CMA FINAL · PAPER 16 · GROUP III

Strategic Cost Management (SCM)

Complete Formula & Practical Application Book — module-wise formulas, real exam-style worked illustrations with stepwise solutions, and a 150-question MCQ bank (15 MCQs × 2 marks per module), built on ICMAI Syllabus 2022.

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Table of Contents

How to use this book: Each module gives you (1) every formula you need, (2) a plain-English note on when/how to apply it in an exam question, (3) fully worked illustrations with step-by-step solutions, and (4) 15 exam-style MCQs (2 marks each) with answers and explanations. Formulas and illustrations are freshly worked for this book to build genuine conceptual clarity — always cross-check the latest ICMAI Study Material/RTP/MTP for any syllabus updates closer to your attempt.

SECTION A — STRATEGIC COST MANAGEMENT FOR DECISION MAKING (60% weightage)

SECTION B — QUANTITATIVE TECHNIQUES IN DECISION MAKING (40% weightage)

SECTION A

Strategic Cost Management for Decision Making

Weightage: 60% of total marks | Modules 1–5

MODULE 1 · SECTION A

Introduction to Strategic Cost Management

Foundational strategic costing concepts — Target Costing, Life Cycle Costing, Kaizen Costing, and Value Chain Analysis — that shift cost management from a scorekeeping to a strategic role.

1. Formulas

Target Cost

Target Cost = Target Selling Price − Target (Desired) Profit Margin

Cost is derived backwards from a market-driven price, unlike traditional cost-plus pricing which starts from cost.

Cost Gap (Value Engineering Target)

Cost Gap = Estimated (Current/Drifting) Cost − Target Cost

The cost gap must be closed through value engineering/value analysis before the product is launched, not by raising price after launch.

Life Cycle Cost

Life Cycle Cost = R&D Cost + Design Cost + Manufacturing Cost + Marketing & Distribution Cost + Customer Service Cost + Cost of Disposal/Decommissioning

Captures the total cost incurred across a product's entire life, not just its manufacturing phase — often 80-90% of life cycle cost is "locked in" at the design stage.

Kaizen Cost Reduction Target

Kaizen Target Cost (Period t) = Previous Period Actual Cost × (1 − Kaizen Reduction Rate)

Kaizen costing targets small, continuous cost reductions during the manufacturing/maturity phase (unlike target costing, applied pre-production).

Value Chain Profitability

Profit Margin at each Value Chain Activity = Revenue Attributable − Cost of that Activity

Used to identify which activities in the chain (inbound logistics → operations → outbound logistics → marketing → service) add the most/least value relative to cost.

2. Practical Application

Target Costing: Best suited to competitive, price-sensitive markets (e.g., consumer electronics, automobiles) where the firm is a "price taker" and must engineer cost down to a market-determined price.

Life Cycle Costing: Critical for products with high upfront R&D/design costs and long usage phases (e.g., pharma, defence equipment, aircraft) — ensures pricing recovers total life cycle cost, not just current-period production cost.

Kaizen vs Target Costing: Target costing acts before production begins (design phase); Kaizen costing acts continuously during production (maturity phase) to sustain margins as prices erode over time.

3. Worked Illustration

Illustration 1.1 — Target Costing & Cost Gap

A company plans to launch a product expected to sell at ₹2,500 per unit. The desired profit margin is 18% of selling price. The current estimated cost (based on existing design) is ₹2,150 per unit.

Step 1 — Target Profit: 18% × 2,500 = ₹450 per unit

Step 2 — Target Cost: 2,500 − 450 = **₹2,050 per unit**

Step 3 — Cost Gap: Estimated Cost − Target Cost = 2,150 − 2,050 = **₹100 per unit**

A cost gap of ₹100 per unit must be closed through value engineering (redesign, alternate materials/processes) before the product is launched, to achieve the desired 18% margin at the market price of ₹2,500.

4. Practice MCQs (15 × 2 Marks)

Q1. Target Costing determines cost by starting from:

A. The current production cost
B. The market-driven selling price, working backwards
C. The competitor's cost structure only
D. Historical average costs

Answer: B

Target Costing = Selling Price − Desired Margin, reversing the traditional cost-plus pricing logic.

Q2. The "cost gap" in target costing must ideally be closed through:

A. Raising the selling price after launch
B. Value engineering/value analysis before production begins
C. Reducing product quality without redesign
D. Ignoring it entirely

Answer: B

Value engineering redesigns the product/process to eliminate unnecessary cost while preserving function, closing the gap pre-launch.

Q3. Life Cycle Costing captures costs across which stages?

A. Only the manufacturing stage
B. R&D, design, manufacturing, marketing, service, and disposal — the entire product life
C. Only the marketing stage
D. Only the disposal stage

Answer: B

Life cycle costing takes a "cradle to grave" view of total cost incurred over the product's complete life.

Q4. Studies suggest that roughly what proportion of a product's life cycle cost gets "locked in" at the design stage?

A. 5-10%
B. 20-30%
C. 80-90%
D. 100% only at production stage

Answer: C

Design decisions commit most future costs even though actual expenditure occurs later — hence the strategic emphasis on getting design right.

Q5. Kaizen Costing is best described as:

A. A one-time cost reduction at the design stage
B. Continuous, incremental cost reduction efforts during the production/maturity phase
C. A pricing strategy for new product launches only
D. A method of inventory valuation

Answer: B

Kaizen costing pursues small, ongoing cost reductions throughout the manufacturing phase, unlike the one-time, pre-production focus of target costing.

Q6. If a product's target selling price is ₹1,000 with desired margin 20% of cost (mark-up on cost), the target cost is:

A. ₹800
B. ₹833.33
C. ₹1,200
D. ₹900

Answer: B

If margin is 20% of cost: Price = Cost + 0.20 Cost = 1.20 Cost. Cost = 1,000/1.20 = ₹833.33.

Q7. Value Chain Analysis primarily helps a firm identify:

A. Only its financial statements
B. Activities that add the most/least value relative to their cost, across the full chain from suppliers to customers
C. Tax liabilities
D. Employee attendance patterns

Answer: B

Value chain analysis decomposes a firm's operations into discrete activities to assess where competitive advantage and cost efficiency can be gained.

Q8. Strategic Cost Management differs from traditional cost accounting mainly because it:

A. Focuses only on historical cost recording
B. Integrates cost information with strategic decision-making and competitive positioning
C. Ignores customer and market factors
D. Applies only to manufacturing costs

Answer: B

SCM uses cost data proactively to support strategic decisions (pricing, product mix, investment) rather than merely recording historical costs.

Q9. A firm using Kaizen Costing achieving a 3% cost reduction target on a previous actual cost of ₹500 per unit should aim for a new cost of:

A. ₹515
B. ₹485
C. ₹500
D. ₹450

Answer: B

Kaizen Target Cost = 500 × (1−0.03) = 500 × 0.97 = ₹485.

Q10. Which of the following industries would benefit MOST from Life Cycle Costing?

A. A fast-moving consumer good with a 3-month shelf life
B. Aircraft manufacturing with decades-long R&D, usage, and service support
C. A single-use retail item
D. Daily perishable groceries

Answer: B

Products with long life spans and significant upfront R&D/design and after-sale service costs benefit most from a total life cycle costing view.

Q11. Value Engineering aims to:

A. Reduce cost while maintaining or improving the product's function/quality
B. Increase cost regardless of function
C. Eliminate the product entirely
D. Only apply to marketing expenses

Answer: A

Value engineering systematically analyses functions to achieve required performance at the lowest possible cost.

Q12. Traditional cost-plus pricing differs from target costing in that it:

A. Starts from cost and adds a margin to arrive at price
B. Starts from price and works backward to determine allowable cost

C. Ignores cost entirely
D. Is identical to target costing

Answer: A

Cost-plus pricing = Cost + Margin = Price (forward calculation), the reverse of target costing's backward approach.

Q13. The primary trigger for using Target Costing is usually:

A. A monopoly market with no competition
B. A highly competitive market where the firm cannot dictate selling price
C. A government-regulated fixed-price product
D. Absence of any cost data

Answer: B

In competitive markets, price is largely set by the market, forcing firms to manage cost to the target rather than pricing based on cost.

Q14. Which cost is typically EXCLUDED from a traditional (non-life-cycle) product costing approach but INCLUDED in life cycle costing?

A. Direct materials
B. Post-sale customer service and disposal/decommissioning costs
C. Direct labour
D. Manufacturing overheads

Answer: B

Traditional costing often stops at the point of sale/production; life cycle costing extends to after-sale service and end-of-life disposal costs.

Q15. A firm following the strategic cost management philosophy would most likely make a pricing/design decision based on:

A. Only the current period's absorption cost
B. Broader strategic factors — competitive position, customer value, and total life cycle economics
C. The previous year's budget alone
D. Random estimation

Answer: B

SCM decisions integrate cost data with strategic, competitive, and customer-value considerations rather than relying on a single period's cost figure.

MODULE 2 · SECTION A

Quality Cost Management

Classifying and measuring the Cost of Quality (COQ) — prevention, appraisal, internal failure and external failure costs — to guide quality investment decisions.

1. Formulas

Total Cost of Quality (COQ)

`COQ = Prevention Cost + Appraisal Cost + Internal Failure Cost + External Failure Cost`

The four categories (PAIE) form the standard COQ classification (per ASQ/CIMA terminology).

Cost of Conformance

`Cost of Conformance = Prevention Cost + Appraisal Cost`

Costs incurred proactively to ensure quality standards are met (getting it right the first time).

Cost of Non-Conformance

`Cost of Non-Conformance = Internal Failure Cost + External Failure Cost`

Costs incurred because of defects — internal (scrap, rework before dispatch) or external (warranty claims, returns, lost customer goodwill after dispatch).

COQ as a % of Sales

`COQ Ratio = Total Cost of Quality / Total Sales × 100`

A key benchmarking and trend-analysis metric — well-run TQM organisations typically target this well below 5%.

Cost of Rework

`Cost of Rework = Additional Material + Labour + Overheads incurred to correct defective units to a saleable condition`

Classified as an Internal Failure Cost.

2. Practical Application

Quality investment trade-off: Increasing spend on prevention and appraisal (conformance costs) reduces failure costs (non-conformance) — the classic "cost of quality" curve shows total COQ is minimised at an optimal quality level, not at zero defects or zero prevention spend.

Shifting the cost mix: Mature quality programs (e.g., Six Sigma, TQM) aim to shift spending from costly failure categories toward cheaper prevention activities — "an ounce of prevention is worth a pound of cure."

External failure costs: Often understated in accounting records because they include hard-to-quantify items like loss of customer goodwill and future lost sales — exam answers should flag this qualitative point.

3. Worked Illustration

Illustration 2.1 — Classifying & Computing Cost of Quality

A company reports: Quality training ₹2,00,000; Inspection of incoming materials ₹1,50,000; Scrap & rework ₹3,00,000; Warranty claims ₹4,50,000; Product testing equipment maintenance ₹1,00,000; Customer returns processing ₹80,000. Total sales = ₹2,50,00,000.

Step 1 — Classify each cost:
Prevention: Quality training = 2,00,000
Appraisal: Incoming material inspection 1,50,000 + Testing equipment maintenance 1,00,000 = 2,50,000
Internal Failure: Scrap & rework = 3,00,000
External Failure: Warranty claims 4,50,000 + Returns processing 80,000 = 5,30,000

Step 2 — Total COQ: 2,00,000 + 2,50,000 + 3,00,000 + 5,30,000 = **₹12,80,000**

Step 3 — COQ as % of Sales: 12,80,000 / 2,50,00,000 × 100 = **5.12%**

Total Cost of Quality = ₹12,80,000 (5.12% of sales). External failure cost is the single largest component — the company should investigate root causes of warranty claims and consider increasing prevention spend to shift the mix.

4. Practice MCQs (15 × 2 Marks)

Q1. Which of the following is a Prevention Cost?

A. Warranty claims
B. Quality training and process design improvement
C. Scrap
D. Customer complaint handling

Answer: B

Prevention costs are incurred to stop defects from occurring in the first place — training and process/design improvement are classic examples.

Q2. Warranty claims and product recalls are classified as:

A. Prevention Cost
B. Appraisal Cost
C. Internal Failure Cost
D. External Failure Cost

Answer: D

These costs arise after the defective product has reached the customer — classic external failure costs.

Q3. Cost of Conformance includes:

A. Prevention + Appraisal costs
B. Internal + External Failure costs
C. Only Prevention cost
D. Only External Failure cost

Answer: A

Conformance costs are proactive costs (prevention and appraisal) incurred to achieve quality standards.

Q4. Scrap and rework of defective units identified before dispatch are classified as:

A. Prevention Cost
B. Appraisal Cost
C. Internal Failure Cost
D. External Failure Cost

Answer: C

Since the defect is caught internally (before reaching the customer), it is an internal failure cost.

Q5. Inspection and testing of finished goods before dispatch is an example of:

A. Prevention Cost
B. Appraisal Cost
C. Internal Failure Cost
D. External Failure Cost

Answer: B

Appraisal costs relate to measuring/inspecting products to detect defects, such as final inspection before dispatch.

Q6. According to the classic Cost of Quality curve, total COQ is minimised when:

A. Prevention and appraisal spending is zero
B. Quality level is at an optimal balance between conformance and non-conformance costs
C. Defect rate is exactly 100%
D. Failure costs are maximised

Answer: B

Total COQ is minimised at an optimal quality investment level, not at zero prevention spend or zero defects (in the traditional COQ model).

Q7. External failure costs are often understated in financial records mainly because they include:

A. Easily quantifiable direct material costs
B. Intangible costs like loss of customer goodwill and future lost sales
C. Only depreciation
D. Only fixed overheads

Answer: B

Reputational damage and lost future sales from dissatisfied customers are real costs but are difficult to measure and often omitted from formal accounts.

Q8. If Total COQ = ₹18,00,000 and Sales = ₹3,00,00,000, the COQ ratio is:

A. 3%
B. 6%
C. 9%
D. 16.67%

Answer: B

COQ Ratio = 18,00,000/3,00,00,000 × 100 = 6%.

Q9. A mature TQM/Six Sigma program typically aims to shift cost mix towards:

A. Higher external failure cost
B. Higher prevention cost and lower failure costs overall
C. Zero quality spending
D. Higher internal failure cost only

Answer: B

Investing more in prevention reduces the much costlier failure categories, lowering total COQ over time.

Q10. Calibration and maintenance of testing/measuring equipment is classified as:

A. Prevention Cost
B. Appraisal Cost
C. Internal Failure Cost
D. External Failure Cost

Answer: B

Maintaining testing equipment supports the inspection/appraisal function, so it's classified as an appraisal cost.

Q11. Redesigning a manufacturing process to reduce the likelihood of future defects is a:

A. Prevention Cost
B. Internal Failure Cost
C. External Failure Cost
D. Not a quality cost at all

Answer: A

Proactive process redesign to prevent defects before they occur is a classic prevention cost.

Q12. Cost of Non-Conformance is also referred to as the cost of:

A. Doing it right the first time

B. Poor quality / doing it wrong
C. Only marketing
D. Only taxation

Answer: B

Non-conformance costs (internal + external failure) represent the cost incurred because quality standards were NOT met.

Q13. Loss of customer goodwill due to a defective product reaching the market is classified under:

A. Prevention Cost
B. Appraisal Cost
C. Internal Failure Cost
D. External Failure Cost

Answer: D

Since the defect reached the customer and damaged goodwill, this is classified as an external failure cost.

Q14. Which pairing correctly matches the cost category with an appropriate example?

A. Prevention — Cost of scrap
B. Appraisal — Statistical process control checks during production
C. Internal Failure — Warranty replacement
D. External Failure — Employee training

Answer: B

SPC checks during production are inspection/measurement activities — appraisal cost. (Scrap is internal failure; warranty replacement is external failure; training is prevention.)

Q15. A key benefit of tracking COQ as a percentage of sales over time is that it allows management to:

A. Ignore quality issues entirely
B. Benchmark and trend quality performance and cost-effectiveness of quality initiatives
C. Calculate income tax liability
D. Set employee salaries

Answer: B

The COQ ratio, tracked over periods, helps management assess whether quality investments are reducing overall quality-related costs.

MODULE 3 · SECTION A · HIGHEST WEIGHTAGE (25%)

Decision Making Techniques

Marginal costing-based short-term decisions: CVP analysis, key factor/limiting factor decisions, make-or-buy, shut-down, and relevant costing for special orders.

1. Formulas

Contribution

`Contribution = Sales − Variable Cost = Fixed Cost + Profit`

The foundation of every marginal-costing decision — only contribution (not full cost) is relevant for most short-term choices.

P/V Ratio (Contribution/Sales Ratio)

`P/V Ratio = Contribution / Sales × 100 = (Change in Profit / Change in Sales) × 100`

Remains constant for a given product mix and cost structure — very useful for quick "what-if" calculations.

Break-Even Point (Units)

`BEP (units) = Fixed Cost / Contribution per Unit`

The output level at which total contribution exactly equals fixed cost (zero profit).

Break-Even Point (Sales Value)

`BEP (₹) = Fixed Cost / P/V Ratio`

Useful when a single BEP value is needed for a multi-product firm using a weighted-average P/V ratio.

Margin of Safety (MOS)

`MOS = Actual (or Budgeted) Sales − BEP Sales; MOS Ratio = MOS / Actual Sales × 100`

Also: MOS = Profit / P/V Ratio — measures the cushion available before the firm starts incurring losses.

Key Factor / Limiting Factor Ranking

`Rank products by: Contribution per unit of the Limiting/Scarce Factor`

When a single resource (machine hours, material, labour) is scarce, maximise total contribution by prioritising the product with the highest contribution per unit of that scarce resource — NOT the highest contribution per unit of output.

Shut-Down Point

`Shut-Down Point (Sales) = Avoidable (Specific) Fixed Cost / P/V Ratio`

Below this sales level, it is cheaper to shut down (and only incur unavoidable fixed costs) than to continue operating.

Make-or-Buy Decision

`Buy if: Purchase Price < Relevant (Marginal) Cost of Making In-house`

Only variable/avoidable costs of making are relevant; ignore unavoidable fixed costs and sunk costs unless the freed capacity has an alternative use (opportunity cost).

Relevant Cost for Special/One-Off Order Pricing

`Minimum Acceptable Price = Relevant (Incremental) Cost + Opportunity Cost of resources diverted from normal business`

Sunk costs and unavoidable fixed costs already being incurred are irrelevant to the special order decision.

2. Practical Application

Key factor decisions — the classic exam trap: Never rank products by contribution per unit alone when a resource is scarce — always divide by the number of scarce-resource units consumed per unit of product.

Make-or-buy with idle capacity that has alternative use: If the capacity freed by buying-in can be used for another profitable product, add that opportunity cost (contribution foregone) to the "cost of making" side before comparing with the buy price.

Shut-down vs continue: A division showing an accounting loss may still be worth continuing if its contribution exceeds its avoidable fixed costs — shutting down only saves avoidable fixed costs, not unavoidable ones.

3. Worked Illustrations

Illustration 3.1 — Key Factor (Limiting Factor) Ranking

A firm makes two products constrained by machine hours (only 10,000 hours available):

Particulars	Product A	Product B
Contribution per unit	₹60	₹80
Machine hours per unit	2	4

Step 1 — Contribution per machine hour: A: 60/2 = ₹30/hr; B: 80/4 = ₹20/hr

Step 2 — Rank by contribution per scarce resource unit: Product A (₹30/hr) ranks ABOVE Product B (₹20/hr) — despite B having higher contribution per unit!

Step 3 — Optimal Plan: Prioritise all available machine hours to Product A first (up to demand limit), then allocate remaining hours to Product B.

Product A should be produced first despite Product B's higher per-unit contribution, because A generates more contribution per unit of the scarce resource (machine hours) — this maximises total contribution from the limited 10,000 hours.

Illustration 3.2 — Make or Buy Decision (with Opportunity Cost)

A component currently made in-house costs: Variable cost ₹45/unit, allocated fixed overhead ₹15/unit (unavoidable), Total cost ₹60/unit. A supplier offers to sell it at ₹52/unit. If the firm buys out, the freed capacity can be used to earn a contribution of ₹10/unit on another product.

Step 1 — Relevant cost of making: Only variable cost is relevant = ₹45/unit (fixed overhead is unavoidable, ignore it)

Step 2 — Add opportunity cost of buying-in: Relevant cost of making (with opportunity cost consideration) = ₹45 (savings if bought) vs. Buy price ₹52, minus alternative use contribution of ₹10 = Net cost of buying = 52 − 10 = ₹42/unit

Step 3 — Compare: Cost of making (relevant) = ₹45; Net cost of buying (after using freed capacity for ₹10 contribution) = ₹42

Since buying (net cost ₹42) is cheaper than making (relevant cost ₹45) once the opportunity to earn ₹10 contribution elsewhere is factored in, the firm should BUY the component and redeploy the freed capacity.

4. Practice MCQs (15 × 2 Marks)

Q1. When a single resource is scarce, products should be prioritised based on:

A. Contribution per unit of product
B. Contribution per unit of the scarce resource
C. Selling price per unit
D. Total fixed cost allocated

Answer: B

Maximising total contribution under a single binding constraint requires ranking by contribution per unit of the scarce resource, not per unit of output.

Q2. In a Make-or-Buy decision, which cost is normally IRRELEVANT (assuming no alternative use of freed capacity)?

A. Variable material cost
B. Variable labour cost
C. Unavoidable fixed overhead already being incurred
D. Purchase price quoted by supplier

Answer: C

Unavoidable fixed overheads continue regardless of the decision, so they are not relevant to the make-or-buy comparison.

Q3. Margin of Safety can also be calculated as:

A. Fixed Cost / P/V Ratio
B. Profit / P/V Ratio
C. Sales × P/V Ratio
D. Fixed Cost × Sales

Answer: B

MOS = Profit/P.V. Ratio is a standard alternative formula, since Profit = MOS × P.V. Ratio.

Q4. A firm should consider shutting down a division (in the short run) when:

A. It shows any accounting loss
B. Its contribution is less than its avoidable (specific) fixed costs
C. Its contribution exceeds avoidable fixed costs
D. Sales are increasing

Answer: B

If contribution can't even cover the fixed costs that would actually be saved by closing, shutting down reduces the loss; otherwise, continuing is better.

Q5. If Sales = ₹10,00,000, Variable Cost = ₹6,00,000, Fixed Cost = ₹3,00,000, the P/V Ratio is:

A. 30%
B. 40%
C. 60%
D. 70%

Answer: B

Contribution = 10,00,000 − 6,00,000 = 4,00,000. P/V Ratio = 4,00,000/10,00,000 ×100 = 40%.

Q6. Using the above data (Q5), the Break-Even Sales is:

A. ₹5,00,000
B. ₹6,00,000
C. ₹7,50,000
D. ₹9,00,000

Answer: C

BEP (₹) = Fixed Cost/P.V. Ratio = 3,00,000/0.40 = ₹7,50,000.

Q7. The minimum acceptable price for a special one-off order (with idle capacity and no alternative use) should at least cover:

A. Full absorption cost including all fixed overheads
B. Only the relevant (incremental/variable) cost of fulfilling the order
C. The regular selling price
D. Historical sunk costs

Answer: B

With idle capacity and no alternative use, only the incremental (relevant) cost needs to be recovered — any price above that adds to contribution.

Q8. Sunk costs in a decision-making context should be:

A. Fully considered as relevant

B. Ignored, as they don't change with the decision
C. Doubled for conservative planning
D. Treated as opportunity costs

Answer: B

Sunk costs have already been incurred and are unaffected by the current decision, so they are excluded from relevant cost analysis.

Q9. If a firm has Fixed Cost = ₹4,00,000 and Contribution per unit = ₹40, its Break-Even Point in units is:

A. 8,000 units
B. 10,000 units
C. 16,000 units
D. 4,000 units

Answer: B

BEP (units) = 4,00,000/40 = 10,000 units.

Q10. Opportunity cost is best defined as:

A. A cost already paid in the past
B. The benefit forgone from the next-best alternative use of a resource
C. A fixed cost that never changes
D. The market price of raw material only

Answer: B

Opportunity cost represents the value of the best alternative given up when a resource is used for a particular purpose.

Q11. When two limiting factors constrain production simultaneously, the correct technique to determine the optimal product mix is:

A. Simple ranking by contribution per unit
B. Linear Programming
C. Break-even analysis alone
D. Payback period

Answer: B

With multiple binding constraints, simple ranking fails — Linear Programming is needed to find the optimal feasible product mix.

Q12. If MOS Ratio is 25% and Actual Sales are ₹8,00,000, the Break-Even Sales is:

A. ₹2,00,000
B. ₹6,00,000
C. ₹6,50,000
D. ₹7,00,000

Answer: B

MOS = 25% × 8,00,000 = 2,00,000. BEP Sales = Actual Sales − MOS = 8,00,000 − 2,00,000 = ₹6,00,000.

Q13. In a shut-down decision, "avoidable fixed cost" refers to fixed costs that:

A. Continue even after shutting down
B. Would be eliminated if the operation/division is shut down
C. Are always variable in nature
D. Relate only to head-office allocations

Answer: B

Avoidable fixed costs are specific to the operation and disappear on closure, unlike unavoidable (common/allocated) fixed costs.

Q14. For CVP (Cost-Volume-Profit) analysis to hold, a key underlying assumption is:

A. Costs can be reliably split into fixed and variable elements, and selling price per unit is constant
B. All costs are variable
C. Fixed costs change with volume
D. Selling price changes with every unit sold

Answer: A

Standard CVP analysis assumes linear cost behaviour (fixed/variable split) and a constant selling price per unit within the relevant range.

Q15. A relevant cost for decision-making must be:

A. A future, incremental cash flow that differs between the alternatives being considered
B. A historical, sunk cost
C. An arbitrarily allocated overhead
D. Identical across all alternatives

Answer: A

Relevant costs are future-oriented and must differ between the decision alternatives — costs identical across all options or already incurred (sunk) are irrelevant.

MODULE 4 · SECTION A

Activity Based Management & Just-in-Time (JIT)

Activity Based Costing/Management (ABC/ABM) for more accurate overhead allocation, value-added vs non-value-added activity analysis, and JIT/backflush costing principles.

1. Formulas

Activity Cost Driver Rate

`Cost Driver Rate = Total Cost of the Activity Pool / Total Quantity of the Cost Driver`

E.g., Machine Set-up Cost Pool / Total Number of Set-ups = Cost per Set-up.

Product Cost under ABC

`Cost of Product = Direct Costs + Σ (Activity Cost Driver Rate × Driver Units Consumed by the Product)`

Overheads are traced via multiple activity cost pools/drivers instead of a single blanket/plant-wide overhead rate.

Value-Added vs Non-Value-Added Cost

`Non-Value-Added Cost = Cost of activities that can be eliminated without reducing product's value to the customer (e.g., inspection, storage, movement)`

ABM uses this classification to target cost reduction efforts at non-value-added activities first.

JIT — Ideal Inventory Holding Cost Reduction

`Inventory Carrying Cost Saved = Reduction in Average Inventory × Carrying Cost Rate per unit`

JIT aims to minimise inventory (ideally near zero buffer) by synchronising production with demand and supplier deliveries.

Backflush Costing — Trigger Point Accounting

`Costs are recorded (flushed back) at a small number of trigger points (e.g., purchase and completion), rather than tracking WIP at every stage`

Simplifies costing procedures in a JIT environment where inventory levels are minimal, making detailed WIP tracking unnecessary/costly.

2. Practical Application

When ABC matters most: ABC gives materially different (and more accurate) product costs than traditional absorption costing when a firm has high overhead relative to direct costs, and diverse products consuming overhead resources in very different proportions (e.g., some products need frequent small-batch set-ups, others don't).

ABM cost reduction focus: Use ABC data to identify high-cost, non-value-added activities (excess material handling, inspection, rework) and target process redesign or elimination there first.

JIT prerequisites: JIT requires reliable suppliers, short set-up times, a stable production schedule, and strong quality control — since there's little buffer stock to absorb supply or quality disruptions.

3. Worked Illustration

Illustration 4.1 — Activity Based Costing

Total Set-up Cost Pool = ₹6,00,000, with 400 set-ups during the year. Product X requires 5 set-ups to produce its annual batch of 2,000 units; Product Y requires 15 set-ups to produce its annual batch of 3,000 units.

Step 1 — Cost Driver Rate: 6,00,000 / 400 set-ups = **₹1,500 per set-up**

Step 2 — Set-up cost allocated to Product X: 5 × 1,500 = ₹7,500; per unit = 7,500/2,000 = **₹3.75/unit**

Step 3 — Set-up cost allocated to Product Y: 15 × 1,500 = ₹22,500; per unit = 22,500/3,000 = **₹7.50/unit**

Product Y bears double the set-up cost per unit (₹7.50 vs ₹3.75) because it requires proportionally more set-ups relative to its batch size — a traditional volume-based overhead rate would have masked this difference and undercosted Y.

4. Practice MCQs (15 × 2 Marks)

Q1. Activity Based Costing (ABC) allocates overheads to products based on:

A. A single plant-wide volume-based rate
B. Multiple cost drivers linked to the activities that actually consume resources
C. Direct labour hours only, regardless of activity
D. Equal allocation to every product

Answer: B

ABC identifies distinct activities and their cost drivers, tracing overheads more accurately than a single blanket rate.

Q2. ABC is most beneficial when a firm has:

A. Low overhead and a single homogeneous product
B. High overhead and diverse products consuming resources in very different proportions
C. No overheads at all
D. Identical products with identical batch sizes

Answer: B

ABC's benefit (more accurate costing) is greatest when overheads are significant and product diversity causes distortions under traditional volume-based costing.

Q3. A non-value-added activity is one that:

A. Directly increases the product's value to the customer
B. Can be eliminated without reducing the value the customer perceives in the product
C. Is always a direct material cost
D. Cannot be identified or measured

Answer: B

Non-value-added activities (e.g., excess handling, storage, inspection) consume resources without adding customer-perceived value — prime targets for elimination.

Q4. JIT (Just-in-Time) production philosophy primarily aims to:

A. Maximise inventory buffers
B. Minimise inventory by synchronising production with actual demand and supply
C. Increase batch sizes indefinitely
D. Eliminate quality control entirely

Answer: B

JIT seeks to produce/procure only what is needed, when needed, minimising inventory holding costs and waste.

Q5. Backflush Costing is typically used in conjunction with:

A. Traditional job costing with detailed WIP tracking
B. JIT environments with minimal inventory, recording costs at a few trigger points
C. Standard absorption costing only
D. Process costing with no automation

Answer: B

Backflush costing simplifies accounting in JIT settings by recording costs only at key trigger points, since detailed WIP tracking adds little value when inventory is minimal.

Q6. If Total Inspection Cost Pool = ₹4,00,000 with 1,000 inspection hours, the cost driver rate per inspection hour is:

A. ₹40
B. ₹400
C. ₹4,000
D. ₹4

Answer: B

Cost Driver Rate = 4,00,000/1,000 = ₹400 per inspection hour.

Q7. Traditional volume-based overhead absorption tends to:

A. Always cost products more accurately than ABC
B. Overcost high-volume, simple products and undercost low-volume, complex products
C. Have no impact on product costing
D. Only apply to service industries

Answer: B

A single volume-based rate spreads overhead evenly by volume, which tends to shift cost burden unfairly from complex/low-volume products onto simple/high-volume ones.

Q8. For JIT to work effectively, a firm most critically needs:

A. Large safety stocks of raw material
B. Reliable suppliers, short set-up times, and strong quality control
C. Unpredictable, fluctuating production schedules
D. Long lead times from suppliers

Answer: B

Since JIT carries minimal buffer stock, dependable supply, quick changeovers, and high quality are essential prerequisites.

Q9. Activity Based Management (ABM) uses ABC data primarily to:

A. Only prepare external financial statements
B. Manage and improve processes by targeting non-value-added activities for reduction/elimination
C. Calculate income tax
D. Set employee salaries

Answer: B

ABM leverages the detailed activity-cost information from ABC to drive process improvement and cost reduction decisions.

Q10. Material handling and storage of work-in-progress inventory awaiting the next process are typically classified as:

A. Value-added activities
B. Non-value-added activities
C. Direct material costs
D. Prevention costs

Answer: B

Storage and unnecessary handling do not add value from the customer's perspective and are targeted for reduction under ABM/JIT.

Q11. Under ABC, if a product requires a disproportionately high number of machine set-ups relative to its production volume, its allocated set-up cost per unit will be:

A. Lower than under traditional volume-based costing
B. Higher than under traditional volume-based costing, revealing the true cost of complexity
C. Identical under both methods
D. Zero

Answer: B

ABC correctly assigns more set-up cost to products causing more set-ups, unlike volume-based costing which would understate this complexity cost.

Q12. Just-in-Time purchasing typically involves:

A. Bulk purchases stored for long periods
B. Frequent, small deliveries synchronised closely with production needs
C. No supplier relationships at all
D. Purchasing only at year-end

Answer: B

JIT purchasing relies on frequent small deliveries timed to actual production needs, minimising raw material inventory.

Q13. A cost pool in ABC refers to:

A. A single direct material item
B. A grouping of overhead costs associated with a particular activity
C. Total sales revenue
D. Cash held in a bank account

Answer: B

A cost pool aggregates all overhead costs related to a specific activity (e.g., all costs of the "machine set-up" activity) before applying a driver rate.

Q14. A limitation often cited for ABC implementation is:

A. It is always cheaper to implement than traditional costing
B. The cost and complexity of identifying activities and cost drivers can be significant
C. It never improves costing accuracy
D. It can only be used in service industries

Answer: B

Implementing ABC requires significant effort in identifying activities, cost pools, and appropriate drivers — a real practical cost/complexity trade-off.

Q15. In a JIT environment, inspection at the receiving dock for incoming materials is often reduced or eliminated by:

A. Increasing safety stock instead
B. Developing long-term quality partnerships with certified/reliable suppliers
C. Ignoring quality altogether
D. Outsourcing all production

Answer: B

JIT firms often build long-term supplier relationships with quality certification, reducing the need for incoming inspection (a non-value-added activity).

MODULE 5 · SECTION A

Evaluating Performance

Standard costing & variance analysis, transfer pricing between divisions, and divisional/managerial performance measures (ROI, RI, EVA, Balanced Scorecard).

1. Formulas

A. Variance Analysis

Material Cost Variance (MCV)

`MCV = (Standard Qty × Standard Price) − (Actual Qty × Actual Price)`

MCV = Material Price Variance + Material Usage Variance.

Material Price & Usage Variance

`Price Variance = Actual Qty × (Standard Price − Actual Price)`
`Usage Variance = Standard Price × (Standard Qty − Actual Qty)`

Standard Qty is the quantity that SHOULD have been used for actual output achieved.

Labour Cost, Rate & Efficiency Variance

`Labour Cost Variance = (SH×SR) − (AH×AR); Rate Variance = AH(SR−AR); Efficiency Variance = SR(SH−AH)`

SH/AH = Standard/Actual Hours; SR/AR = Standard/Actual Rate.

Fixed Overhead Variances

`FOH Cost Variance = Absorbed FOH − Actual FOH`
`= Expenditure Variance + Volume Variance`
`Volume Variance = Efficiency Variance + Capacity Variance`

Expenditure Variance = Budgeted FOH − Actual FOH; Volume Variance = Absorbed FOH − Budgeted FOH.

Sales Variances

`Sales Value Variance = Actual Sales − Budgeted Sales`
`= Sales Price Variance + Sales Volume Variance`

Sales Volume Variance can be further split into Sales Mix Variance + Sales Quantity Variance for multi-product firms.

B. Divisional Performance & Transfer Pricing

Return on Investment (ROI)

`ROI = Net Operating Profit / Capital Employed (Investment) × 100`

A relative (%) measure — can discourage a manager from accepting a project with return above the cost of capital but below the division's current average ROI.

Residual Income (RI)

`RI = Net Operating Profit − (Capital Employed × Cost of Capital / Required Rate of Return)`

An absolute (₹) measure — encourages goal congruence better than ROI, since managers accept any project earning above the cost of capital.

Economic Value Added (EVA)

`EVA = NOPAT − (Capital Employed × WACC)`

NOPAT = Net Operating Profit After Tax. Similar concept to RI but uses WACC and typically several accounting adjustments (e.g., capitalising R&D).

Transfer Price — General Rule

`Minimum Transfer Price = Marginal (Variable) Cost + Opportunity Cost to the Selling Division`

If the selling division has spare capacity, opportunity cost = 0, so minimum transfer price = marginal cost.

2. Practical Application

Investigating variances: Not every variance needs investigation — apply "management by exception," investigating only significant variances (in absolute rupee terms or as a % of standard) that are controllable and cost-effective to correct.

ROI vs RI for goal congruence: A division with high current ROI may reject a genuinely good project (return > cost of capital but < current ROI) to avoid dragging down its average — RI/EVA avoid this dysfunctional behaviour since they reward any project clearing the cost-of-capital hurdle.

Transfer pricing with external market: If a perfectly competitive external market exists for the intermediate product, market price is generally the best transfer price, preserving divisional autonomy and correct decision signals.

3. Worked Illustrations

Illustration 5.1 — Material Variances

Standard: 100 kg of material at ₹20/kg for the actual output achieved. Actual: 110 kg purchased and used at ₹18/kg.

Step 1 — Material Cost Variance: (100×20) − (110×18) = 2,000 − 1,980 = **₹20 (Favourable)**

Step 2 — Material Price Variance: AQ(SP−AP) = 110 × (20−18) = 110 × 2 = **₹220 (Favourable)**

Step 3 — Material Usage Variance: SP(SQ−AQ) = 20 × (100−110) = 20 × (−10) = **₹200 (Adverse)**

Step 4 — Check: Price Variance (220 F) + Usage Variance (200 A) = 20 (F) = MCV ✓

Overall material cost was ₹20 favourable — but this masks a favourable price effect (₹220 F, cheaper material bought) largely offset by an adverse usage effect (₹200 A, more material consumed than standard) — worth investigating if the cheaper material caused excess wastage.

Illustration 5.2 — ROI vs Residual Income (Goal Congruence Problem)

Division has Capital Employed = ₹50,00,000 and current Net Operating Profit = ₹12,50,000 (Current ROI = 25%). Cost of Capital = 12%. A new project requires additional investment of ₹5,00,000, expected to earn additional profit of ₹90,000 (project ROI = 18%).

Step 1 — Effect on Divisional ROI if accepted: New ROI = (12,50,000+90,000)/(50,00,000+5,00,000) = 13,40,000/55,00,000 = 24.36% — LOWER than current 25%

Step 2 — Manager's likely decision under ROI evaluation: Manager may REJECT the project since it drags down divisional ROI, even though 18% return exceeds the 12% cost of capital.

Step 3 — Residual Income of the new project alone: RI = 90,000 − (5,00,000 × 12%) = 90,000 − 60,000 = **+₹30,000 (positive)**

Under RI, the project adds positive residual income (₹30,000) and should be ACCEPTED — RI correctly motivates goal-congruent behaviour, whereas ROI could wrongly cause the manager to reject a value-adding project.

4. Practice MCQs (15 × 2 Marks)

Q1. Material Price Variance is calculated as:

A. Standard Qty × (Standard Price − Actual Price)
B. Actual Qty × (Standard Price − Actual Price)
C. Actual Qty × Actual Price

D. Standard Qty × Standard Price

Answer: B

Price Variance isolates the price effect using the actual quantity purchased/used: AQ(SP−AP).

Q2. A key advantage of Residual Income (RI) over Return on Investment (ROI) as a performance measure is that RI:

A. Is always a higher number than ROI
B. Better promotes goal congruence by encouraging acceptance of any project earning above the cost of capital
C. Does not require knowledge of capital employed
D. Is unaffected by the cost of capital

Answer: B

Since RI rewards absolute value added above the cost of capital, managers are motivated to accept all value-adding projects, unlike under ROI.

Q3. The minimum transfer price, when the selling division has NO spare capacity (fully utilised), should be:

A. Marginal cost only
B. Marginal cost plus the opportunity cost (contribution foregone from the external market)
C. Zero
D. Always equal to full cost regardless of capacity

Answer: B

With no spare capacity, transferring internally means giving up an external sale, so the lost contribution must be added as opportunity cost.

Q4. Fixed Overhead Volume Variance is calculated as:

A. Budgeted FOH − Actual FOH
B. Absorbed FOH − Budgeted FOH
C. Absorbed FOH − Actual FOH
D. Actual FOH × Standard Rate

Answer: B

Volume Variance = Absorbed FOH − Budgeted FOH, reflecting the effect of actual output differing from budgeted output.

Q5. If Labour Rate Variance is ₹500 (Adverse) and Labour Efficiency Variance is ₹800 (Favourable), the total Labour Cost Variance is:

A. ₹1,300 Favourable
B. ₹300 Favourable
C. ₹300 Adverse
D. ₹1,300 Adverse

Answer: B

Labour Cost Variance = Rate Variance + Efficiency Variance = (−500) + 800 = ₹300 Favourable.

Q6. EVA (Economic Value Added) is computed as:

A. NOPAT + (Capital Employed × WACC)
B. NOPAT − (Capital Employed × WACC)
C. NOPAT / Capital Employed
D. Capital Employed − NOPAT

Answer: B

EVA = Net Operating Profit After Tax minus a capital charge (Capital Employed × WACC).

Q7. "Management by exception" in variance analysis means:

A. Investigating every single variance regardless of size
B. Investigating only significant/material variances that are cost-effective to control
C. Ignoring all variances
D. Only investigating favourable variances

Answer: B

Management by exception focuses limited investigative resources on the variances that matter most (in size and controllability), not every minor deviation.

Q8. Sales Volume Variance for a multi-product firm can be further split into:

A. Price Variance and Usage Variance
B. Sales Mix Variance and Sales Quantity Variance
C. Rate Variance and Efficiency Variance
D. Expenditure Variance and Capacity Variance

Answer: B

Sales Volume Variance breaks down into a Mix Variance (change in proportion of products sold) and a Quantity Variance (change in total units sold).

Q9. If a division has ROI higher than its current average, accepting a new project with return above the cost of capital but below the current ROI creates the risk that the manager will:

A. Always accept the project
B. Reject the project to protect the division's average ROI, even though it's value-adding
C. Ignore the cost of capital entirely
D. Immediately resign

Answer: B

This is the classic dysfunctional behaviour risk of using ROI as a sole performance measure — a value-adding project may be rejected to protect the division's average.

Q10. When a perfectly competitive external market exists for an intermediate product, the most appropriate transfer price is usually:

A. Full cost plus a large arbitrary mark-up
B. The prevailing external market price
C. Zero
D. An amount fixed permanently regardless of market conditions

Answer: B

Market price preserves correct economic signals and divisional autonomy when a competitive external market for the product exists.

Q11. Fixed Overhead Expenditure Variance is calculated as:

A. Budgeted Fixed Overhead − Actual Fixed Overhead
B. Absorbed Fixed Overhead − Budgeted Fixed Overhead
C. Actual Fixed Overhead × Standard Rate
D. Standard Hours × Standard Rate

Answer: A

Expenditure Variance isolates the spending effect: Budgeted FOH − Actual FOH incurred.

Q12. The Balanced Scorecard evaluates organisational performance across which typical perspectives?

A. Only financial perspective
B. Financial, Customer, Internal Business Process, and Learning & Growth
C. Only customer satisfaction surveys
D. Only employee headcount

Answer: B

The Balanced Scorecard (Kaplan & Norton) evaluates performance holistically across these four linked perspectives, not financial measures alone.

Q13. If Capital Employed = ₹20,00,000, Cost of Capital = 10%, and Net Operating Profit = ₹3,00,000, the Residual Income is:

A. ₹1,00,000
B. ₹2,00,000
C. ₹3,00,000
D. ₹5,00,000

Answer: A

RI = 3,00,000 − (20,00,000 × 10%) = 3,00,000 − 2,00,000 = ₹1,00,000.

Q14. Negotiated transfer pricing is most appropriate when:

A. There is a perfect external market with no bargaining needed

B. No perfect external market exists and both divisions have some bargaining power over the internal price
C. Only one division exists in the company
D. Transfer pricing is banned by law

Answer: B

Negotiation works well when market price isn't clearly determinable and both divisional managers have autonomy to agree on mutually acceptable terms.

Q15. A limitation of ROI as a divisional performance measure is that it:

A. Always encourages optimal investment decisions
B. Can motivate managers to reject value-adding projects that would lower their division's current average ROI
C. Is unaffected by asset valuation methods
D. Cannot be manipulated by managers

Answer: B

Because ROI is a ratio, managers focused on maintaining a high average may reject genuinely value-adding investments — a well-documented dysfunctional incentive.

SECTION B

Quantitative Techniques in Decision Making

Weightage: 40% of total marks | Modules 6–10

MODULE 6 · SECTION B

Linear Programming

Formulating and solving resource-allocation problems using an objective function and constraints — graphical method for two variables, and shadow price interpretation.

1. Formulas

General LP Formulation

Maximise (or Minimise) $Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n$
Subject to: $a_1x_1+a_2x_2+\ldots \leq/\geq/= b_i$ (for each constraint i); $x_1,x_2,\ldots \geq 0$

Z = objective function (usually profit/contribution to maximise, or cost to minimise); x_i = decision variables (units to produce/allocate).

Graphical Method (2-variable problems)

Plot each constraint as a line → identify the feasible region (satisfying all constraints) → evaluate Z at every corner (vertex) point of the feasible region

The optimal solution always occurs at one of the corner points of the feasible region (Fundamental Theorem of LP).

Shadow Price (Dual Value)

Shadow Price = Change in Optimal Objective Function Value per unit increase in the RHS of a BINDING constraint

Shadow price of a non-binding (slack) constraint is always zero — the constraint isn't limiting the optimal solution.

Slack / Surplus Variable

Slack (for ≤ constraint) = RHS − LHS at the optimal solution; Surplus (for ≥ constraint) = LHS − RHS

Zero slack/surplus means the constraint is binding (fully utilised) at the optimum.

2. Practical Application

Identifying decision variables: Always define decision variables clearly first (e.g., x_1 = units of Product A, x_2 = units of Product B) before writing the objective function and constraints — most marks are lost from incorrect formulation, not calculation.

Using shadow price for decisions: A positive shadow price on a resource (e.g., machine hours) tells management the maximum premium worth paying to acquire one more unit of that scarce resource.

Sensitivity/range analysis: Shadow prices are valid only within a certain range of the RHS value — beyond that range, the set of binding constraints (and hence the shadow price) may change.

3. Worked Illustration

Illustration 6.1 — Graphical LP Solution

Maximise $Z = 40x_1 + 30x_2$, subject to: $2x_1 + x_2 \leq 40$ (Machine hours); $x_1 + 2x_2 \leq 50$ (Labour hours); $x_1, x_2 \geq 0$.

Step 1 — Find intersection of the two constraints (corner point): Solve $2x_1+x_2=40$ and $x_1+2x_2=50$ simultaneously.
From eqn 1: $x_2 = 40-2x_1$. Substitute into eqn 2: $x_1 + 2(40-2x_1) = 50 \Rightarrow x_1+80-4x_1=50 \Rightarrow -3x_1=-30 \Rightarrow x_1=10, x_2=20$

Step 2 — Evaluate Z at all corner points:
(0,0): Z=0 | (20,0): Z=800 | (0,25): Z=750 | (10,20): Z=40(10)+30(20)=400+600=**1,000**

Step 3 — Identify optimal point: Maximum Z = ₹1,000 occurs at (x_1=10, x_2=20) — both constraints are binding here.

Optimal solution: produce 10 units of Product 1 and 20 units of Product 2, giving maximum contribution of ₹1,000, fully utilising both machine hours and labour hours.

4. Practice MCQs (15 × 2 Marks)

Q1. In Linear Programming, the optimal solution to a maximisation/minimisation problem occurs at:

A. The centre of the feasible region
B. One of the corner (vertex) points of the feasible region
C. Outside the feasible region
D. A random interior point

Answer: B

The Fundamental Theorem of Linear Programming states the optimum always occurs at a vertex (corner point) of the feasible region.

Q2. The Shadow Price of a resource represents:

A. The market price of the resource
B. The change in the optimal objective function value per unit increase in that resource's availability
C. The total cost of the resource used
D. A fixed accounting rate

Answer: B

Shadow price measures the marginal value of relaxing a binding constraint by one unit.

Q3. A non-binding constraint at the optimal solution has a shadow price of:

A. A large positive number
B. Zero
C. A negative number always
D. Equal to the objective function coefficient

Answer: B

If a constraint isn't fully used (has slack) at the optimum, relaxing it further has no effect on the objective function — shadow price = 0.

Q4. For a ≤ type constraint, "slack" refers to:

A. LHS minus RHS
B. RHS minus LHS (unused capacity of that resource)
C. Always zero
D. The objective function value

Answer: B

Slack = RHS − LHS represents the unused portion of a resource constraint at a given solution.

Q5. The graphical method of solving LP problems is limited to:

A. Any number of decision variables
B. Problems with only two decision variables
C. Only minimisation problems
D. Only integer solutions

Answer: B

The graphical method works only for two-variable problems since it relies on plotting constraints on a 2-dimensional plane.

Q6. In LP formulation, the non-negativity constraint ($x_i \geq 0$) exists because:

A. Decision variables like units produced cannot logically be negative

B. It simplifies the objective function only
C. It has no real-world meaning
D. It only applies to minimisation problems

Answer: A

Since decision variables typically represent physical quantities (units, hours), negative values would be meaningless.

Q7. If a resource constraint is binding at the optimal solution, its slack value is:

A. Positive
B. Zero
C. Negative
D. Undefined

Answer: B

A binding constraint is fully utilised (LHS = RHS at optimum), so its slack is exactly zero.

Q8. The feasible region in a Linear Programming problem is defined as:

A. The area violating at least one constraint
B. The set of all points satisfying all constraints simultaneously (including non-negativity)
C. Only the origin point
D. The objective function line itself

Answer: B

The feasible region contains every combination of decision variable values that satisfies all constraints at once.

Q9. If two different corner points give the SAME (best) value of the objective function, the LP problem has:

A. No solution
B. Multiple (alternate) optimal solutions
C. An infeasible solution
D. An unbounded solution

Answer: B

When the objective function is parallel to a constraint boundary, every point along that boundary segment yields the same optimal value — multiple optima.

Q10. An LP problem is said to be "unbounded" when:

A. The feasible region is empty
B. The objective function can be increased (or decreased) indefinitely within the feasible region
C. There is exactly one feasible solution
D. All constraints are equalities

Answer: B

An unbounded LP has a feasible region that is not enclosed in the direction of optimisation, so Z can grow without limit.

Q11. An LP problem with no feasible region satisfying all constraints simultaneously is called:

A. Unbounded
B. Infeasible
C. Degenerate
D. Optimal

Answer: B

Infeasibility occurs when the constraints are mutually contradictory, leaving no point that satisfies all of them.

Q12. Simplex method is generally preferred over the graphical method when:

A. There are only 2 decision variables
B. There are more than 2 decision variables
C. There are no constraints
D. The objective function is non-linear

Answer: B

The Simplex algorithm can handle LP problems with any number of variables, unlike the 2-variable-only graphical method.

Q13. If a resource has a shadow price of ₹25 per hour, a firm should be willing to pay up to _____ to acquire one additional hour of that resource.

A. ₹0
B. ₹25
C. ₹50
D. An unlimited amount

Answer: B

The shadow price directly indicates the maximum premium worth paying for one more unit of that binding resource.

Q14. In LP, decision variables typically represent:

A. Fixed costs
B. The quantities to be decided (e.g., units of each product to produce)
C. Historical sales figures
D. Tax rates

Answer: B

Decision variables are the unknowns the model solves for — typically production/allocation quantities.

Q15. Sensitivity analysis in LP examines:

A. How the optimal solution changes with variations in objective function coefficients or constraint RHS values
B. Only the initial feasible solution
C. Employee productivity only
D. Tax implications of the solution

Answer: A

Sensitivity analysis studies the range over which coefficients/RHS values can change without altering the optimal basis/solution structure.

MODULE 7 · SECTION B

Transportation, Assignment & Game Theory

Special-structure LP problems: minimising transportation cost (NW Corner/Least Cost/VAM + MODI), the Assignment problem (Hungarian method), and competitive Game Theory.

1. Formulas

A. Transportation Problem

Initial Basic Feasible Solution (IBFS) Methods

North-West Corner Method (ignores cost); Least Cost Method; Vogel's Approximation Method (VAM — uses penalty = difference between two lowest costs in each row/column)

VAM generally gives the IBFS closest to the optimal solution, minimising the number of iterations needed for optimality testing.

Optimality Test — MODI (Modified Distribution) Method

For each occupied (basic) cell: $u_i + v_j = C_{ij}$. For each unoccupied cell: $\Delta_{ij} = C_{ij} - (u_i + v_j)$

Solution is optimal (for minimisation) when all $\Delta_{ij} \geq 0$. If any $\Delta_{ij} < 0$, that cell can improve the solution — reallocate along its closed loop.

Degeneracy Check

Number of Basic (occupied) Cells required = $m + n - 1$ (m = rows/sources, n = columns/destinations)

If occupied cells < $m+n-1$, the solution is degenerate — add an infinitesimally small allocation (ε) to an independent unoccupied cell to proceed with MODI.

B. Assignment Problem

Hungarian Method — Steps

1. **Row reduction (subtract row minimum from each row)**
2. **Column reduction (subtract column minimum from each column)**
3. **Cover all zeros with minimum number of lines**
4. **If lines = n (order of matrix), optimal assignment exists; else adjust matrix and repeat**

Used for minimising total cost (or maximising total profit, by first converting to an equivalent minimisation problem) of assigning n jobs to n workers/machines, one-to-one.

Maximisation Assignment Problem

Convert to minimisation by: New Matrix Value = (Largest Value in Matrix) − Each Original Value

Then apply the standard Hungarian minimisation method on the converted matrix.

C. Game Theory

Value of Game — Pure Strategy (Saddle Point)

Maximin (Row Player) = Minimax (Column Player) ⇒ Saddle point exists, Value of Game = that common value

Maximin = highest of the row-minimums; Minimax = lowest of the column-maximums.

Mixed Strategy — 2×2 Game (No Saddle Point)

For payoff matrix [[a,b],[c,d]]:
Probability for Row Player's Strategy 1: $p = (d-c) / (a+d-b-c)$
Value of Game: $V = (ad-bc) / (a+d-b-c)$

Used when no saddle point exists (Maximin ≠ Minimax) — players must randomise their strategies with these optimal probabilities.

Principle of Dominance

`A strategy is dominated (and can be eliminated) if another strategy is always at least as good, regardless of the opponent's choice`

Used to reduce the size of a payoff matrix before solving, especially for matrices larger than 2×2.

2. Practical Application

Choosing an IBFS method: VAM is preferred in exams when time permits, since it usually yields a solution needing fewer MODI iterations than NW Corner (fast but crude) or Least Cost.

Unbalanced transportation/assignment problems: If total supply ≠ total demand (or jobs ≠ workers), add a dummy source/destination (or dummy job/worker) with zero cost to balance the problem before solving.

Game theory in business: Used to model competitive strategic decisions (e.g., pricing wars, advertising spend) between two rival firms where each firm's optimal choice depends on the other's likely response.

3. Worked Illustrations

Illustration 7.1 — Assignment Problem (Hungarian Method)

Cost matrix for assigning 3 jobs to 3 workers (₹):

	Job 1	Job 2	Job 3
Worker A	10	12	9
Worker B	8	11	7
Worker C	13	10	12

Step 1 — Row reduction (subtract row min: A−9, B−7, C−10):
A: 1, 3, 0 | B: 1, 4, 0 | C: 3, 0, 2

Step 2 — Column reduction (col minimums are 1,0,0 — subtract from column 1 only):
A: 0, 3, 0 | B: 0, 4, 0 | C: 2, 0, 2

Step 3 — Cover zeros with minimum lines & find optimal assignment: Assign A→Job1 or Job3, B→Job1 or Job3, C→Job2. Testing: A→Job3, B→Job1, C→Job2 gives a valid one-to-one assignment.

Step 4 — Compute total cost from ORIGINAL matrix: A→Job3 (9) + B→Job1 (8) + C→Job2 (10) = **₹27**

Optimal assignment: Worker A→Job 3, Worker B→Job 1, Worker C→Job 2, at a minimum total cost of ₹27.

Illustration 7.2 — Game Theory (Mixed Strategy, 2×2)

Payoff matrix (Row Player's gain) — no saddle point exists: [[a,b],[c,d]] = [[4, 2], [1, 5]]

Step 1 — Check for saddle point: Row minimums: 2, 1 → Maximin=2. Column maximums: 4, 5 → Minimax=4. Since Maximin (2) ≠ Minimax (4), no saddle point — mixed strategy needed.

Step 2 — Optimal probability for Row Player's Strategy 1 (p): p = (d−c)/(a+d−b−c) = (5−1)/(4+5−2−1) = 4/6 = **0.667**; Strategy 2 probability = 1−0.667 = 0.333

Step 3 — Value of the Game: V = (ad−bc)/(a+d−b−c) = (4×5 − 2×1)/6 = (20−2)/6 = 18/6 = **3.0**

The Row Player should play Strategy 1 with probability 0.667 and Strategy 2 with probability 0.333, yielding an expected game value of 3.0 (this is the payoff the Row Player can guarantee regardless of the opponent's strategy).

4. Practice MCQs (15 × 2 Marks)

Q1. Which method for finding the Initial Basic Feasible Solution in a transportation problem generally produces the solution closest to optimal?

A. North-West Corner Method
B. Least Cost Method
C. Vogel's Approximation Method (VAM)
D. Random allocation

Answer: C

VAM uses penalty costs to make smarter initial allocations, typically requiring fewer iterations to reach optimality than NW Corner or Least Cost.

Q2. In the MODI method, a transportation solution is optimal (for minimisation) when:

A. All Δij values for unoccupied cells are ≥ 0
B. All Δij values are negative
C. There are no occupied cells
D. Total cost equals zero

Answer: A

Non-negative opportunity costs (Δij) for all unoccupied cells confirm no further cost reduction is possible — the solution is optimal.

Q3. If total supply does not equal total demand in a transportation problem, the correct approach is to:

A. Discard the problem as unsolvable
B. Add a dummy source or destination with zero cost to balance it
C. Randomly adjust actual supply figures
D. Ignore the imbalance

Answer: B

A dummy row/column with zero transportation cost balances supply and demand, allowing standard solution methods to be applied.

Q4. The number of basic (occupied) cells required for a non-degenerate transportation solution with m sources and n destinations is:

A. $m \times n$
B. $m + n$
C. $m + n - 1$
D. $m - n$

Answer: C

A non-degenerate basic feasible solution has exactly $m+n-1$ occupied cells, matching the number of independent constraints.

Q5. In the Assignment problem's Hungarian method, after row and column reduction, the minimum number of lines needed to cover all zeros should equal:

A. The number of rows minus 1
B. The order (n) of the matrix, for an optimal assignment to exist
C. Always 1
D. Twice the order of the matrix

Answer: B

When the minimum number of covering lines equals the matrix order (n), a complete one-to-one optimal assignment is achievable.

Q6. To convert a maximisation Assignment problem into a minimisation problem, each cell value is transformed by:

A. Adding the matrix's largest value
B. Subtracting each value from the matrix's largest value
C. Multiplying by -1 only
D. Dividing by the matrix's smallest value

Answer: B

New Value = Largest Value in Matrix − Original Value converts a maximisation problem into an equivalent minimisation problem.

Q7. A saddle point in a two-person zero-sum game exists when:

A. Maximin value equals Minimax value
B. Maximin value is always less than Minimax value
C. There is no unique optimal strategy
D. The game has more than two players

Answer: A

A saddle point (pure strategy equilibrium) exists exactly when the row player's maximin equals the column player's minimax.

Q8. When no saddle point exists in a 2×2 game, the players should use:

A. A single pure strategy always
B. A mixed strategy, randomising between their available strategies with specific probabilities
C. No strategy at all
D. Only the highest-payoff strategy regardless of the opponent

Answer: B

Without a saddle point, optimal play requires randomising strategies according to calculated probabilities to guarantee the game's value.

Q9. The Principle of Dominance in game theory is used to:

A. Increase the size of the payoff matrix
B. Eliminate strategies that are never better than an alternative, reducing the matrix size
C. Guarantee a saddle point always exists
D. Calculate transportation costs

Answer: B

Dominance eliminates strategies that are always inferior (or equal) to another strategy for a player, simplifying the game before solving.

Q10. For payoff matrix [[6,2],[3,7]], the Maximin and Minimax values are:

A. Maximin=3, Minimax=6
B. Maximin=2, Minimax=7
C. Maximin=6, Minimax=3
D. Maximin=7, Minimax=2

Answer: A

Row minimums: Row1=min(6,2)=2, Row2=min(3,7)=3 → Maximin=3. Column maximums: Col1=max(6,3)=6, Col2=max(2,7)=7 → Minimax=6.

Q11. A degenerate transportation solution is one where:

A. Occupied cells exceed m+n−1
B. Occupied cells are fewer than m+n−1
C. The solution is automatically optimal
D. Supply always exceeds demand

Answer: B

Degeneracy occurs when the number of basic (occupied) cells falls short of m+n−1, requiring a small allocation (ε) to proceed with MODI.

Q12. The Assignment problem is a special case of which broader class of optimisation problem?

A. Game Theory problem
B. Transportation problem (with all supplies and demands equal to 1)
C. Simulation model
D. Regression analysis

Answer: B

The Assignment problem is a special, balanced transportation problem where each source supplies exactly 1 unit and each destination demands exactly 1 unit.

Q13. In VAM, the "penalty" for each row/column is calculated as:

A. The sum of all costs in that row/column
B. The difference between the two lowest costs in that row/column
C. The highest cost in that row/column

D. Always zero

Answer: B

VAM's penalty highlights the opportunity cost of not allocating to the cheapest cell in each row/column, guiding smarter initial allocation.

Q14. If the value of a game is zero (fair game), it implies:

A. Neither player has an advantage over the other under optimal play
B. One player always wins
C. The game cannot be solved
D. Both players get the maximum possible payoff

Answer: A

A zero game value means the game is fair — neither player gains a systematic advantage when both play their optimal strategies.

Q15. For an unbalanced Assignment problem (unequal number of jobs and workers), the correct approach is to:

A. Refuse to solve it
B. Add dummy job(s) or worker(s) with zero cost to balance the matrix before applying the Hungarian method
C. Multiply all costs by the difference
D. Assign randomly without any method

Answer: B

Adding dummy rows/columns with zero cost balances the matrix, after which the standard Hungarian method can be applied.

MODULE 8 · SECTION B

Simulation, Network Analysis (PERT/CPM) & Learning Curve

Monte Carlo simulation for probabilistic problems, project scheduling using PERT/CPM (critical path, floats, crashing), and the Learning Curve effect on labour cost.

1. Formulas

A. Network Analysis — PERT/CPM

PERT — Expected Activity Time

`te = (to + 4tm + tp) / 6`

to = optimistic time, tm = most likely time, tp = pessimistic time. Based on the Beta probability distribution.

PERT — Variance of Activity Time

$\sigma^2 = [(tp - to) / 6]^2$

Variance of the critical path = sum of variances of all activities lying on the critical path (used to estimate project completion probability via the normal distribution).

Total Float (Slack)

`Total Float = Latest Start (LS) − Earliest Start (ES) = Latest Finish (LF) − Earliest Finish (EF)`

Activities on the Critical Path have ZERO total float — any delay in them delays the entire project.

Critical Path

`Critical Path = The longest path (by duration) through the network from start to finish`

Determines the minimum possible project completion time; all its activities have zero float.

CPM — Cost Slope (for Crashing)

`Cost Slope = (Crash Cost − Normal Cost) / (Normal Time − Crash Time)`

To reduce project duration at minimum extra cost, crash the critical activity with the LOWEST cost slope first.

B. Learning Curve

Learning Curve Model

`Y = a × X^b, where b = log(Learning Rate %) / log(2)`

Y = average time (or cost) per unit for X cumulative units; a = time for the 1st unit; b is negative for learning rate <100%.

80% Learning Curve Rule (common exam case)

`Cumulative average time per unit falls by 20% every time cumulative output DOUBLES`

E.g., if unit 1 takes 100 hrs, cumulative average for 2 units = 80 hrs, for 4 units = 64 hrs, for 8 units = 51.2 hrs, and so on.

Incremental (Marginal) Unit Time

`Time for nth unit = (Total time for n units) − (Total time for n−1 units)`

Total time for n units = Cumulative Average Time per unit (at n) × n.

C. Simulation

Monte Carlo Simulation — Random Number Assignment

Assign a Random Number Range to each outcome, proportional to its Cumulative Probability

Random numbers are then drawn (from tables or generated) to simulate a large number of trials and estimate expected outcomes (e.g., average demand, waiting time).

2. Practical Application

Critical Path identification: Always compute ES/EF (forward pass) and LS/LF (backward pass) for every activity — the critical path is the chain of activities where ES=LS and EF=LF (zero float) throughout.

Crashing decisions: Only crash activities ON the critical path — crashing a non-critical activity wastes money without shortening the project, and crashing may create a NEW critical path once the original one is shortened enough.

Learning curve in budgeting: Apply the learning curve to labour-cost budgets for new products/processes with repetitive manual tasks — ignoring it typically overstates budgeted labour cost and understates achievable margins as workers gain experience.

3. Worked Illustrations

Illustration 8.1 — PERT Expected Time & Variance

An activity has: Optimistic time = 4 days, Most Likely time = 7 days, Pessimistic time = 16 days.

Step 1 — Expected time: $t_e = (4 + 4\times7 + 16)/6 = (4+28+16)/6 = 48/6 =$ **8 days**

Step 2 — Variance: $\sigma^2 = [(16-4)/6]^2 = [12/6]^2 = 2^2 =$ **4**

Expected activity duration = 8 days, with a variance of 4 (Standard Deviation = 2 days) — this variance feeds into estimating the probability of overall project completion by a target date.

Illustration 8.2 — 80% Learning Curve

The first unit of a new product takes 200 labour hours. The workforce experiences an 80% learning curve.

Step 1 — Cumulative average time for 2 units: 200 × 80% = 160 hours/unit; Total for 2 units = 320 hours

Step 2 — Cumulative average time for 4 units: 160 × 80% = 128 hours/unit; Total for 4 units = 512 hours

Step 3 — Time for units 3 & 4 combined (incremental): Total(4 units) − Total(2 units) = 512 − 320 = **192 hours**

While the first 2 units together take 320 hours, units 3 and 4 combined take only 192 hours — demonstrating the efficiency gain from learning as cumulative output doubles.

4. Practice MCQs (15 × 2 Marks)

Q1. In PERT, the expected time formula te = (to+4tm+tp)/6 is based on which probability distribution?

A. Normal distribution
B. Beta distribution
C. Poisson distribution
D. Binomial distribution

Answer: B

PERT's weighted-average time formula is derived from the properties of the Beta probability distribution.

Q2. Activities on the Critical Path have a Total Float equal to:

A. A large positive number

B. Zero
C. A negative number
D. Equal to the project duration

Answer: B

Critical path activities have zero slack — any delay directly delays the entire project.

Q3. In CPM crashing, to reduce project duration at minimum extra cost, the manager should first crash the critical activity with the:

A. Highest cost slope
B. Lowest cost slope
C. Longest normal time
D. Shortest crash time

Answer: B

Cost slope represents the extra cost per unit time saved — crashing the lowest-cost-slope activity first minimises total crashing cost.

Q4. Under an 80% learning curve, when cumulative output doubles, the cumulative AVERAGE time per unit:

A. Increases by 20%
B. Falls to 80% of its previous level (a 20% reduction)
C. Remains unchanged
D. Doubles

Answer: B

An 80% learning rate means cumulative average time per unit becomes 80% of its prior value every time output doubles.

Q5. Monte Carlo Simulation uses random numbers primarily to:

A. Guarantee a single, deterministic outcome
B. Model and replicate the probabilistic behaviour of uncertain variables over many trials
C. Eliminate the need for probability distributions
D. Calculate depreciation

Answer: B

Simulation generates random numbers mapped to probability distributions to model uncertain variables across many repeated trials.

Q6. The Critical Path in a project network is defined as:

A. The shortest path from start to finish
B. The longest path from start to finish, determining minimum project duration
C. Any random path through the network
D. The path with the fewest activities

Answer: B

The critical path is the longest sequence of dependent activities, setting the minimum time in which the project can be completed.

Q7. If an activity's optimistic time = 2 days, most likely = 5 days, pessimistic = 8 days, its expected time is:

A. 4 days
B. 5 days
C. 6 days
D. 8 days

Answer: B

te = (2+4×5+8)/6 = (2+20+8)/6 = 30/6 = 5 days.

Q8. Total Float for a non-critical activity is generally:

A. Always negative
B. Zero
C. Positive, representing the allowable delay without affecting overall project completion
D. Equal to the activity's total duration

Answer: C

Non-critical activities have positive float/slack, meaning they can be delayed by that amount without extending the project.

Q9. The learning curve effect is most relevant for:

A. Fully automated processes with no human labour input
B. Repetitive manual tasks where workers gain efficiency through practice
C. One-off tasks never repeated
D. Raw material purchase costs only

Answer: B

Learning curves apply where repeated performance of a manual/labour-intensive task leads to measurable efficiency gains over time.

Q10. If Crash Cost = ₹5,000, Normal Cost = ₹3,000, Normal Time = 10 days, Crash Time = 8 days, the Cost Slope is:

A. ₹500/day
B. ₹1,000/day
C. ₹2,000/day
D. ₹250/day

Answer: B

Cost Slope = (5,000−3,000)/(10−8) = 2,000/2 = ₹1,000 per day.

Q11. The variance of the overall project completion time (for the critical path) is calculated as:

A. The variance of only the longest single activity
B. The sum of the variances of all activities lying on the critical path
C. The average of all activity variances in the network
D. Always zero

Answer: B

Since critical path activities are assumed independent, their individual variances are summed to get the total project time variance.

Q12. A key limitation of simulation as a decision-making technique is that it:

A. Always gives the exact optimal solution
B. Provides an approximate answer based on repeated trials, not a guaranteed optimum
C. Cannot be used with probability distributions
D. Requires no computational effort

Answer: B

Simulation approximates likely outcomes through repeated random trials — it does not mathematically guarantee the single best (optimal) solution like LP does.

Q13. If crashing the critical path activities reduces the project duration sufficiently, it is possible that:

A. No other path can ever become critical
B. A previously non-critical path may become the new critical path
C. The project duration will always remain the same
D. All floats become negative

Answer: B

As the original critical path shortens through crashing, another path's duration may equal or exceed it, making it the new critical path.

Q14. In the learning curve formula Y = aX^b, the exponent "b" is:

A. Always positive
B. Negative, reflecting decreasing time/cost per unit as cumulative output rises
C. Always equal to 1
D. Unrelated to the learning rate

Answer: B

Since learning reduces average time per unit as output rises, b = log(learning rate)/log(2) is negative for learning rates below 100%.

Q15. PERT is generally more suitable than CPM when:

A. Activity times are known with certainty
B. Activity times are uncertain and best represented by three time estimates (optimistic, most likely, pessimistic)
C. There is no need for a project network at all
D. Only cost data is available, with no time estimates

Answer: B

PERT was developed for projects with uncertain/probabilistic activity durations, using three-point time estimates, unlike CPM's deterministic single-time-estimate approach.

MODULE 9 · SECTION B

Business Application of Maxima & Minima

Using differential calculus to find profit-maximising output levels and cost-minimising decisions — marginal analysis and the first/second derivative tests.

1. Formulas

Marginal Cost & Marginal Revenue

Marginal Cost (MC) = d(Total Cost)/dQ; Marginal Revenue (MR) = d(Total Revenue)/dQ

MC and MR represent the rate of change of total cost/revenue with respect to one additional unit of output (Q).

Profit Maximisation — First Order Condition

Profit (π) = TR − TC. Maximised where: dπ/dQ = 0 ⇒ MR = MC

The classic economic rule: profit is maximised at the output level where marginal revenue equals marginal cost.

Second Order Condition (confirming a Maximum)

$d^2\pi/dQ^2 < 0$ confirms a MAXIMUM (not a minimum) at that output level

If $d^2\pi/dQ^2 > 0$, the point found is a minimum instead — always check the second derivative's sign.

Cost Minimisation

Minimise Total Cost: dTC/dQ = 0 with $d^2TC/dQ^2 > 0$ confirming a minimum

Commonly applied to derive the Economic Order Quantity (EOQ) by minimising Total Inventory Cost (ordering + carrying cost) with respect to order size.

Economic Order Quantity (via Calculus)

EOQ = √(2DS / Cc)

D = annual demand, S = ordering cost per order, Cc = carrying cost per unit p.a. — derived by minimising Total Cost = (D/Q)S + (Q/2)Cc with respect to Q.

2. Practical Application

MR=MC rule in pricing: Used to derive optimal selling price/output when demand and cost functions are given as equations of Q (e.g., P = a−bQ) — differentiate TR and TC, set equal, solve for Q, then find price from the demand equation.

Always confirm maximum vs minimum: Exam solutions frequently lose marks by finding a stationary point (first derivative = 0) but forgetting to check the second derivative's sign to confirm it's actually a maximum (for profit) or minimum (for cost).

EOQ link to inventory decisions: The calculus-based derivation of EOQ reinforces WHY the formula balances ordering cost (falls as Q rises) against carrying cost (rises as Q rises) — useful for explaining the concept, not just applying the formula.

3. Worked Illustration

Illustration 9.1 — Profit Maximisation using Calculus

Demand function: P = 500 − 2Q. Total Cost function: TC = 100Q + 5,000.

Step 1 — Total Revenue: TR = P × Q = (500−2Q)Q = $500Q - 2Q^2$

Step 2 — Profit function: $\pi = TR - TC = (500Q-2Q^2) - (100Q+5{,}000) = 400Q - 2Q^2 - 5{,}000$

Step 3 — First derivative, set to zero: $d\pi/dQ = 400 - 4Q = 0 \Rightarrow Q =$ **100 units**

Step 4 — Second derivative check: $d^2\pi/dQ^2 = -4 < 0 \rightarrow$ confirms MAXIMUM

Step 5 — Optimal Price & Maximum Profit: P = 500−2(100) = ₹300; $\pi = 400(100)-2(100)^2-5{,}000 = 40{,}000-20{,}000-5{,}000 =$ **₹15,000**

Profit is maximised at an output of 100 units, sold at a price of ₹300 per unit, generating maximum profit of ₹15,000.

4. Practice MCQs (15 × 2 Marks)

Q1. Profit is maximised at the output level where:

A. Total Revenue is maximised regardless of cost
B. Marginal Revenue equals Marginal Cost (and the second derivative of profit is negative)
C. Total Cost is minimised regardless of revenue
D. Average Cost equals Marginal Cost only

Answer: B

The MR=MC rule (with the second-order condition $d^2\pi/dQ^2<0$) is the standard calculus-based profit maximisation condition.

Q2. If $d^2\pi/dQ^2 > 0$ at a stationary point where $d\pi/dQ=0$, this point represents:

A. A maximum profit point
B. A minimum profit point (not what we want for maximisation)
C. An inflection point always
D. An undefined point

Answer: B

A positive second derivative at a stationary point indicates a minimum, not the maximum we seek in a profit-maximisation problem.

Q3. Marginal Cost is defined mathematically as:

A. Total Cost divided by total output
B. The derivative of Total Cost with respect to output (dTC/dQ)
C. Fixed Cost per unit
D. Average Variable Cost

Answer: B

MC is the rate of change of total cost as output changes — mathematically, the first derivative of TC with respect to Q.

Q4. If $TR = 300Q - 3Q^2$, Marginal Revenue is:

A. $300 - 3Q$
B. $300 - 6Q$
C. $300Q - 6Q$
D. $600Q$

Answer: B

$MR = d(TR)/dQ = d(300Q-3Q^2)/dQ = 300 - 6Q$.

Q5. In deriving the EOQ formula via calculus, Total Inventory Cost is minimised by differentiating with respect to:

A. Time
B. Order Quantity (Q)
C. Annual Demand (D) only
D. Carrying Cost Rate only

Answer: B

EOQ is found by setting d(Total Cost)/dQ = 0, where Total Cost = ordering cost + carrying cost, both expressed as functions of Q.

Q6. If Total Cost $TC = Q^2 - 20Q + 500$, the output level that minimises cost is:

A. Q=5
B. Q=10
C. Q=20
D. Q=25

Answer: B

$dTC/dQ = 2Q-20 = 0 \Rightarrow Q=10$. Second derivative = 2 > 0, confirming a minimum.

Q7. Why must the second derivative always be checked after finding a stationary point in these business optimisation problems?

A. It's an optional formality with no real purpose
B. To confirm whether the stationary point is actually a maximum or a minimum
C. It only matters for linear functions
D. It replaces the need for the first derivative entirely

Answer: B

Setting the first derivative to zero only locates a stationary point — the second derivative's sign confirms whether it's a maximum, minimum, or neither.

Q8. At the profit-maximising output level, if MR > MC just before that point, it implies:

A. Producing more units would increase profit further, up to the point where MR=MC
B. The firm should immediately stop production
C. Profit is already at its maximum
D. Total cost is negative

Answer: A

As long as MR exceeds MC, each additional unit adds more revenue than cost, increasing profit — production should continue until MR=MC.

Q9. Given Demand: $P = 200-4Q$ and $TC = 20Q$, the profit-maximising quantity Q is:

A. 10
B. 20
C. 22.5
D. 45

Answer: C

$TR=200Q-4Q^2$; $\pi=200Q-4Q^2-20Q=180Q-4Q^2$. $d\pi/dQ=180-8Q=0 \Rightarrow Q=22.5$.

Q10. The classical EOQ model assumes Total Cost consists of:

A. Only ordering cost
B. Ordering cost and carrying (holding) cost, which trade off against each other as order quantity changes
C. Only carrying cost
D. Selling price and profit margin only

Answer: B

EOQ balances ordering cost (which falls with larger, less-frequent orders) against carrying cost (which rises with larger average inventory).

Q11. If a firm's profit function is $\pi = 100Q - Q^2 - 500$, the maximum profit achievable is:

A. ₹1,500
B. ₹2,000
C. ₹2,500
D. ₹5,000

Answer: B

$d\pi/dQ=100-2Q=0 \Rightarrow Q=50$. $\pi=100(50)-(50)^2-500=5{,}000-2{,}500-500=$ ₹2,000. Second derivative $=-2<0$ confirms maximum.

Q12. Marginal Revenue at any output level can also be interpreted as:

A. The average revenue per unit sold
B. The additional revenue generated from selling one more unit
C. The total revenue for all units combined
D. The fixed component of revenue

Answer: B

MR measures the incremental revenue impact of selling exactly one additional unit of output.

Q13. In business applications, calculus-based maxima/minima techniques are used mainly for:

A. Recording historical transactions
B. Optimising continuous decision variables like output level, price, or order quantity
C. Preparing statutory financial statements
D. Auditing procedures

Answer: B

Calculus optimisation is applied where a continuous variable (Q, price, order size) needs to be set at its profit-maximising or cost-minimising level.

Q14. If Average Cost (AC) is minimised, at that output level AC equals:

A. Fixed Cost
B. Marginal Cost
C. Total Revenue
D. Zero

Answer: B

At the output level where Average Cost is at its minimum, AC = MC (a standard result from differentiating the AC function).

Q15. A firm facing demand P=a−bQ maximises revenue (not profit) at the output level where:

A. MR = MC
B. MR = 0
C. Price = Marginal Cost
D. Total Cost = 0

Answer: B

Revenue (not profit) maximisation occurs where the derivative of TR with respect to Q equals zero, i.e., MR=0 — a distinct condition from profit maximisation (MR=MC).

MODULE 10 · SECTION B

Business Forecasting (Time Series & Regression) & Data Analytics

Regression analysis for forecasting, time series decomposition (trend, seasonal, cyclical, irregular), and an introduction to data analytics tools used in modern cost management.

1. Formulas

Simple Linear Regression Line

$$Y = a + bX$$

Y = dependent (forecast) variable, X = independent variable, a = intercept, b = slope (regression coefficient).

Regression Coefficient "b" (Least Squares)

$$b = [n\Sigma XY - \Sigma X\Sigma Y] / [n\Sigma X^2 - (\Sigma X)^2]$$

n = number of paired observations. Minimises the sum of squared deviations of actual Y from the fitted line.

Regression Constant "a"

$$a = (\Sigma Y - b\Sigma X) / n = \bar{Y} - b\bar{X}$$

Ensures the regression line passes through the point of means (mean of X, mean of Y).

Coefficient of Correlation (r)

$$r = [n\Sigma XY - \Sigma X\Sigma Y] / \sqrt{[n\Sigma X^2-(\Sigma X)^2][n\Sigma Y^2-(\Sigma Y)^2]}$$

Ranges from −1 to +1. Coefficient of Determination = r^2 = proportion of variation in Y explained by X.

Time Series — Multiplicative Model

$$Y = T \times S \times C \times I$$

Y=actual value, T=Trend, S=Seasonal, C=Cyclical, I=Irregular component. (Additive model: Y = T+S+C+I is used as an alternative when fluctuations don't scale with the trend level.)

Seasonal Index

Seasonal Index = (Average value for that season / Overall average of all seasons) × 100

An index of 100 = no seasonal effect; above 100 = above-average season; below 100 = below-average season.

Trend by Moving Averages

Moving Average (period n) = Average of n consecutive time-period values, rolled forward one period at a time

Smooths out short-term/seasonal fluctuations to reveal the underlying trend — choose n to match the length of the seasonal cycle (e.g., 4 for quarterly data, 12 for monthly data).

2. Practical Application

Regression for cost estimation: Widely used to split semi-variable costs into fixed and variable elements (High-Low method is a simplified 2-point version; regression uses ALL data points for a statistically better fit).

Interpreting r^2: An r^2 of 0.85 means 85% of the variation in the dependent variable (e.g., total cost) is explained by the independent variable (e.g., output level) — useful for judging how reliable a cost/sales forecast is likely to be.

Data Analytics in cost management: Modern SCM increasingly uses descriptive (what happened), diagnostic (why), predictive (what will happen), and prescriptive (what should we do) analytics — moving cost management from historical reporting toward forward-looking decision support.

3. Worked Illustration

Illustration 10.1 — Simple Linear Regression for Cost Forecasting

Output (X, '000 units) and Total Cost (Y, ₹'000) for 5 months: (2,20), (4,28), (6,34), (8,40), (10,48).

X	Y	XY	X²
2	20	40	4
4	28	112	16
6	34	204	36
8	40	320	64
10	48	480	100

Step 1 — Sums (n=5): $\Sigma X=30$, $\Sigma Y=170$, $\Sigma XY=1{,}156$, $\Sigma X^2=220$

Step 2 — Regression coefficient b: $b = [5(1{,}156) - (30)(170)] / [5(220) - (30)^2] = [5{,}780-5{,}100]/[1{,}100-900] = 680/200 =$ **3.4**

Step 3 — Regression constant a: $a = (170 - 3.4\times30)/5 = (170-102)/5 = 68/5 =$ **13.6**

Step 4 — Regression equation & forecast: $Y = 13.6 + 3.4X$. For X=12 ('000 units): $Y = 13.6+3.4(12) = 13.6+40.8 =$ **₹54.4 thousand**

Fixed cost component ≈ ₹13,600 (the "a" value), variable cost ≈ ₹3.40 per unit ("b" value, since X is in '000 units and Y in ₹'000, effectively ₹3.40/unit). Forecast total cost at 12,000 units output ≈ ₹54,400.

4. Practice MCQs (15 × 2 Marks)

Q1. In the regression line Y = a + bX, the coefficient "b" represents:

A. The Y-intercept (fixed component)
B. The slope — the average change in Y for a one-unit change in X
C. The total sum of Y values
D. The correlation coefficient

Answer: B

"b" is the slope of the regression line, representing the rate of change of the dependent variable per unit change in the independent variable.

Q2. The Coefficient of Determination (r^2) represents:

A. The slope of the regression line
B. The proportion of variation in the dependent variable explained by the independent variable
C. The Y-intercept
D. The total number of observations

Answer: B

r^2 measures how much of the variability in Y is statistically explained by X — a higher r^2 indicates a better-fitting model.

Q3. In time series analysis, the "Seasonal" component refers to:

A. Long-term upward or downward movement
B. Regular, periodic fluctuations tied to the calendar (e.g., quarters, months)
C. Random, unpredictable events
D. Long-duration business cycle swings

Answer: B

Seasonal variation is a regular, calendar-linked pattern (e.g., higher ice cream sales in summer) recurring within each year.

Q4. The Multiplicative Time Series Model is expressed as:

A. Y = T+S+C+I
B. Y = T × S × C × I
C. Y = T/S/C/I
D. Y = T−S−C−I

Answer: B

The multiplicative model expresses the actual value as the product of Trend, Seasonal, Cyclical, and Irregular components.

Q5. A Seasonal Index of 120 for a particular quarter means:

A. That quarter's value is 120% below the overall average
B. That quarter's value is typically 20% above the overall average
C. There is no seasonal effect
D. Sales are exactly zero in that quarter

Answer: B

A Seasonal Index above 100 indicates the season's typical value exceeds the overall average — 120 means 20% above average.

Q6. The Moving Averages method for trend estimation works by:

A. Using only the first and last data points
B. Averaging a fixed number of consecutive periods, rolling forward one period at a time, to smooth out short-term fluctuations
C. Ignoring all data points except the mean
D. Using only the highest value in the series

Answer: B

Moving averages smooth a time series by averaging over a rolling window, reducing the impact of seasonal/random noise to reveal the trend.

Q7. If the correlation coefficient r = 0.9, the coefficient of determination r^2 equals:

A. 0.81 (81%)
B. 0.90 (90%)
C. 0.09 (9%)
D. 1.80 (180%)

Answer: A

$r^2 = 0.9^2 = 0.81$, meaning 81% of the variation in Y is explained by X.

Q8. Regression analysis is preferred over the High-Low method for cost estimation mainly because regression:

A. Uses only two extreme data points
B. Uses ALL available data points, giving a statistically more reliable fixed-variable cost split
C. Ignores all data except the median
D. Cannot be used for cost estimation at all

Answer: B

Regression incorporates every observation, reducing the distortion risk from relying on just the highest and lowest points (as the High-Low method does).

Q9. The "Cyclical" component in time series analysis refers to:

A. Fluctuations tied strictly to the calendar year
B. Longer-term, wave-like fluctuations often linked to overall business/economic cycles
C. Completely random, unpredictable events like strikes
D. Only the long-term linear trend

Answer: B

Cyclical variations are longer-duration swings (often several years), typically associated with broader economic booms and recessions, unlike the shorter, calendar-linked seasonal component.

Q10. Predictive analytics, as a category of data analytics, focuses on:

A. Describing what has already happened
B. Forecasting what is likely to happen in the future using historical data and models

C. Recommending specific prescribed actions
D. Only auditing past transactions

Answer: B

Predictive analytics uses historical data, statistics, and modelling techniques to forecast future outcomes.

Q11. "Prescriptive Analytics" goes a step further than predictive analytics by:

A. Only describing past events
B. Recommending specific actions to achieve a desired future outcome
C. Ignoring forecasts entirely
D. Only visualising raw data

Answer: B

Prescriptive analytics builds on predictions to suggest concrete recommended actions/decisions.

Q12. If $\Sigma X=50$, $\Sigma Y=250$, $n=5$, and $b=4$, the regression constant "a" is:

A. 10
B. 30
C. 50
D. 90

Answer: A

$a = (\Sigma Y - b\Sigma X)/n = (250 - 4\times50)/5 = (250-200)/5 = 50/5 = 10$.

Q13. The Irregular (Random) component of a time series represents:

A. Predictable seasonal swings
B. Unpredictable, one-off variations (e.g., natural disasters, strikes) not explained by trend, seasonal, or cyclical factors
C. The overall long-term trend
D. Business cycle fluctuations only

Answer: B

Irregular variations are residual, non-systematic fluctuations caused by unforeseen one-off events.

Q14. A correlation coefficient close to 0 indicates:

A. A strong linear relationship between the two variables
B. Little to no linear relationship between the two variables
C. A perfect negative relationship
D. A perfect positive relationship

Answer: B

A correlation coefficient near zero suggests the two variables have little or no linear association.

Q15. In modern strategic cost management, tools for data analytics are primarily introduced to help managers:

A. Replace all financial reporting with raw data dumps
B. Extract actionable cost/business insights from large volumes of structured and unstructured data
C. Eliminate the need for any cost accounting
D. Only comply with statutory audit requirements

Answer: B

Data analytics tools help cost managers derive meaningful, actionable insights from big data to support more informed strategic decisions.