

**GUJARAT TECHNOLOGICAL UNIVERSITY**  
**BE-5 SEMESTER – OLD PAPER – S22 TO W25 – Q&A BANK (Theory)**

**Subject Name & Code:**  
**Operation Research (3151910)**

---

**Unit 1: Introduction to Operations Research & Linear Programming**

**Repeated Questions:**

1. **Discuss various applications of Operation Research.**

Appeared in: S25 (Q1a, 03 marks), S22 (Q1a, 03 marks)

---

**Answer:**

- **Production management:** Scheduling, inventory control, quality control.
- **Marketing:** Advertising budget allocation, product pricing, sales forecasting.
- **Finance:** Investment portfolio optimization, cash flow management.
- **Transportation:** Route planning, vehicle scheduling, logistics.
- **Healthcare:** Hospital staffing, equipment replacement, patient scheduling.
- **Defense:** Resource allocation, weapon targeting, logistics planning.
- **Agriculture:** Crop rotation planning, fertilizer mix optimization.
- **Real-world application:** Airline crew scheduling (saves millions annually) and supply chain network design.

○

2. **What are the assumptions in Linear Programming Problem (LPP)?**

Appeared in: S25 (Q2a, 03 marks), S24 (Q2a, 03 marks)

---

**Answer:**

1. **Proportionality** – Contribution of each variable is directly proportional to its value.
2. **Additivity** – Total objective and constraints are sum of individual contributions.
3. **Divisibility** – Decision variables can take any non-negative real value (fractional allowed).
4. **Certainty** – All parameters (costs, coefficients, resources) are known and constant.
5. **Finite choices** – Finite number of decision variables and constraints.
6. **Linearity** – All relationships are linear (no products, powers, or non-linear terms).
7. **Non-negativity** – Variables cannot be negative.

○

3. **Discuss various phases in solving an OR problem.**

Appeared in: S23 (Q1b, 04 marks), W25 (Q1b, 04 marks)

---

**Answer:**

1. **Problem definition** – Identify the objective, constraints, and decision variables.
  2. **Data collection** – Gather relevant quantitative and qualitative information.
  3. **Model formulation** – Translate real problem into mathematical (LP, IP, etc.).
  4. **Model solution** – Apply appropriate technique (simplex, graphical, etc.).
  5. **Validation & testing** – Check model against real data and refine.
  6. **Implementation** – Apply solution to actual system and monitor results.
- Real-world application: In supply chain optimization, phases ensure the model matches

warehouse capacities and delivery constraints before deploying.

○

4. **Explain graphically: (a) No feasible solution (b) Unbounded solution in LPP.**

Appeared in: S25 (Q1b, 04 marks), S24 (Q1a, 03 marks)

**Answer:**

**(a) No feasible solution**

- No point satisfies all constraints simultaneously.
- In graph, feasible region is empty (constraints are contradictory).
- *Example:*  $x \leq 2$  and  $x \geq 3$  together.

**[DG PROMPT – No feasible solution]**

*Title:* Infeasible LPP graphical representation

*Description:* Draw X and Y axes. Plot constraint lines (e.g.,  $x+y \leq 3$ ,  $x+y \geq 5$ ). Show that the half-planes do not overlap. Label the region ‘No intersection – Infeasible’. Use dashed lines for strict inequalities.

**(b) Unbounded solution**

- Feasible region is not closed in the direction of objective improvement.
- Objective value can increase (maximization) or decrease (minimization) infinitely.
- *Example:* Maximize  $Z = x+y$  subject to  $x \geq 0$ ,  $y \geq 0$  (no upper bound).

**[DG PROMPT – Unbounded solution]**

*Title:* Unbounded LPP graphical representation

*Description:* Draw axes. Show a constraint like  $x \geq 0$ ,  $y \geq 0$ . Draw objective function line moving outward without hitting any boundary. Indicate with arrows that region extends to infinity.

○

5. **Define slack and surplus variables in LPP.**

Appeared in: S22 (Q2a, 03 marks)

**Answer:**

- **Slack variable** – Added to a “ $\leq$ ” constraint to convert it into equality. Represents unused resource.
  - *Example:*  $x + y \leq 10 \rightarrow x + y + s = 10$ ,  $s \geq 0$ .
- **Surplus variable** – Subtracted from a “ $\geq$ ” constraint to convert it into equality. Represents excess above requirement.
  - *Example:*  $x + y \geq 5 \rightarrow x + y - t = 5$ ,  $t \geq 0$ .

○

**Other Important Questions:**

1. **Define OR. Discuss origin and development of OR.**

Appeared in: S23 (Q1a, 03 marks)

**Answer:**

**Definition:** Operations Research (OR) is a scientific approach to decision-making that uses mathematical models, statistics, and algorithms to optimize complex systems.

**Origin & development:**

- **World War II (1940s)** – Military OR teams in UK/USA for radar placement, convoy routing.
- **1950s** – Adapted to industry (production, inventory).

- **1960s** – Simplex method (Dantzig), introduction of computers.
- **1970–90s** – Spread to service sectors, finance, healthcare.
- **2000s onwards** – Integration with AI, big data, machine learning.

○

## 2. Explain the scope of OR in various sectors.

Appeared in: S23 (Q1c, 07 marks)

### Answer:

- **Manufacturing** – Production scheduling, inventory control (EOQ), quality control.
- **Transportation** – Route optimization (Vogel's method), fleet management.
- **Telecom** – Network design, bandwidth allocation.
- **Banking** – ATM cash replenishment, loan portfolio optimization.
- **Healthcare** – Staff rostering, patient flow, equipment replacement.
- **Agriculture** – Crop mix, irrigation scheduling.

Real-world application: Amazon uses OR for warehouse location and delivery route optimization.

○

## 3. What is Linear Programming Problem? Discuss scope and role in solving management problems.

Appeared in: S24 (Q1c, 07 marks)

### Answer:

**Definition:** LPP is a mathematical technique to find the best outcome (max profit / min cost) subject to linear constraints.

### Scope in management:

- **Product mix decision** – What to produce and in what quantity.
- **Resource allocation** – Limited raw materials, labour, capital.
- **Transportation & assignment** – Minimize shipping cost / maximize efficiency.
- **Blending problems** – Fuel, feed, chemical mixtures.

**Role:** Provides optimal, non-intuitive solutions quickly; aids managerial planning.

○

## 4. Discuss limitations of OR.

Appeared in: W25 (Q1a, 03 marks)

### Answer:

1. **High cost** – Requires specialized software, experts, and time.
2. **Assumptions** – Often unrealistic (linearity, certainty, divisibility).
3. **Data dependency** – Output quality depends on input accuracy.
4. **Implementation gap** – Managers may resist model-based recommendations.
5. **Complexity** – Large real problems become computationally infeasible.
6. **Quantitative only** – Ignores qualitative factors (human behaviour, morale).

○

## 5. Write characteristics of Operations Research.

Appeared in: W24 (Q1a, 03 marks)

### Answer:

- **Systems orientation** – Considers entire system, not isolated parts.

- **Interdisciplinary approach** – Uses mathematics, economics, engineering.
- **Model building** – Represents real situations via mathematical models.
- **Optimization** – Seeks best feasible solution (max/min).
- **Quantitative analysis** – Relies on numbers and algorithms.
- **Decision support** – Aids managers, not replaces judgment.

○  
6. **Discuss limitations of LPP.**  
Appeared in: W24 (Q1b, 04 marks)

---

**Answer:**

1. **Linearity assumption** – Many real relationships are non-linear.
2. **Certainty assumption** – Parameters assumed constant, but actual may vary.
3. **Divisibility** – Some variables must be integer (LPP gives fractional).
4. **Single objective** – Cannot handle multiple conflicting goals directly.
5. **Large scale** – Time-consuming for many variables/constraints.
6. **Sensitivity** – Small changes in data may drastically alter solution.

○  
7. **Sketch graphical representation of: (1) Infeasible solution, (2) Redundant constraint.**  
Appeared in: W24 (Q1c, 07 marks)

---

**Answer:**

- (1) Infeasible solution** – See Q.4(a) for diagram prompt.  
**(2) Redundant constraint** – A constraint that does not affect the feasible region; it is automatically satisfied when others are met.

**[DG PROMPT – Redundant constraint]**

*Title:* Redundant constraint graphical representation

*Description:* Draw X and Y axes. Plot two binding constraints that form a closed feasible region (e.g.,  $x+y \leq 6$ ,  $x \leq 4$ ,  $y \leq 4$ ). Then plot a third constraint  $x+y \leq 10$  – this line lies outside the region and does not cut it. Label it “Redundant constraint”.

○  
8. **Explain relationship between primal and dual solution.**  
Appeared in: W25 (Q2a, 03 marks)

---

**Answer:**

- **Primal (maximization) ↔ Dual (minimization).**
- **Weak duality** – Objective value of dual is always  $\geq$  objective of primal (for max primal).
- **Strong duality** – At optimality, primal objective = dual objective.
- **Complementary slackness** – If a primal variable is positive, the corresponding dual constraint is tight (and vice versa).
- **Dual variables** – Represent shadow prices (marginal value of resources).

Real-world application: In production planning, dual variables tell the worth of extra raw material.

9. **Define: Basic Feasible Solution, Objective Function, Degenerate Solution, Optimal Feasible Solution.**  
Appeared in: S23 (Q2b, 04 marks)

---

**Answer:**

- **Basic Feasible Solution (BFS)** – A solution at a corner point of the feasible region where number of positive variables  $\leq$  number of constraints.
- **Objective Function** – The linear function ( $Z = c_1x_1 + c_2x_2\dots$ ) to be maximized or minimized.
- **Degenerate Solution** – A BFS where one or more basic variables have value zero.
- **Optimal Feasible Solution** – A BFS that gives the best (maximum/minimum) value of the objective function satisfying all constraints.

○

**10. What are applications of LPP?**

Appeared in: S23 (Q2a, 03 marks)

**Answer:**

- **Manufacturing** – Product mix, production scheduling.
- **Transportation** – Minimize shipping cost, route planning.
- **Finance** – Portfolio selection, capital budgeting.
- **Agriculture** – Crop area allocation, fertilizer mix.
- **Marketing** – Media selection, advertising budget.
- **HR** – Staff assignment, shift scheduling.

Real-world application: Oil refineries use LPP to blend crude oils into gasoline meeting octane specifications at least cost.

○

**11. Write general mathematical formulation of LP problem.**

Appeared in: W22 (Q1b, 04 marks)

**Answer:****General form (maximization):**Maximize  $Z = c_1x_1 + c_2x_2 + \dots + c_nx_n$ 

Subject to:

$$a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n \leq b_1$$

$$a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n \leq b_2$$

...

$$a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n \leq b_m$$

$$x_1, x_2, \dots, x_n \geq 0$$

- $c_j$  = profit coefficients
- $a_{ij}$  = technology coefficients
- $b_i$  = resource availabilities

○

**12. State and explain various characteristics of Linear Programming.**

Appeared in: W22 (Q1a, 03 marks)

**Answer:**

1. **Linearity** – Objective and constraints are linear.
2. **Deterministic** – All parameters are known constants.
3. **Additivity** – Total activity = sum of individual activities.

4. **Proportionality** – One unit of variable contributes constant amount.
5. **Divisibility** – Variables can be fractional.
6. **Non-negativity** – Variables cannot be negative.
7. **Finite number** – Limited number of alternatives (variables and constraints).

○

---

## Unit 2: Transportation & Assignment Problems

### Repeated Questions:

#### 1. What is degeneracy in transportation problem?

Appeared in: S25 (Q2b, 04 marks), W25 (Q3a OR, 03 marks), S22 (Q3a, 03 marks)

#### Answer:

Degeneracy occurs when the number of allocated cells in the basic feasible solution is less than  $(m + n - 1)$ . This leads to a zero in a basic cell, causing cycling or inability to compute optimality test directly.

#### Causes:

- When a supply and demand are satisfied simultaneously at a cell (tie).

#### Remedy:

- Introduce a very small  $\varepsilon$  (epsilon) in an empty cell to restore  $m+n-1$  occupied cells.

○

#### 2. How profit maximization problem can be solved using assignment technique?

Appeared in: S25 (Q4b, 04 marks), S22 (Q3a, 03 marks), W25 (Q3a, 03 marks)

#### Answer:

1. Convert profit matrix into cost matrix by subtracting each profit from the maximum profit of that row (or column).
2. Alternatively, use the **Hungarian algorithm on the original profit matrix** by performing row/column reductions on profits directly – the maximized total profit is obtained.
3. Standard assignment minimizes cost; for maximization, either:
  - Replace profit  $p_{ij}$  with  $M - p_{ij}$  ( $M =$  large number) and then minimize.
  - Or subtract each row's max from all entries in that row, then proceed with standard Hungarian.

Real-world application: Assigning salespersons to territories to maximize total sales revenue.

○

#### 3. Explain unbalanced assignment problems.

Appeared in: S24 (Q3a, 03 marks), W22 (Q3a, 03 marks)

#### Answer:

An assignment problem is unbalanced if number of rows  $\neq$  number of columns.

#### Solution approach:

- If more workers than jobs  $\rightarrow$  add dummy columns (jobs) with zero cost.
- If more jobs than workers  $\rightarrow$  add dummy rows (workers) with zero cost.
- Then solve using Hungarian algorithm as a balanced square matrix.

**Note:** Dummy assignments represent unassigned workers or jobs.

○

#### 4. Discuss various methods of getting Initial Basic Feasible Solution (IBFS) in transportation problem.

Appeared in: S24 (Q3a OR, 03 marks), S23 (Q3b, 04 marks)

#### Answer:

1. **North-West Corner Rule (NWCR)** – Start from top-left, allocate  $\min(\text{supply}, \text{demand})$ , move right/down. (Fast but poor solution)

2. **Row Minima Method** – Allocate to smallest cost in each row, then proceed.
3. **Column Minima Method** – Similar but column-wise.
4. **Vogel's Approximation Method (VAM)** – Compute penalties (difference between two smallest costs) for each row/col; allocate to smallest cost in row/col with highest penalty. (Most accurate IBFS, close to optimal)

Real-world application: Logistics firms use VAM to get a near-optimal shipping plan before optimizing further.

○

5. **How will you define transportation problem? Give mathematical statement.**

Appeared in: S24 (Q3b OR, 04 marks), S23 (Q3a, 03 marks)

**Answer:**

**Definition:** A transportation problem seeks to minimize the cost of shipping a homogeneous product from  $m$  sources (supply) to  $n$  destinations (demand) subject to supply and demand constraints.

**Mathematical statement:**

$$\text{Minimize } Z = \sum_{i=1}^m \sum_{j=1}^n c_{ij} x_{ij}$$

Subject to:

$$\sum_{j=1}^n x_{ij} = a_i \quad (i = 1, 2, \dots, m) \text{ (supply constraints)}$$

$$\sum_{i=1}^m x_{ij} = b_j \quad (j = 1, 2, \dots, n) \text{ (demand constraints)}$$

$$x_{ij} \geq 0$$

where  $a_i$  = supply at source  $i$ ,  $b_j$  = demand at destination  $j$ ,  $c_{ij}$  = unit cost,  $x_{ij}$  = quantity shipped.

○

**Other Important Questions:**

1. **Explain significance of positive, zero, and negative opportunity cost in transportation problem.**

Appeared in: S22 (Q1b, 04 marks)

**Answer:**

○

2. **Is it possible to solve assignment problem using transportation technique? Explain with reason.**

Appeared in: S25 (Q3b, 04 marks)

**Answer:**

○

3. **Explain "Transportation problem is a special case of LPP".**

Appeared in: W24 (Q3a, 03 marks)

---

**Answer:**

- 4. **Write canonical form of transportation problem.**  
Appeared in: W24 (Q3a OR, 03 marks)

---

**Answer:**

- 5. **Write difference between transportation and assignment problems.**  
Appeared in: W24 (Q3b OR, 04 marks)

---

**Answer:**

- 6. **Explain transportation problems with prohibited routes.**  
Appeared in: W22 (Q3a OR, 03 marks)

---

**Answer:**

- 7. **What are trans-shipment problems? Explain with example.**  
Appeared in: S24 (Q3b, 04 marks), W22 (Q3b OR, 04 marks)

---

**Answer:**

- 8. **Explain the difference between transportation and assignment problems.**  
Appeared in: W23 (Q3a OR, 03 marks)

---

**Answer:**

- 9. **Describe mathematical formulation of assignment problem.**  
Appeared in: W23 (Q3b OR, 04 marks)

---

**Answer:**

- 10. **What do you understand by balanced and unbalanced transportation problem? How is unbalanced problem tackled?**  
Appeared in: W23 (Q3a, 03 marks)

---

**Answer:**

- 11. **Explain steps in Modified Distribution (MODI) method.**  
Appeared in: W23 (Q3b, 04 marks)

---

**Answer:**

○  
**12. Describe procedure to solve Travelling Salesman Problem.**  
Appeared in: W22 (Q3b, 04 marks)

---

**Answer:**

○  
**13. Explain steps of Travelling Salesman Problem.**  
Appeared in: S25 (Q3c OR, 07 marks)

---

**Answer:**

○

---

## Unit 3: Queuing Theory

### Repeated Questions:

1. Define the following terms relating to customer's behavior in queue:

(A) Balking (B) Jockeying (C) Reneging

Appeared in: S25 (Q4a, 03 marks), S22 (Q4a OR, 03 marks), W23 (Q2b, 04 marks)

#### Answer:

Term	Definition
<b>Balking</b>	Customer refuses to join the queue upon arrival (because queue is too long).
<b>Jockeying</b>	Customer switches from one queue to another (in multi-queue systems) hoping for faster service.
<b>Reneging</b>	Customer joins the queue but leaves after waiting too long without being served.

Real-world application: Supermarket checkout lines – customers balk if long, renege if slow.

2. Explain Kendall's notation for queuing system.

Appeared in: S24 (Q5a, 03 marks), W23 (Q4b OR, 04 marks)

#### Answer:

Kendall's notation: **A / B / C / D / E / F**

- **A** – Arrival process (M = Markovian, D = Deterministic, G = General)
- **B** – Service time distribution (M, D, G, etc.)
- **C** – Number of parallel servers
- **D** – Queue discipline (FCFS, LCFS, SIRO, etc.)
- **E** – Maximum system capacity (queue + servers)
- **F** – Calling population size (infinite/finite)

*Example:* M/M/1/FCFS/∞/∞ – Poisson arrivals, exponential service, single server.

3. Explain the queuing model as indicated by the following notation: **M/D/1 : FCFS/∞/∞**

Appeared in: S24 (Q4b, 04 marks), W22 (Q4a, 03 marks)

#### Answer:

- **M** – Markovian / Poisson arrival process (exponential inter-arrival times).
- **D** – Deterministic service time (constant).
- **1** – Single server.
- **FCFS** – First-come first-service queue discipline.
- ∞ (first) – Infinite system capacity (no limit on queue length).
- ∞ (second) – Infinite population size.

#### Characteristics:

- Used for automated processes (e.g., machine, toll booth with fixed service time).
- Performance measures:  $L_q = \frac{\rho^2}{2(1-\rho)}$  where  $\rho = \lambda/\mu$ .

Real-world application: Automatic car wash – arrivals random, service time fixed.

○

**Other Important Questions:****1. Define the elements of a Queuing System.**

Appeared in: S24 (Q4a OR, 03 marks), S23 (Q4a OR, 03 marks)

**Answer:**

1. **Arrival process** – Pattern of customer arrivals (Poisson, deterministic).
2. **Service mechanism** – Number of servers, service time distribution.
3. **Queue discipline** – Order of serving (FCFS, LCFS, priority).
4. **System capacity** – Maximum number of customers allowed (finite/infinite).
5. **Calling population** – Source of customers (finite/infinite).

○

**2. Classify the Queuing Models.**

Appeared in: W24 (Q4a, 03 marks)

**Answer:**

- **By number of servers** – Single server (M/M/1), multi-server (M/M/c).
- **By service time distribution** – Markovian (M), Deterministic (D), General (G).
- **By queue discipline** – FCFS, LCFS, Priority, Random.
- **By system capacity** – Finite (buffer size N) or infinite.
- **By population** – Finite or infinite calling population.

○

**3. What is float? Discuss in brief: (i) Total float (ii) Free float.**

Appeared in: S25 (Q4b, 04 marks)

**Answer:**

○

**4. Define: Queue and give its classification. Mention applications of each type of queue.**

Appeared in: W22 (Q4b, 04 marks)

**Answer:**

**Queue:** A line of waiting customers (humans, jobs, packets) awaiting service.

**Classification with applications:**

Type	Description	Application
Single queue – single server	One line, one server	Small retail shop
Single queue – multiple servers	One line, several servers	Bank teller counter
Multiple queues – multiple servers	Separate lines per server	Supermarket checkout
Priority queue	High-priority customers	Hospital emergency

Type	Description	Application
	served first	room
Cyclic queue	Servers serve in round-robin	Computer processor scheduling

---

## Unit 4 – Inventory Control

(Topics: Inventory classification, Different cost associated to Inventory, Economic order quantity, Inventory models with deterministic demands, ABC analysis and VED analysis)

### Repeated Questions

#### 1. What is inventory? Discuss benefits and limitations of inventory.

Appeared in: W23 (Q4b, 04 marks), W24 (Q4b, 04 marks)

#### Answer:

**Inventory:** Stock of goods/materials held for future use (raw materials, WIP, finished goods).

#### Benefits:

- Prevents stock-outs and lost sales.
- Allows economies of scale (bulk purchasing).
- Smooths production fluctuations.
- Buffers against supply/demand uncertainty.

#### Limitations (disadvantages):

- Ties up capital.
- Storage, insurance, handling costs.
- Risk of obsolescence, damage, theft.
- May hide production inefficiencies.

Real-world application: Amazon's fulfillment centres use inventory to guarantee next-day delivery.

○

#### 2. Discuss various costs involved in an Inventory model.

Appeared in: S25 (Q3a, 03 marks), W24 (Q5a, 03 marks)

#### Answer:

1. **Ordering cost** (or Setup cost) – Cost per purchase order (paperwork, transportation).
2. **Holding (Carrying) cost** – Warehousing, insurance, obsolescence, capital cost.
3. **Shortage (Stock-out) cost** – Lost sales, backorder expenses, customer goodwill loss.
4. **Purchase cost** – Price per unit (may be quantity-dependent).

○

### Other Important Questions

#### 1. What do you mean by inventory? What are the advantages and disadvantages of it?

Appeared in: S22 (Q5a, 03 marks)

#### Answer:

Similar to Q. above (benefits/limitations). See answer for “What is inventory? Discuss benefits and limitations.”

○

## 2. Why inventory is known as necessary evil?

Appeared in: S23 (Q4a, 03 marks)

### Answer:

Inventory is “necessary” because it ensures smooth production and customer service. It is an “evil” because it ties up capital, incurs carrying costs, and risks obsolescence. Companies try to minimize inventory (Just-in-Time philosophy) but cannot eliminate it completely due to uncertainties. Thus, it is a trade-off – necessary for operations but undesirable financially.

○

## 3. Derive the equation for Economic Order Quantity (EOQ) for constant demand with the condition of no shortage.

Appeared in: S23 (Q4b, 04 marks)

### Answer:

#### Given:

- $D$  = Annual demand (units/year)
- $C_o$  = Ordering cost per order (₹)
- $C_h$  = Holding cost per unit per year (₹)

**Formula:** Total cost = Ordering cost + Holding cost

$$TC(Q) = \frac{D}{Q} \cdot C_o + \frac{Q}{2} \cdot C_h$$

#### Derivation:

1. Differentiate  $TC(Q)$  w.r.t  $Q$ :

$$\frac{d(TC)}{dQ} = -\frac{DC_o}{Q^2} + \frac{C_h}{2}$$

2. Set derivative = 0 for minimum:

$$\frac{C_h}{2} = \frac{DC_o}{Q^2} \Rightarrow Q^2 = \frac{2DC_o}{C_h}$$

3. Therefore:

$$EOQ = \sqrt{\frac{2DC_o}{C_h}}$$

**Final answer:**  $Q^* = \sqrt{\frac{2DC_o}{C_h}}$

○

## 4. Discuss different costs associated with Inventory.

Appeared in: S24 (Q4a, 03 marks)

**Answer:**

Same as “Discuss various costs involved in an Inventory model” (see above).

○

**5. Discuss ABC analysis.**

Appeared in: S24 (Q4b, 04 marks)

**Answer:**

ABC analysis classifies inventory items based on annual consumption value (price × quantity).

Category	% of items	% of value	Control level
<b>A</b>	~10%	~70%	Tight control, frequent review, high security
<b>B</b>	~20%	~20%	Moderate control, periodic review
<b>C</b>	~70%	~10%	Loose control, bulk ordering, low security

Real-world application: Spare parts in a car factory – Engine components (A), interior trims (B), nuts/bolts (C).

○

**6. Write a short note on ABC analysis of inventory control technique.**

Appeared in: S25 (Q3c, 07 marks)

**Answer:**

**Principle:** Pareto’s 80/20 rule – small percentage of items account for high percentage of value.

**Procedure:**

1. Calculate annual usage value = unit cost × annual demand for each item.
2. Rank items in descending order of annual value.
3. Compute cumulative percentage of items and cumulative value.
4. Classify:
  - **A:** Top 70-80% of value, next ~10-20% of items.
  - **B:** Next 15-20% of value, next ~20-30% of items.
  - **C:** Remaining 5-10% of value, ~50-70% of items.

**Diagram prompt – ABC curve:**

[DG PROMPT]

*Title:* ABC Analysis Pareto Curve

*Description:* Draw X-axis as ‘Cumulative % of items’ (0-100%), Y-axis as ‘Cumulative % of value’ (0-100%). Plot a convex curve starting from origin, rising steeply then flattening. Mark points: (20,70) for A-B boundary, (50,90) for B-C boundary. Shade three regions.

**Advantages:**

- Focuses managerial attention where it matters most.

- Reduces inventory cost without affecting service level.

**Limitations:**

- Ignores criticality of non-A items (e.g., low-value but essential spares).

**Real-world application:** Hospitals use ABC to manage surgical supplies – expensive implants (A) vs. bandages (C).

○

**7. Classify the inventory with suitable examples.**

Appeared in: W22 (Q3a, 03 marks)

---

**Answer:**

Type	Description	Example
Raw materials	Unprocessed inputs	Steel sheets, plastic granules
Work-in-progress (WIP)	Partially finished goods	Car on assembly line
Finished goods	Final products ready for sale	Packed smartphones
Maintenance/repair/ops (MRO)	Supplies for operations	Lubricants, tools
Transit inventory	Goods in transportation	Goods on ship

○

**8. Define inventory. Why is it necessary to control?**

Appeared in: W25 (Q4a, 03 marks)

---

**Answer:**

**Definition:** Inventory is the stock of physical goods held for future production or sale.

**Need for control:**

- Avoid over-investment (capital blockage).
- Prevent stock-outs (lost sales).
- Minimize carrying costs (storage, insurance).
- Reduce obsolescence and spoilage.
- Improve cash flow and profitability.

○

**9. Discuss costs associated with inventory control.**

Appeared in: W25 (Q4b, 04 marks)

---

**Answer:**

Same as “Discuss various costs involved in an Inventory model” (see above)

## Unit 5: Replacement Theory

### Repeated Questions:

1. **Explain Group Replacement Policy with suitable example.**

Appeared in: S25 (Q4b OR, 04 marks), S22 (Q4b OR, 04 marks)

#### Answer:

**Group replacement policy:** All items in a group (e.g., all bulbs in a factory) are replaced at fixed intervals regardless of individual condition.

#### Procedure:

1. Determine probability distribution of failure.
2. Compute cost of individual replacement (failed items).
3. Compute cost of group replacement at various intervals.
4. Choose interval that minimizes total cost.

**Example:** Streetlight bulbs – replace all every 6 months. Cost of replacing 100 bulbs = ₹5000. Cost per individual failure = ₹100. If failure rate increases after 6 months, group replacement may be cheaper.

Real-world application: LED panels in digital billboards.

○

2. **Explain how replacement theory is used for items whose maintenance cost varies with time.**

Appeared in: W24 (Q4b, 04 marks)

#### Answer:

For items (e.g., vehicles, machines) that deteriorate gradually, maintenance cost increases with age. Replacement theory finds the optimal time to replace the item to minimize **average annual cost** = (purchase price – salvage value + total maintenance cost) / number of years.

#### Steps:

1. Collect data on maintenance cost each year.
2. Compute cumulative maintenance cost.
3. Calculate total cost if replaced at end of year n.
4. Compute average annual cost.
5. Choose n giving the lowest average cost.

Real-world application: Car fleet management – decide when to replace taxicabs.

○

### Other Important Questions:

1. **Explain Procedure for Group Replacement Theory.**

Appeared in: S25 (Q3a OR, 03 marks)

#### Answer:

1. **Collect failure data** – Probability of failure in each time period (e.g., month).
2. **Compute expected number of failures** each period using probability distribution.
3. **Calculate individual replacement cost** = cost per failure × number of failures.
4. **Calculate group replacement cost** = cost of replacing all items at once.
5. **For each replacement interval** (e.g., 1,2,3,... months), compute total cost = group cost + individual failures cost for all periods.
6. **Divide by interval length** to get average cost per period.

7. **Select interval** with minimum average cost.

**Example:** Light bulbs – group replacement every 3 months may give lowest cost.

○

2. **Discuss Individual Replacement vs. Group Replacement.**

Appeared in: S23 (Q3b OR, 04 marks)

---

**Answer:**

○

3. **Define: Discount Rate, Money Value, Present Worth Factor.**

Appeared in: S23 (Q3a OR, 03 marks)

---

**Answer:**

○

4. **Describe some important replacement situations.**

Appeared in: S24 (Q5b OR, 04 marks), W22 (Q5a OR, 03 marks)

---

**Answer:**

1. **Gradual deterioration** – Maintenance cost rises over time (vehicle, machine).
2. **Sudden failure** – Items fail randomly (light bulbs, electronic components).
3. **Group replacement** – Replace entire set periodically.
4. **Individual replacement** – Replace only failed items.
5. **Technological obsolescence** – Replace due to new better model (computers).
6. **Capital equipment replacement** – Old machine vs new (higher output).

○

5. **Explain briefly difference in replacement of items that deteriorate gradually vs. items that fail suddenly.**

Appeared in: W25 (Q4c OR, 07 marks)

---

**Answer:**

Parameter	Gradual deterioration	Sudden failure
<b>Failure pattern</b>	Wear out; failure probability increases with age	Random; constant failure rate
<b>Maintenance cost</b>	Increases over time	Constant or unpredictable
<b>Replacement decision</b>	Optimal age based on average cost	Often group replacement or individual upon failure
<b>Example</b>	Car, industrial machine	Light bulb, electronic chip

○



## Unit 6: Game Theory

### Repeated Questions:

1. **Define in context of Game Theory: Strategy, Player, Saddle Point, Pure Strategy, Mixed Strategy.**

Appeared in: S25 (Q4a OR, 03 marks), W25 (Q4a OR, 03 marks), W24 (Q4a OR, 03 marks)

---

#### Answer:

Term	Definition
<b>Strategy</b>	A complete plan of action for a player in every possible situation.
<b>Player</b>	An individual or group making decisions in a game.
<b>Saddle point</b>	Position in pay-off matrix where $\max(\min) = \min(\max)$ ; equilibrium.
<b>Pure strategy</b>	Player always chooses the same action (no randomness).
<b>Mixed strategy</b>	Player chooses actions with certain probabilities (randomization).

2. **What is “zero-sum” in context of Game Theory?**

Appeared in: S22 (Q4a, 03 marks), W25 (Q4a, 03 marks), W23 (Q4a OR, 03 marks)

---

#### Answer:

A **zero-sum game** is one where the total gain of all players is zero. One player's gain is exactly equal to the other's loss.

**Example:** Two players – Player A wins ₹100, Player B loses ₹100 → sum = 0.

**Property:** Perfectly competitive; interests are completely opposite.

3. **What is “dominance rule” in Game Theory?**

Appeared in: S25 (Q3a, 03 marks)

---

#### Answer:

Dominance rule reduces the size of a pay-off matrix by eliminating dominated strategies.

- **Row dominance** (for player A, maximizing): If every element in row  $i$  is  $\geq$  corresponding element in row  $k$ , then row  $i$  dominates row  $k$  ( $k$  can be deleted).
- **Column dominance** (for player B, minimizing): If every element in column  $j$  is  $\leq$  corresponding element in column  $l$ , then column  $j$  dominates column  $l$  ( $l$  can be deleted).

Real-world application: In marketing, a company can drop an inferior advertising strategy if another strategy yields higher profit in all market conditions.

---

### Other Important Questions:

1. **List different methods for solving Game Problems.**

Appeared in: W22 (Q4a OR, 03 marks)

**Answer:**

1. **Pure strategy** – Saddle point (maximin = minimax).
2. **Mixed strategy (2×2)** – Odds method or formula method.
3. **Mixed strategy (m×n)** – Dominance, then graphical method (for 2×n or m×2).
4. **Linear programming** – Convert game to LPP (for larger games).
5. **Iterative method** (approximate).

○

2. **Write important assumptions of Game Theory.**

Appeared in: W22 (Q4b OR, 04 marks)

**Answer:**

1. **Rational players** – Each player selects strategies to maximize own gain.
2. **Zero-sum** – Total payoff is constant (often zero).
3. **Complete information** – Each player knows all strategies and payoffs.
4. **Simultaneous moves** – Players act without knowing opponent's move.
5. **Finite number** of players, strategies.
6. **No cooperation** – Players do not form coalitions.

○

3. **Discuss characteristics of Game Theory.**

Appeared in: W24 (Q4b OR, 04 marks)

**Answer:**

- **Competitive situation** – At least two decision-makers.
- **Conflict of interest** – What one gains, the other loses (in zero-sum).
- **Strategy-based** – Outcome depends on choices of all players.
- **Pay-off matrix** – Summarises outcomes.
- **Equilibrium concept** – Saddle point or mixed strategy equilibrium.
- **Solution methods** – Graphical, LPP, algebraic.

○

4. **Write down mathematical formula for Game Theory.**

Appeared in: S24 (Q4a, 03 marks), S23 (Q5a, 03 marks)

**Answer:**

For a **2×2 zero-sum game** with pay-off matrix  $\begin{bmatrix} a & b \\ c & d \end{bmatrix}$  (player A's payoffs), the **value of game V** and **mixed strategies** are:

$$V = \frac{ad - bc}{a + d - b - c}$$

Probability that A plays row 1:  $p = \frac{d-c}{a+d-b-c}$

Probability that B plays column 1:  $q = \frac{d-b}{a+d-b-c}$

(Assume no saddle point; denominators non-zero.)

○

5. **What are types of strategies for Game Theory?**

Appeared in: S24 (Q4b OR, 04 marks), S23 (Q5b, 04 marks)

---

**Answer:**

Type	Description
<b>Pure strategy</b>	Single deterministic action chosen by a player.
<b>Mixed strategy</b>	Probability distribution over multiple pure strategies.
<b>Optimal strategy</b>	Strategy that maximizes gain or minimizes loss (equilibrium).
<b>Dominant strategy</b>	Always better regardless of opponent's choice.
<b>Pareto optimal</b>	Cannot improve one player without harming another (non-zero-sum).

○

6. **Define: Saddle Point. How is it found?**

Appeared in: W25 (Q5b OR, 04 marks)

---

**Answer:**

**Saddle point** is an entry in the pay-off matrix that is simultaneously the minimum of its row and the maximum of its column (i.e., the value at which  $\max\min = \min\max$ ).

**How to find:**

1. For each row, find the minimum value.
2. Choose the **maximum** of these row minima = **maximin**.
3. For each column, find the maximum value.
4. Choose the **minimum** of these column maxima = **minimax**.
5. If  $\maximin = \minimax$ , that common value is the saddle point; both players' optimal pure strategies.

Real-world application: In an oligopoly pricing game, a saddle point indicates a stable Nash equilibrium.

○

---

## Unit 7: Decision Theory

### Repeated Questions:

#### 1. Explain EMV, EOL, EVPI.

Appeared in: S25 (Q5a, 03 marks)

#### Answer:

Term	Definition
<b>EMV (Expected Monetary Value)</b>	Sum of (payoff $\times$ probability) for each decision alternative; choose max EMV.
<b>EOL (Expected Opportunity Loss)</b>	Sum of (opportunity loss $\times$ probability); choose min EOL. (EMV + EOL = constant)
<b>EVPI (Expected Value of Perfect Information)</b>	Difference between expected payoff with perfect information and EMV without perfect information. $EVPI = EPPI - EMV^*$ where EPPI = expected payoff with perfect info.

Real-world application: A farmer chooses crop based on weather forecast (EMV), and EVPI tells maximum worth of a perfect weather forecast.

#### 2. Discuss difference between decision-making under certainty, uncertainty, and risk.

Appeared in: S22 (Q5a, 03 marks), W23 (Q5a OR, 03 marks), W24 (Q5c OR, 07 marks)

#### Answer:

Criterion	Certainty	Risk	Uncertainty
<b>Knowledge</b>	Full knowledge of outcomes	Probabilities known	Probabilities unknown
<b>Information level</b>	Perfect	Probabilistic (known probabilities)	No probabilistic information
<b>Decision criteria</b>	Choose outcome with best payoff	EMV, EOL, EUT	Maximax, Maximin, Hurwicz, Laplace, Minimax regret
<b>Example</b>	Deposit in fixed deposit (interest guaranteed)	Stock market investment (historical return probabilities)	Launching a new product (no prior data)

#### Explanation:

- **Certainty** – Each action leads to a single known outcome.
- **Risk** – Multiple outcomes with known probabilities (e.g., roulette).

- **Uncertainty** – Multiple outcomes but no probabilities; use decision rules.  
**Real-world application:** Pharmaceutical R&D – clinical trial results (risk) vs. completely new disease (uncertainty).

○

---

**Other Important Questions:**
**1. Explain Decision Tree.**

 Appeared in: S25 (Q3b OR, 04 marks), W22 (Q2a, 03 marks)
 

---

**Answer:**

A decision tree is a graphical tool representing sequential decisions under uncertainty.

**Components:**

- **Square node** – Decision point.
- **Circle node** – Chance event (probabilities shown).
- **Branches** – Alternatives or outcomes.
- **End nodes** – Payoffs.

**Procedure:**

1. Draw the tree from left to right.
2. Assign probabilities to chance branches.
3. Roll back (calculate EMV at chance nodes, choose best at decision nodes).

**[DG PROMPT – Decision Tree]**
*Title:* Decision Tree for investment problem

*Description:* Start with a square node “Invest”. Two branches: “New product” (square) and “Existing product”. For “New product”, a chance node (circle) with branches “Success (0.6)” leading to profit 100, “Failure (0.4)” leading to loss 50. Show EMV calculations.

 Real-world application: Oil exploration – decide to drill or not based on seismic test results.
 

---

○

**2. Explain steps for Decision Theory approach.**

 Appeared in: S25 (Q5c OR, 07 marks)
 

---

**Answer:**

1. **Identify the decision problem** – Define objectives, alternatives, and uncertain events.
2. **List alternatives** (actions) available to the decision-maker.
3. **Identify possible states of nature** (future conditions) – mutually exclusive, exhaustive.
4. **Construct payoff (or loss) matrix** – Each cell = outcome for alternative  $i$  under state  $j$ .
5. **Assign probabilities** (if risk) to states; otherwise use uncertainty criteria.
6. **Choose decision criterion** – EMV (risk), Maximin/Maximax (uncertainty).
7. **Evaluate and select the optimal alternative** – Compute criterion value for each alternative, choose best.
8. **Perform sensitivity analysis** – Check how changes in probabilities/payoffs affect decision.

 Real-world application: Choosing a new manufacturing plant location – consider demand states (high, medium, low).
 

---

3. **What is EMV? How is it computed as decision-making criterion?**

Appeared in: W25 (Q5b, 04 marks)

**Answer:**

**EMV (Expected Monetary Value)** is the weighted average of payoffs under different states of nature, using probabilities as weights.

**For alternative i:**

$$EMV_i = \sum_{j=1}^n P_j \cdot O_{ij}$$

where  $P_j$  = probability of state j,  $O_{ij}$  = payoff of alternative i in state j.

**Decision rule:** Choose the alternative with **highest EMV** (for profit) or **lowest EMV** (for cost).

**Example:** Alternative A: (profit 100 with  $p=0.5$ , profit 0 with  $p=0.5$ )  $\rightarrow$   $EMV=50$ ;

Alternative B: (profit 60 always)  $\rightarrow$   $EMV=60$   $\rightarrow$  choose B.

4. **Explain procedure steps for Hurwicz criterion.**

Appeared in: W24 (Q5b, 04 marks)

**Answer:**

Hurwicz criterion (realism criterion) is used under uncertainty. It uses a coefficient of optimism  $\alpha$  ( $0 \leq \alpha \leq 1$ ).

**Steps:**

1. For each alternative, identify best payoff (B) and worst payoff (W).
2. Compute **Hurwicz value** =  $\alpha \times B + (1-\alpha) \times W$ .
3. Choose alternative with **highest** Hurwicz value (for profit).
  - $\alpha = 1$   $\rightarrow$  maximax (optimistic).
  - $\alpha = 0$   $\rightarrow$  maximin (pessimistic).
  - $\alpha = 0.5$   $\rightarrow$  Laplace (equally likely) but not exactly; it's a trade-off.

Real-world application: Launching a new product – an optimistic manager ( $\alpha=0.8$ ) weighs high success strongly.

5. **Explain various steps involved in decision-making.**

Appeared in: S25 (Q5c OR, 07 marks), W23 (Q5a, 03 marks)

**Answer:**

This is essentially the same as “steps for Decision Theory approach” (see above). Provide the same 8 steps.

**Alternative shorter list for 7 marks:**

1. Define the problem.
2. Specify objectives.
3. Generate alternatives.
4. Identify states of nature.
5. Construct payoff table.
6. Assign probabilities (if risk).
7. Apply decision criterion.
8. Choose and implement.

○  
6. **Discuss difference between decision-making under certainty and under conflict.**

Appeared in: W22 (Q2b, 04 marks)

---

**Answer:**

Aspect	Certainty	Conflict (Game Theory)
<b>Environment</b>	Single decision-maker, nature as opponent	Two or more rational opponents
<b>Information</b>	Full knowledge of outcomes	Opponent's strategies may be partially unknown
<b>Outcome</b>	Determined by decision plus fixed condition	Determined by choices of all players
<b>Solution</b>	Choose best payoff	Saddle point or mixed strategy
<b>Example</b>	Buying a train ticket (fixed price)	Chess, bidding in auction

○

---

## Unit 8: Project Management (PERT & CPM)

### Repeated Questions:

#### 1. Differentiate between CPM and PERT.

Appeared in: S24 (Q5a OR, 03 marks), W23 (Q5b, 04 marks), W22 (Q5b OR, 04 marks)

---

#### Answer:

Parameter	CPM	PERT
<b>Full form</b>	Critical Path Method	Program Evaluation & Review Technique
<b>Activity times</b>	Deterministic (single time estimate)	Probabilistic (3 estimates – optimistic, most likely, pessimistic)
<b>Focus</b>	Cost-time trade-off (crashing)	Time estimation with uncertainty
<b>Model type</b>	Deterministic	Probabilistic
<b>Used for</b>	Repetitive / construction projects	R&D / one-time projects
<b>Slack</b>	Calculated	Calculated

#### 2. Define: Activity, Event, Dummy Activity, Float.

Appeared in: W24 (Q5a, 03 marks), W23 (Q5b OR, 04 marks)

---

#### Answer:

Term	Definition
<b>Activity</b>	A task requiring time and resources, represented by an arrow in network.
<b>Event</b>	A point in time marking start or completion of an activity (node).
<b>Dummy activity</b>	A fictitious activity (zero time) showing logical dependency; used to maintain precedence.
<b>Float (slack)</b>	Amount of time an activity can be delayed without delaying project completion. Types: Total float, Free float, Independent float.

#### 3. Explain predecessor, successor, and dummy activity with diagram.

Appeared in: S22 (Q5a, 03 marks), W25 (Q5a OR, 03 marks)

---

#### Answer:

- **Predecessor** – Activity that must be completed before another can start.

- **Successor** – Activity that follows a predecessor.
- **Dummy activity** – Dotted arrow linking events to show dependency without duration.

[DG PROMPT – Predecessor, successor, dummy]

*Title:* Network diagram with dummy activity

*Description:* Draw three nodes (1,2,3). Arrow A from 1→2 (predecessor). Arrow B from 2→3 (successor). To show that activity D depends on C but not on B, add a dummy dotted arrow from node of C to node of D. Label “Dummy (0 time)”.

○

#### Other Important Questions:

1. **What is replacement? Explain with real examples.**

Appeared in: S25 (Q5a OR, 03 marks)

#### Answer:

**Replacement** is the decision to substitute an existing asset (machine, equipment, bulb) with a new one due to wear, failure, or obsolescence.

#### Examples:

- Replacing old office computers with new faster ones.
- Changing worn-out tyres of a truck.
- Replacing fluorescent tubes in a factory every 6 months (group replacement).

○

2. **Explain term “Crashing of network”. Why is it required?**

Appeared in: S23 (Q5b, 04 marks)

#### Answer:

#### Ans:

**Crashing** is the process of reducing project duration by allocating additional resources (overtime, extra crews) to critical activities, at an increased cost.

#### Why required?

- Meet a deadline.
- Avoid penalty clauses.
- Gain incentive bonus for early completion.
- Respond to client request.

#### Procedure:

1. Identify critical path.
2. Select least-cost activity to crash.
3. Crash incrementally until desired duration or until cost exceeds benefit.

Real-world application: Construction projects – adding night shifts to finish before rainy season.

○

3. **Discuss rules of network construction.**

Appeared in: S25 (Q5b OR, 04 marks)

#### Answer:

1. Each activity must be represented by one and only one arrow.
2. No two activities can have the same start and end nodes (use dummy if needed).
3. The network must have a single start node (no predecessor) and a single end node.
4. Arrows should flow from left to right (no looping).

5. All nodes must be numbered uniquely; numbers increase along arrow direction.
6. An activity cannot start until all its predecessors are complete.
7. Dummy activities (zero time) may be used to maintain precedence logic.

○

**4. Define: Event, Activity, Total float w.r.t. CPM/PERT.**

Appeared in: S23 (Q5a OR, 03 marks)

---

**Answer:**

- **Event** – A point in time (node) indicating start/finish of activities.
- **Activity** – A task with duration (arrow).
- **Total float** – The maximum delay allowed for an activity without delaying project completion.

$$TF = LS - ES = LF - EF$$

where LS = late start, ES = early start, LF = late finish, EF = early finish.

○

**5. Explain D.R. Fulkerson's rule for network diagram.**

Appeared in: W22 (Q5b, 04 marks)

---

**Answer:**

Fulkerson's rule is used for numbering nodes (events) in a network to maintain logical ordering.

**Steps:**

1. The initial node is numbered 1.
2. Delete all outgoing arrows from numbered nodes to expose new unnumbered nodes.
3. Number the next node(s) in order (2,3,...) ensuring no node is numbered until all its predecessor nodes are numbered.
4. Repeat until all nodes are numbered.

**Purpose:** Avoids backward numbering and ensures each activity flows from lower number to higher number (topological order).

○

**6. Explain term "Looping" in context of network scheduling.**

Appeared in: W24 (Q5a OR, 03 marks)

---

**Answer:**

**Looping** is an error in network diagram where a sequence of activities forms a closed loop (e.g., A → B → C → A).

**Causes:**

- Improper use of dummy activities.
- Mistaken precedence relationships.

**Consequence:**

- Makes calculation of event times impossible (infinite loop).
- Invalid network.

**Remedy:** Redraw network ensuring acyclic structure (no path from a node back to itself).

○

**7. Differentiate between forward and backward planning.**

Appeared in: W24 (Q5b OR, 04 marks)

**Answer:**

<b>Parameter</b>	Forward planning	Backward planning
<b>Direction</b>	Compute earliest times (ES, EF) from start to end.	Compute latest times (LS, LF) from end to start.
<b>Start point</b>	Project start (time 0).	Project finish (deadline).
<b>Output</b>	Earliest project completion time.	Latest allowable start times.
<b>Use</b>	To find critical path and total float.	To determine schedule slack.
<b>Formula</b>	$ES = \max (EF_{predecessors}), EF = ES + t$	$LF = \min (LS_{successors}), LS = LF - t$

○

8. **Mention any two limitations of Critical Path.**

Appeared in: W25 (Q5a, 03 marks)

**Answer:**

1. **Assumes deterministic durations** – Real projects have uncertainty (PERT addresses this).
2. **Does not consider resource constraints** – Critical path may change if resources are limited (leads to resource-constrained scheduling).
3. **Ignores non-critical activity delays** – Even non-critical paths can become critical if delayed enough.
4. **Requires accurate time estimates** – Poor estimates render critical path meaningless.

○

\*\*\*\*\*