DegreeLive

Bachelor of Business Administration (BBA) | Fifth Semester | UK5DSCMGT301

Operations Management

Course Code: UK5DSCMGT301 • Module 5 Notes

degreelive.in

Module 5: Materials Management and Maintenance Engineering

Operations Management • Course Code: UK5DSCMGT301

Chapter 1: Materials Management and Selective Inventory Control

1.1 Scope, Objectives, and Integrated Functions of Materials Management

Materials Management is an integrated operational function responsible for planning, acquiring, storing, handling, and controlling the flow of materials across an enterprise from their initial raw state through production to final distribution. In typical manufacturing industries, materials account for **50% to 70% of total product manufacturing costs**. Consequently, an operational reduction of merely five percent in material expenditures frequently yields a greater expansion in corporate net profit than a twenty percent expansion in gross sales revenue.

The integrated materials management framework pursues foundational operational objectives:

- *Continuity of Production:* Ensuring uninterrupted availability of raw materials, sub-assemblies, and maintenance supplies to prevent catastrophic factory line shutdowns.
- *Cost Minimization:* Procuring quality inputs at optimal prices, securing favorable credit terms, and eliminating unnecessary material-handling transit expenses.
- *Inventory Optimization:* Minimizing working capital tied up in dormant inventory while preventing stockouts through scientific replenishment rules.
- *Quality Assurance:* Guaranteeing that procured components strictly conform to engineering technical specifications and chemical purity tolerances.
- *Vendor Relationship Management:* Cultivating cooperative, long-term partnerships with certified supplier networks to secure technological collaboration and priority delivery.

1.2 Selective Inventory Control Techniques

Modern industrial enterprises maintain thousands of distinct Stock-Keeping Units (SKUs). Exercising uniform managerial control over every single item is neither economically viable nor operationally practical. Enterprises deploy **Selective Inventory Control** methodologies based on Pareto's Law of the Vital Few and Trivial Many:

1. ABC Analysis (Based on Annual Monetary Value of Consumption):

- *Class A Items:* Account for roughly **10% to 15% of total inventory items**, but represent **70% to 80% of total annual consumption value**. These are high-value critical components (e.g., engines, precision microprocessors). They demand stringent managerial oversight, low buffer stocks, weekly stock reconciliations, and executive purchase approvals.
- *Class B Items:* Account for roughly **20% to 25% of total items**, and represent **15% to 20% of annual consumption value**. Moderate control, monthly reviews, and standard economic order

Degreelive

quantities.

- *Class C Items:* Account for roughly **60% to 70% of total items**, but represent a mere **5% to 10% of total annual consumption value**. These are low-cost hardware items (e.g., standard screws, washers, lubricating grease). They utilize decentralized purchase orders, simple two-bin replenishment systems, and large safety stock cushions to avoid stockout downtime.

2. Other Classical Selective Control Matrix Typologies:

Technique	Classification Criterion	Managerial Application
VED Analysis	Criticality to production: Vital (V), Essential (E), Desirable (D).	Vital spare parts must be stocked at all times; their absence causes total plant shutdowns.
FSN Analysis	Velocity of material consumption: Fast-moving (F), Slow-moving (S), Non-moving (N).	Identifies obsolete and dormant stocks (N) for write-off and warehouse space clearance.
SDE Analysis	Procurement difficulty: Scarce (S), Difficult (D), Easy (E).	Scarce imported materials require long lead-time procurement and strategic stockpiling.
HML Analysis	Unit purchase price: High (H), Medium (M), Low (L).	Dictates level of financial authorization required for purchasing approvals.
XYZ Analysis	Value of physical stock stored in the warehouse.	Used in conjunction with ABC analysis to optimize warehouse layout and security.

1.3 Vendor Evaluation and Rating: The Weighted Point Method

To eliminate subjective bias and establish objective vendor accountability, procurement managers deploy the **Weighted Point Method**. Performance categories—typically Quality (conformance rate), Delivery (on-time reliability), and Price (competitiveness)—are assigned strategic weights that sum to 1.00. Each vendor's performance is monitored over an operating quarter and scored on a 100-point scale:

> `Vendor Composite Performance Score = (Weight_Q × Score_Q) + (Weight_D × Score_D) + (Weight_P × Score_P)`
>
> Where: Quality Score is based on accepted lots %, Delivery Score is on-time shipments %, and Price Score benchmarks quote against lowest bid.

Worked Numerical Problem (Vendor Rating): Apex Automotive evaluates two prospective tier-1 suppliers of cast iron brake rotors. Corporate procurement assigns the following weights: Quality = 0.40; Delivery Reliability = 0.35; and Price Competitiveness = 0.25. Performance data for the previous quarter is recorded as follows:

- *Supplier Alpha:* Delivered 50 shipments. Quality: 48 shipments accepted without defects (Score = [48/50] × 100 = 96.0). Delivery: 45 shipments arrived strictly on schedule (Score = [45/50] × 100 = 90.0). Price: Quoted Rs 850 per unit against the lowest industry bid of Rs 800 (Price Score = [800 / 850] × 100 = 94.12).
- *Supplier Beta:* Delivered 50 shipments. Quality: 44 shipments accepted without defects (Score = [44/50] × 100 = 88.0). Delivery: 49 shipments arrived strictly on schedule (Score = [49/50] × 100 = 98.0). Price: Quoted Rs 800 per unit, which was the lowest market bid (Price Score = [800 / 800] × 100 = 100.0).

Computational Resolution:
Supplier Alpha Composite Score: (0.40 × 96.0) + (0.35 × 90.0) + (0.25 × 94.12) = 38.40 + 31.50 + 23.53 = **93.43**.
Supplier Beta Composite Score: (0.40 × 88.0) + (0.35 × 98.0) + (0.25 × 100.0) = 35.20 + 34.30 + 25.00 = **94.50**.
Managerial Decision: **Supplier Beta** achieves the higher overall vendor rating (94.50 vs 93.43), primarily driven by flawless on-time delivery (98%) and the lowest market price, making Beta the preferred primary contractor.

1.4 Comprehensive Numerical Problem: ABC Inventory Classification

To demonstrate the mathematical implementation of ABC inventory analysis, consider Precision Tools Ltd, which stocks ten distinct raw material items. Annual consumption units and unit purchase costs are detailed below:

Item No.	Annual Usage (Units)	Unit Cost (Rs)	Annual Value (Rs)	% Value	Category
Item 101	2,000	500	10,00,000	35.71%	**Class A**
Item 102	1,500	600	9,00,000	32.14%	**Class A**
Item 103	4,000	75	3,00,000	10.71%	**Class B**
Item 104	2,500	80	2,00,000	7.14%	**Class B**
Item 105	1,000	100	1,00,000	3.57%	**Class B**
Item 106	5,000	16	80,000	2.86%	**Class C**
Item 107	6,000	10	60,000	2.14%	**Class C**
Item 108	8,000	6	48,000	1.71%	**Class C**
Item 109	10,000	5	50,000	1.79%	**Class C**
Item 110	12,000	5	60,000	2.14%	**Class C**
Total	**52,000 units**	-	**Rs 27,98,000**	**100.0%**	-

DegreeLive

Managerial Stratification Summary:

- **Class A (Items 101, 102):** Represent 2 out of 10 items (20% of inventory items) but account for Rs 19,00,000 out of Rs 27,98,000 (**67.91% of total consumption value**). Managed under strict daily oversight, tight safety stocks, and frequent order releases.
- **Class B (Items 103, 104, 105):** Represent 3 out of 10 items (30% of inventory items) and account for Rs 6,00,000 (**21.44% of total consumption value**). Managed under standard monthly reviews.
- **Class C (Items 106, 107, 108, 109, 110):** Represent 5 out of 10 items (50% of items) but account for only Rs 2,98,000 (**10.65% of total consumption value**). Managed using simple visual two-bin systems with generous safety stocks.

1.5 Stores Accounting: Bin Cards versus Stores Ledger

In industrial materials management, accurate record-keeping of inventory receipts, physical issues, and balance quantities is vital for financial reconciliation and preventing theft or misappropriation. Operations maintain two complementary records:

Comparative Feature	Bin Card	Stores Ledger
Physical Custody	Maintained inside the physical warehouse, attached directly to the storage bin, rack, or shelf.	Maintained in the Cost Accounting and Finance Department, typically digitized in an ERP system.
Responsible Personnel	Storekeeper or warehouse inventory clerk.	Cost Accountant or financial inventory specialist.
Data Recorded	Records purely **quantitative physical movements** (units received, units issued, balance on hand).	Records both **quantities and monetary values** (unit prices, total issue value, monetary balance).
Timing of Recording	Entries are posted in real-time immediately when goods are physically placed in or removed from the bin.	Entries are posted periodically from verified Goods Received Notes and Material Requisition Slips.
Reconciliation Function	Serves as the frontline physical check during periodic or perpetual inventory stock-taking audits.	Serves as the basis for financial statement inventory valuation and costing of goods sold.

3.7 The Eight Pillars of Total Productive Maintenance

The Japan Institute of Plant Maintenance established the Eight Pillars of TPM to achieve comprehensive operational transformation across equipment, personnel, and organizational culture:

TPM Pillar	Core Objective	Shop-Floor Operational Actions
1. Autonomous Maintenance (Jishu Hozen)	Empower machine operators to maintain their own equipment.	Daily cleaning, lubrication, bolt tightening, and simple visual fault diagnosis by operators.
2. Focused Improvement (Kobetsu Kaizen)	Systematically eradicate the "16 Major Equipment Losses."	Cross-functional project teams tackle chronic micro-stops, speed reductions, and setup delays.
3. Planned Maintenance	Achieve zero unplanned breakdowns at optimal maintenance cost.	Implementing predictive vibration monitoring, oil spectrometry, and scheduled overhauls.
4. Quality Maintenance (Hinshitsu Hozen)	Achieve zero product quality defects caused by machinery.	Establishing machine condition parameters that guarantee zero defect generation.
5. Early Equipment Management	Shorten commissioning time for newly installed machinery.	Designing machinery for easy maintenance, cleanability, and rapid ergonomic access.
6. Education and Training	Elevate multi-skilling and technical maintenance competence.	Formal apprentice schools and simulation training for machine operation and repair.
7. Health, Safety, and Environment	Achieve zero workplace accidents and zero environmental spills.	Ergonomic risk assessments, machine interlock guards, and environmental waste control.
8. Office TPM	Eliminate bureaucratic waste in administrative support functions.	Streamlining purchase order processing, order dispatching, and administrative workflows.

Chapter 2: Quantitative Inventory Models and Material Requirements Planning

2.1 The Classical Economic Order Quantity (EOQ) Model

Formulated by Ford W. Harris in 1913 and popularized by R.H. Wilson, the **Economic Order Quantity (EOQ)** model identifies the replenishment batch size that minimizes the total annual cost of inventory management by balancing two opposing cost forces: *Ordering Costs* (which decrease on an annual basis as order size increases) and *Carrying / Holding Costs* (which increase linearly with average inventory size).

Underlying Assumptions of the Classical EOQ Model: (1) Annual demand (D) is known, constant, and continuous; (2) Order replenishment is instantaneous (batch arrives all at once); (3)

Lead time is zero or constant; (4) Unit purchase price is fixed with no volume quantity discounts; (5) Ordering cost per order (S) is fixed regardless of order quantity; (6) Annual holding cost per unit (H) is constant; and (7) Stockouts are prohibited.

```
Annual Ordering Cost = (D / Q) × S
Annual Holding Cost = (Q / 2) × H
Total Annual Inventory Cost (TC) = [(D / Q) × S] + [(Q / 2) × H]
Economic Order Quantity (EOQ) = Square Root of [(2 × D × S) / H]
```

Where: D = Annual Demand (Units), S = Setup / Ordering Cost per Order (Currency), H = Annual Holding Cost per Unit per Year (Currency), and Q = Order Quantity.

Comprehensive Numerical Demonstration (Classical EOQ): A manufacturer of electrical switchgear consumes 10,000 copper connectors annually. Sourcing costs incurred per purchase order (administrative requisitions, vendor communication, inspection) equal Rs 500. The holding cost per unit per year is estimated at Rs 4 (incorporating capital cost, insurance, warehousing space, and physical obsolescence). The working year consists of 250 operating days, and vendor lead time is 5 working days.

Computational Resolution:

1. Optimal Economic Order Quantity (EOQ):
EOQ = Square Root of [(2 × 10,000 × Rs 500) / Rs 4]
= Square Root of [1,00,00,000 / 4] = Square Root of [25,00,000] = **1,581.14 → 1,581 units**.

2. Annual Financial Costs at EOQ:
Number of Orders per Year = D / EOQ = 10,000 / 1,581.14 = **6.325 orders/year**.
Annual Ordering Cost = 6.325 × Rs 500 = **Rs 3,162.28**.
Annual Holding Cost = (1,581.14 / 2) × Rs 4 = 790.57 × Rs 4 = **Rs 3,162.28**.
Total Annual Variable Cost: Rs 3,162.28 + Rs 3,162.28 = **Rs 6,324.56**.
Mathematical Invariant: At EOQ, Annual Ordering Cost exactly equals Annual Holding Cost!

3. Reorder Point (ROP) Determination:
Daily Demand (d) = Annual Demand / Operating Days = 10,000 / 250 = 40 units per day.
Reorder Point (ROP) = Daily Demand × Lead Time (L) = 40 units/day × 5 days = **200 units**.
Managerial Rule: Whenever physical stock falls to 200 units, the inventory controller must immediately dispatch a replenishment order for 1,581 units.

2.2 Material Requirements Planning (MRP I) and Manufacturing Resource Planning (MRP II)

While EOQ is suited for independent demand items (finished goods whose demand originates outside the factory), components and raw materials exhibit **Dependent Demand**—their demand is derived mathematically from the production schedule of the parent finished good. Joseph Orlicky pioneered **Material Requirements Planning (MRP I)** to manage dependent demand.

The Three Foundational Inputs of an MRP System:

DegreeLive

- **1. Master Production Schedule (MPS):** Specifies exactly what end products are to be manufactured, in what quantities, and by which calendar delivery weeks.
- **2. Bill of Materials (BOM):** The hierarchical engineering blueprint or product recipe listing every sub-assembly, intermediate component, and raw material required to manufacture one unit of finished product, detailing quantities per parent.
- **3. Inventory Records File:** Real-time database containing current on-hand stock, scheduled receipts from suppliers, allocated stock for ongoing production, and purchasing lead times for every SKU.

MRP Mechanics: The MRP engine performs *BOM Explosion*, working downward through product levels to calculate Gross Requirements, subtracts on-hand stock and scheduled receipts to determine Net Requirements, and applies lead-time offsetting to establish Planned Order Release dates.

Evolution toward MRP II and Enterprise Resource Planning (ERP): In the 1980s, Oliver Wight expanded MRP into **Manufacturing Resource Planning (MRP II)** by integrating financial accounting, labour capacity planning (Rough-Cut Capacity Planning), machine loading, and purchasing cash flows into a closed-loop system. In the 1990s, MRP II evolved into **Enterprise Resource Planning (ERP)** (e.g., SAP, Oracle), synchronizing sales, human resources, supply chain, and global finance across enterprise boundaries on a unified relational database.

2.3 EOQ with All-Units Quantity Discounts

In commercial industrial purchasing, suppliers frequently offer volume discounts to encourage larger order batches. To evaluate whether taking a quantity discount is financially advantageous, the operations manager must balance the savings from lower purchase prices and fewer orders against the higher inventory carrying costs of holding larger batches. The total annual cost equation becomes:

> `Total Annual Cost (TC) = (D × P) + [(D / Q) × S] + [(Q / 2) × (I × P)]`
>
> Where: P = Unit Purchase Price, I = Annual Holding Cost Rate (% of unit price), S = Ordering Cost per order, and D = Annual Demand.

Worked Problem (Quantity Discounts): Annual demand D = 5,000 units; Ordering cost S = Rs 490 per order; Annual inventory carrying charge rate I = 20% of unit price. The supplier quotes the following price discount schedule:

- Category 1 (Order Quantity 1 to 999 units): Unit Price P1 = Rs 50.00.
- Category 2 (Order Quantity 1,000 to 1,999 units): Unit Price P2 = Rs 48.00.
- Category 3 (Order Quantity 2,000 units and above): Unit Price P3 = Rs 46.00.

Step-by-Step Resolution:

Step 1: Compute EOQ at the lowest price (P3 = Rs 46):
H3 = 20% of Rs 46 = Rs 9.20.
EOQ3 = Square Root of [(2 × 5,000 × Rs 490) / 9.20] = Square Root of [49,00,000 / 9.20] = Square Root of [5,32,608.7] = **729.8 units**.

Feasibility Check: 729.8 units is NOT eligible for the Rs 46 price (which requires Q ≥ 2,000 units). Therefore, the lowest feasible order quantity to obtain the Rs 46 price is the price break quantity: **Q3 = 2,000 units**.

Step 2: Compute EOQ at the next price (P2 = Rs 48):
H2 = 20% of Rs 48 = Rs 9.60.
EOQ2 = Square Root of [(2 × 5,000 × Rs 490) / 9.60] = Square Root of [49,00,000 / 9.60] = Square Root of [5,10,416.7] = **714.4 units**.
Feasibility Check: 714.4 units is NOT eligible for the Rs 48 price (which requires 1,000 to 1,999 units). Lowest feasible quantity to obtain Rs 48 price is **Q2 = 1,000 units**.

Step 3: Compute EOQ at standard price (P1 = Rs 50):
H1 = 20% of Rs 50 = Rs 10.00.
EOQ1 = Square Root of [(2 × 5,000 × Rs 490) / 10.00] = Square Root of [4,90,000] = **700 units**.
Feasibility Check: 700 units falls between 1 and 999 units → **Q1 = 700 units is FEASIBLE**.

Step 4: Compare Total Annual Costs at each feasible candidate quantity:

- **At Q1 = 700 units (P = Rs 50):**
  Material Cost = 5,000 × Rs 50 = Rs 2,50,000.
  Ordering Cost = (5,000 / 700) × Rs 490 = 7.143 × Rs 490 = Rs 3,500.
  Holding Cost = (700 / 2) × Rs 10 = 350 × Rs 10 = Rs 3,500.
  Total Cost TC1 = Rs 2,50,000 + Rs 3,500 + Rs 3,500 = Rs 2,57,000.
- **At Q2 = 1,000 units (P = Rs 48):**
  Material Cost = 5,000 × Rs 48 = Rs 2,40,000.
  Ordering Cost = (5,000 / 1,000) × Rs 490 = 5 × Rs 490 = Rs 2,450.
  Holding Cost = (1,000 / 2) × (0.20 × Rs 48) = 500 × Rs 9.60 = Rs 4,800.
  Total Cost TC2 = Rs 2,40,000 + Rs 2,450 + Rs 4,800 = Rs 2,47,250.
- **At Q3 = 2,000 units (P = Rs 46):**
  Material Cost = 5,000 × Rs 46 = Rs 2,30,000.
  Ordering Cost = (5,000 / 2,000) × Rs 490 = 2.5 × Rs 490 = Rs 1,225.
  Holding Cost = (2,000 / 2) × (0.20 × Rs 46) = 1,000 × Rs 9.20 = Rs 9,200.
  Total Cost TC3 = Rs 2,30,000 + Rs 1,225 + Rs 9,200 = Rs 2,40,425.

Decision: **Order Quantity Q = 2,000 units** yields the absolute minimum total annual cost of **Rs 2,40,425**, saving Rs 16,575 annually compared to ordering at the standard EOQ of 700 units. Management should take the maximum discount.

Chapter 3: Maintenance Engineering and Total Productive Maintenance (TPM)

3.1 Maintenance Strategies: Breakdown, Preventive, and Predictive

Industrial machinery represents substantial capital investment. Unplanned machine failures interrupt assembly lines, generate defective scrap, miss delivery deadlines, and jeopardize operator safety.

Operations executives coordinate three distinct maintenance strategies:

- **1. Corrective / Breakdown Maintenance (Run-to-Failure):** Operating equipment until catastrophic failure occurs, then initiating emergency repairs. Viable only for non-critical, redundant assets where replacement is cheap and failure causes zero downstream operational disruption (e.g., replacing standard light bulbs). For critical production lines, breakdown maintenance results in exorbitant overtime, lost production, and catastrophic collateral machine damage.
- **2. Preventive Maintenance (Time-Based / Usage-Based):** Executing planned inspections, lubrication, component replacements, and machine overhauls at scheduled calendar intervals or operating hour thresholds (e.g., changing automotive engine oil every 10,000 km). While dramatically slashing unexpected breakdowns, preventive maintenance can lead to unnecessary component replacements while parts still have useful operating life.
- **3. Predictive Maintenance (Condition-Based Maintenance):** Utilizing advanced non-destructive sensing technologies—including vibration analysis, oil spectrometry, acoustic ultrasonic testing, and infrared thermography—to monitor real-time mechanical health. Components are serviced only when sensor data signals imminent failure patterns, eliminating both unexpected breakdowns and premature maintenance costs.

3.2 Reliability Metrics: MTBF, MTTR, and Availability

Engineering asset management relies on definitive quantitative reliability metrics:

```
Failure Rate (λ) = Number of Failures / Total Operating Hours
Mean Time Between Failures (MTBF) = Total Operating Hours / Number of Failures
= 1 / λ
Mean Time to Repair (MTTR) = Total Repair Downtime Hours / Number of Failures
Inherent System Availability (A) = MTBF / (MTBF + MTTR)
```

Where: MTBF measures operational reliability, MTTR measures serviceability speed, and Availability measures the percentage of time the asset is fully operational.

Worked Problem (Reliability and Availability): An automated robotic welding cell operated for 5,000 hours over an annual period. During this timeframe, the cell experienced 8 unplanned mechanical breakdowns, requiring an aggregate total of 40 hours of repair downtime.

Calculation:
MTBF = 5,000 operating hours / 8 failures = **625 hours per failure**.
MTTR = 40 total downtime hours / 8 failures = **5 hours per repair**.
System Availability (A) = 625 / (625 + 5) = 625 / 630 = **0.9921 or 99.21%**.
Managerial Interpretation: The robotic cell demonstrates strong operational reliability with 99.21% machine availability.

3.3 Total Productive Maintenance (TPM) and the Eight Pillars

Pioneered by Seiichi Nakajima at the Japan Institute of Plant Maintenance (JIPM), **Total Productive Maintenance (TPM)** is an innovative holistic maintenance philosophy that seeks to achieve **Zero Breakdowns, Zero Accidents, and Zero Defects** through total employee participation.

Traditional manufacturing maintained an adversarial separation between machine operators ("I operate the machine") and maintenance technicians ("You fix the machine"). TPM dismantles this siloe through **Autonomous Maintenance (Jishu Hozen)**, training frontline operators to perform daily cleaning, routine lubrication, bolt tightening, and basic diagnostic inspections themselves.

The **Eight Pillars of TPM** encompass: (1) Autonomous Maintenance (Jishu Hozen); (2) Focused Improvement (Kobetsu Kaizen); (3) Planned Maintenance; (4) Quality Maintenance (Hinshitsu Hozen); (5) Early Equipment Management; (6) Education and Training; (7) Health, Safety, and Environment; and (8) Office TPM.

3.4 Overall Equipment Effectiveness (OEE) Metric

The core quantitative metric of TPM is **Overall Equipment Effectiveness (OEE)**, which measures how effectively an industrial manufacturing asset is utilized relative to its theoretical potential. OEE decomposes machine losses into three distinct multiplicative dimensions:

> `OEE (%) = Availability Rate × Performance Rate × Quality Rate`
>
> Availability Rate = (Actual Operating Run Time / Planned Operating Time) × 100
> Performance Rate = (Actual Total Output / Theoretical Standard Output during Run Time) × 100
> Quality Rate = (Good Conforming Units Produced / Total Units Produced) × 100

Comprehensive Worked Problem (OEE Calculation): An injection molding machine operates an 8-hour shift (480 minutes). Planned maintenance and meal breaks total 30 minutes, leaving Planned Operating Time = 450 minutes. The machine suffers unexpected downtime of 50 minutes, resulting in Actual Operating Run Time = 400 minutes. The theoretical cycle speed is 2 parts per minute (standard output = 800 parts in 400 minutes). During the shift, the machine produced 720 parts. Final inspection reveals that 36 parts were defective rejects (good parts = 684 parts).

Step-by-Step Resolution:
1. Availability Rate: 400 run minutes / 450 planned minutes = **0.8889 (88.89%)**.
2. Performance Rate: 720 actual parts / (400 minutes × 2 parts/min) = 720 / 800 = **0.9000 (90.00%)**.
3. Quality Rate: 684 good parts / 720 total parts = **0.9500 (95.00%)**.
Overall Equipment Effectiveness (OEE):
OEE = 0.8889 × 0.9000 × 0.9500 = **0.7600 or 76.00%**.
World-Class Benchmark: World-Class OEE is defined as 85.0% (Availability ≥ 90%, Performance ≥ 95%, Quality ≥ 99.9%). With an OEE of 76.0%, management should focus on eliminating the 50 minutes of unplanned machine downtime to raise availability.

2.4 Stochastic Inventory Control: Safety Stock and Service Levels

When daily consumer demand or vendor lead time is subject to random statistical variability, maintaining inventory based strictly on deterministic EOQ models results in frequent stockouts during replenishment lead times. Operations managers establish a **Buffer Stock (Safety Stock)** to protect against demand surges or delivery delays.

When daily demand is normally distributed with mean d and standard deviation σ_d, and lead time L is constant in days, the safety stock and reorder point are formulated as:

```
Safety Stock (SS) = Z × σ_d × Square Root of L
Reorder Point (ROP) = (Average Daily Demand × Lead Time) + Safety Stock
```

Where: Z is the standard normal deviate corresponding to the desired cycle service level (e.g., Z = 1.645 for 95% service level; Z = 2.33 for 99% service level).

Worked Numerical Problem (Safety Stock): Daily demand for an industrial solvent is normally distributed with an average of 50 liters per day and a standard deviation (σ_d) of 10 liters per day. Supplier replenishment lead time is fixed at 9 days. Corporate customer service policy mandates a 95% cycle service level (Z = 1.645).

Calculation:
Expected Demand during Lead Time = 50 liters/day × 9 days = 450 liters.
Standard Deviation of Lead Time Demand (σ_L) = 10 × Square Root of 9 = 10 × 3 = 30 liters.
Safety Stock (SS) = 1.645 × 30 liters = 49.35 → **50 liters**.
Reorder Point (ROP) = 450 liters + 50 liters = **500 liters**.
Managerial Rule: Whenever physical inventory declines to 500 liters, place a replenishment order. The 50 liters of safety stock provides 95% statistical assurance that stockouts will not occur before the delivery arrives.

3.6 Comprehensive Numerical Problem: Individual versus Group Replacement Policy

A manufacturing plant uses 1,000 high-intensity inspection lamps. The cost of replacing an individual lamp on failure is Rs 60. Alternatively, if all lamps are replaced simultaneously in a scheduled group replacement, the cost drops to Rs 20 per lamp. The probability of lamp failure across operating months is recorded below:

Operating Month	Failure Probability (P_i)	Lamps Failing in Month i (N_i)	Cumulative Monthly Failures
Month 1	0.10	N1 = 1,000 × 0.10 = 100	100
Month 2	0.20	N2 = (1,000 × 0.20) + (100 × 0.10) = 210	310
Month 3	0.40	N3 = (1,000 × 0.40) + (100 × 0.20) + (210 × 0.10) = 441	751

Operating Month	Failure Probability (P_i)	Lamps Failing in Month i (N_i)	Cumulative Monthly Failures
Month 4	0.30	N4 = (1,000 × 0.30) + (100 × 0.40) + (210 × 0.20) + (441 × 0.10) = 426	1,177

Evaluation of Policies:

Mean Life of a Lamp: (1 × 0.10) + (2 × 0.20) + (3 × 0.40) + (4 × 0.30) = 0.10 + 0.40 + 1.20 + 1.20 = **2.90 months**.
Average failures per month = 1,000 / 2.90 = 344.83 lamps/month.
Cost of Individual Replacement Policy: 344.83 lamps × Rs 60 = **Rs 20,689.80 per month**.

Cost of Group Replacement Policies:
Group replacement cost = 1,000 lamps × Rs 20 = Rs 20,000.

- *Replace at End of Month 1:* [Rs 20,000 + (100 failures × Rs 60)] / 1 = [Rs 20,000 + Rs 6,000] / 1 = **Rs 26,000 per month**.
- *Replace at End of Month 2:* [Rs 20,000 + (310 failures × Rs 60)] / 2 = [Rs 20,000 + Rs 18,600] / 2 = Rs 38,600 / 2 = **Rs 19,300 per month**.
- *Replace at End of Month 3:* [Rs 20,000 + (751 failures × Rs 60)] / 3 = [Rs 20,000 + Rs 45,060] / 3 = Rs 65,060 / 3 = **Rs 21,686.67 per month**.

Optimal Decision: The plant should implement a **Group Replacement Policy at the end of every 2 months**. At Rs 19,300 per month, it provides the lowest operational cost, saving Rs 1,389.80 per month compared to the individual replacement strategy.

3.5 Summary of Materials Management and Maintenance

Materials management and maintenance engineering represent the foundational guardians of industrial operating efficiency and physical asset longevity. Selective inventory control techniques ensure that working capital is concentrated where financial impact is greatest. The classical EOQ model provides mathematical balance between ordering and holding costs, while MRP systems synchronize dependent demand across complex bills of materials. Implementing predictive maintenance and Total Productive Maintenance elevates machine reliability and empowers frontline workers, maximizing Overall Equipment Effectiveness across the entire manufacturing lifecycle.

degreelive