number of observations exceeding 561 cm:

$$= 1000 \times 0.0228 = 22.8 \approx \boxed{23}$$

(b) Number of observations between 520.5 cm and 547.5 cm

Step 1: Find Z-scores

For $X = 520.5$:

$$Z = \frac{520.5 - 534}{13.5} = \frac{-13.5}{13.5} = -1$$

For $X = 547.5$:

$$Z = \frac{547.5 - 534}{13.5} = \frac{13.5}{13.5} = 1$$

Step 2: Find area between Z = -1 and Z = 1

$$P(-1 < Z < 1) = P(Z < 1) - P(Z < -1) = 0.8413 - 0.1587 = 0.6826$$

So, the number of observations in that range:

$$= 1000 \times 0.6826 = 682.6 \approx \boxed{683}$$

Final Answers:

- Observations exceeding 561 cm: ≈ **23**
- Observations between 520.5 cm and 547.5 cm: ≈ **683**

5. Write short notes on any three of the following:

a) Level of significance

Level of Significance: An Explanation

In the field of statistics, particularly in hypothesis testing, the **level of significance** (denoted by the Greek letter α, alpha) is a fundamental concept. It represents the probability of rejecting a true null hypothesis, essentially defining the threshold for what we consider as "statistically significant." In simple terms, it tells us how much risk we are willing to take in concluding that a difference or relationship exists when, in fact, it does not.

Definition

The **level of significance** is the probability of making a **Type I error**, which occurs when a true null hypothesis is incorrectly rejected. For example, if we test whether a new drug is more effective than an existing one, the null hypothesis (H_0) may state that there is no difference in effectiveness. If we reject this null hypothesis based on our data, even though it is actually true, we have committed a Type I error.

Formally,

$$\text{Level of Significance } (\alpha) = P(\text{Rejecting } H_0 \mid H_0 \text{ is true})$$

Common Values

The level of significance is chosen **before** conducting the test and is typically set at values like:

- **0.05 (5%)** — most commonly used.
- **0.01 (1%)** — used for stricter testing, minimizing risk of Type I error.
- **0.10 (10%)** — used in more exploratory or less critical tests.

A significance level of 0.05 means there is a 5% chance of rejecting the null hypothesis when it is actually true — a 5% risk of drawing a wrong conclusion due to random chance.

Role in Hypothesis Testing

Hypothesis testing involves the following steps:

1. State the null hypothesis (H_0) and the alternative hypothesis (H_1).
2. Choose a level of significance (α).
3. Collect data and compute the test statistic (e.g., z-score, t-score).
4. Determine the critical value(s) or p-value.
5. Compare the p-value with α:
    - If $\mathbf{p \leq \alpha}$, reject the null hypothesis.
    - If $\mathbf{p > \alpha}$, fail to reject the null hypothesis.

The level of significance acts as a **cutoff point**. If the p-value is smaller than this threshold, the result is said to be **statistically significant**.

Example

Suppose a quality control manager tests whether a machine produces items with a mean weight of 500 grams. The null hypothesis is H_0: $\mu = 500$ grams. The manager sets $\alpha = 0.05$. After collecting sample data, the computed p-value is 0.03. Since $0.03 < 0.05$, the manager rejects the null hypothesis and concludes the machine is not producing items with the desired mean weight.

Importance

- **Risk control**: Helps balance the need to detect real effects with the risk of making false claims.
- **Scientific credibility**: Establishes the standard for claiming research findings are not due to random chance.
- **Consistency**: Provides a uniform rule across studies for drawing conclusions.

Conclusion

The **level of significance** is a crucial statistical tool that helps determine whether observed data deviate sufficiently from the null hypothesis to warrant its rejection. It sets the boundary between what is considered statistically likely versus unlikely under the assumption that the null hypothesis is true. Understanding and appropriately choosing α is key to sound decision-making in research and data analysis.

b) Quartile Deviation

Quartile Deviation, also known as the **semi-interquartile range**, is a measure of **statistical dispersion** or **spread**. It indicates the degree to which data values are spread around the central value, especially the **median**. It is particularly useful for understanding variability in a dataset, especially when the data contain outliers or are not symmetrically distributed.

Definition

The **Quartile Deviation (QD)** is defined as half the difference between the third quartile (Q_3) and the first quartile (Q_1). Mathematically:

$$\text{Quartile Deviation (QD)} = \frac{Q_3 - Q_1}{2}$$

Here,

- **Q_1** (First Quartile) is the value below which 25% of the data fall.
- **Q_3** (Third Quartile) is the value below which 75% of the data fall.
- The difference **(Q_3 - Q_1)** is called the **interquartile range (IQR)**.

Thus,

$$\text{QD} = \frac{\text{IQR}}{2}$$

Interpretation

Quartile Deviation gives the average spread of the middle 50% of a dataset. A **small QD** indicates that the central values are closely clustered, while a **large QD** shows more dispersion or variability among the central values.

This measure is **less affected by extreme values** (outliers) than standard deviation, making it more **robust**, especially for **skewed distributions** or ordinal data.

Example

Consider the following data (in ascending order):

10, 12, 14, 16, 18, 20, 22, 24, 26

- **Q_1** = 14 (25th percentile)
- **Q_3** = 24 (75th percentile)

$$\mathrm{QD} = \frac{24 - 14}{2} = \frac{10}{2} = 5$$

So, the quartile deviation is **5**, which means the middle 50% of data lie within ±5 units of the median.

Uses and Significance

1. **Robust Measure**: Unlike mean and standard deviation, quartile deviation is not influenced by extreme values. This makes it ideal for **income data**, **test scores**, or **housing prices**, where outliers may be present.
2. **Understanding Central Spread**: It focuses on the central half of the data, providing insights into consistency and reliability of the core data points.
3. **Ordinal Data**: Suitable for ordinal-level data where mean or standard deviation may not be meaningful.
4. **Box Plot Representation**: Quartile deviation complements box plots which display Q_1, median, and Q_3, making it useful in **exploratory data analysis**.

Limitations

- **Ignores Extremes**: QD does not consider the outer 50% of the data, so it misses information in the tails of the distribution.
- **Less Precise for Normal Data**: For normally distributed data, **standard deviation** gives a more complete measure of variability.
- **Not Suitable for All Purposes**: It is not useful where detailed statistical inference is required, especially when working with full distribution-based methods.

Conclusion

Quartile Deviation is a simple yet powerful tool to understand the variability within the middle half of a dataset. It is especially valuable when working with **non-normal**, **skewed**, or **ordinal data**, where traditional measures like standard deviation may not be appropriate. While it has some limitations, its robustness against outliers makes it an essential part of descriptive statistics, particularly in **social sciences**, **economics**, and **education research**.

c) Criterion of optimism

The *Criterion of Optimism*, also known as the *Maximax Criterion*, is a decision-making approach used under conditions of uncertainty. It reflects an optimistic or risk-seeking attitude, where the decision-maker assumes that the most favorable outcome will occur. This method is ideal for individuals or organizations that are willing to take risks for the possibility of high rewards.

Concept and Meaning

In real-world scenarios, decision-makers often encounter situations where the outcomes of their choices are uncertain. For example, launching a new product in a competitive market might succeed or fail depending on unpredictable market conditions. The Criterion of Optimism helps in such decision-making by assuming the best-case scenario for each alternative and choosing the one with the highest possible payoff.

Mathematically, the Maximax approach involves:

1. Listing all possible alternatives and their associated outcomes under different states of nature.
2. Identifying the maximum payoff for each alternative.
3. Selecting the alternative with the highest of these maximum payoffs.

This criterion is forward-looking and assumes favorable external conditions. It does not consider the likelihood of the states occurring; instead, it focuses solely on the most attractive outcomes.

Example

Suppose a company is evaluating three investment options, with projected profits (in lakhs) under three different market conditions:

Investment Option	Optimistic	Moderate	Pessimistic
A	100	60	20
B	80	70	40
C	120	50	-10

According to the Criterion of Optimism:

- Max payoff for A = 100
- Max payoff for B = 80
- Max payoff for C = 120

Since 120 is the highest among the maximum payoffs, option C would be selected. The decision-maker believes that the best-case scenario (earning ₹120 lakhs) will occur and chooses accordingly.

Characteristics

- **Optimistic Bias**: This method assumes that the best outcome will occur, which may not always be realistic.
- **Risk-Taking**: It is suitable for entrepreneurs and innovators who are willing to take high risks for high returns.
- **No Probability Involvement**: It does not take into account the probability of different outcomes; it only considers the most favorable.
- **Easy to Apply**: The method is simple and quick, making it useful when time is limited.

Advantages

- Encourages innovation and bold strategies.
- Motivates aggressive decision-making in highly competitive or rapidly changing environments.
- Useful in situations where one has control over outcomes or can influence success.

Limitations

- It ignores the risks and worst-case scenarios, which could lead to heavy losses.
- Not ideal for risk-averse individuals or organizations with limited resources.
- It lacks balance and might lead to over-optimism.

Conclusion

The Criterion of Optimism or Maximax criterion is a valuable decision-making tool for those who are willing to bet on the most favorable outcomes. While it promotes bold choices and high rewards, it also comes with significant risks. Therefore, it is best applied in environments where optimism is justified by opportunity and where losses from failure are manageable.