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OPERATIONS MANAGEMENT

EXAM REVISION NOTES

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MODULE I

NATURE, SCOPE, FUNCTIONS & STRATEGIC OBJECTIVES OF OPERATIONS MANAGEMENT

Nature, Scope, Functions & Strategic Objectives of Operations Management: Operations Management (OM) is the systematic direction, coordination, and control of the processes that transform diverse inputs —including raw materials, human labor, capital equipment, energy, and information—into finished goods and services of higher economic value.

Structural Comparison: Manufacturing Goods versus Delivering Services: Operations management principles apply across both physical manufacturing and service delivery, though their operational dynamics differ significantly:

- **Tangibility & Consumption:** ; Intangible customer experience; simultaneous production and consumption (inseparability).
- **Inventory & Buffer Capacity:** ; Perishable capacity; unused service hours (empty airline seats, vacant hotel rooms) cannot be inventoried.
- **Customer Interaction Degree:** ; High direct customer involvement; customers actively participate in the service delivery environment.
- **Quality Measurement & Standards:** ; Subjective, perceptual evaluation influenced by psychological factors, employee empathy, and responsiveness.

Mathematical Formulations of Operational Productivity: Productivity is the economic measure of operational efficiency, defined as the ratio of outputs produced to inputs consumed:

- **Single-Factor (Partial) Productivity:** Formula: Labor Productivity = (Total Output (units or monetary value) / Labor Input (hours or wages)) Formula: Machine Productivity = (Total Output (units) / Machine Hours Utilized)
- **Multi-Factor Productivity (MFP):** Measures output relative to a combined bundle of key inputs: Formula: Multi-Factor Productivity = (Total Output / Labor Cost + Material Cost + Overhead Cost)
- **Formula:** Labor Productivity = (Total Output (units or monetary value) / Labor Input (hours or wages))
- **Formula:** Machine Productivity = (Total Output (units) / Machine Hours Utilized)

The Four Core Competitive Priorities: Operations managers establish strategic focus by concentrating resources on four fundamental Competitive Priorities:

- **1. Cost / Price Leadership:** ; Walmart, Southwest Airlines, Ryanair, IKEA, Costco.
- **2. Quality Excellence:** High-Performance Design Quality: Superior features and tolerances.
- **3. Time / Speed Delivery:** Rapid Delivery Speed: Minimizing customer order lead time.
- **4. Operational Flexibility:** Product/Customization Flexibility: Ability to modify designs and tailor products.

Operations Strategy Across the Product Life Cycle (PLC): As products transition through the market lifecycle, operational priorities shift dynamically:

- **Introduction:** ; Job shop / process layouts; general-purpose equipment; subcontracting or small pilot capacity.
- **Growth:** ; Batch flow or assembly lines; dedicated machinery; scaling capacity ahead of demand curve.
- **Maturity:** ; Dedicated assembly lines; high automation; economies of scale; lean inventory control.
- **Decline:** ; Pruning unprofitable product variants; depreciated equipment; minimal new capital expenditure.

Factors Influencing Industrial Location Decisions: Strategic location analysis evaluates a balanced portfolio of primary and secondary factors:

- **Proximity to Raw Materials & Suppliers:** , paper mills located near timber forests, iron ore smelting plants located near mining pits).
- **Proximity to Target Consumer Markets:** , soft drink bottling plants, commercial bakeries), as well as all service delivery facilities.
- **Labor Market Factors:** Regional availability of technical skills, local prevailing wage rates, labor union density, educational infrastructure, and workforce productivity.
- **Transportation & Infrastructure Logistics:** Direct access to multi-modal transport networks—including deep-water container ports, interstate freight rail terminals, highway corridors, and international airports—along with utility reliability (uninterrupted electrical grid power, natural gas, high-capacity water, industrial wastewater disposal).
- **Government Policies, Taxation & Special Economic Zones (SEZs):** Regional tax holidays, import duty waivers, streamlined environmental permitting, and state industrial development subsidies.

Solved Numerical Problem: Center of Gravity Calculation: Business Scenario: An e-commerce logistics conglomerate operating across Kerala must establish a centralized automated regional fulfillment center to supply four major municipal fulfillment hubs.

- **Strategic Managerial Recommendation:** 71)—situated strategically between Kochi and Thrissur—which minimizes aggregate ton-kilometer transportation expenditures across the four municipal markets.

Solved Numerical Problem: Locational Break-Even Analysis: Business Scenario: A manufacturing firm evaluates three candidate locations (Site A, Site B, Site C) for a new production facility.

- **Site A:** Fixed Cost FC_A=Rs.
- **Site B:** Fixed Cost FC_B=Rs.
- **Site C:** Fixed Cost FC_C=Rs.
- **Site A:** For production volume Q<30,000 units: is optimal (lowest total cost).
- **Site B:** For volume 30,000≤Q≤80,000 units: is optimal.

Quantitative Assembly Line Balancing: Principles & Formulas: In product layouts (assembly lines), Line Balancing is the mathematical technique of assigning tasks to sequential workstations such that the idle time across all workstations is minimized, and the desired production rate is satisfied.

- **Desired Cycle Time (C):** The maximum allowable time a product unit spends at each workstation to meet customer demand: Formula: C = (Available Operating Production Time per Period / Desired Customer Demand Output per Period) = (T / D)
- **Theoretical Minimum Number of Workstations (N_{min}):** Formula: Nmin = [(∑ i=1k ti / C) (rounded up)] Where $\sum t_i$ is the Sum of of task t × across all k elemental tasks, rounded up to the nearest integer.
- **Line Balance Efficiency (E):** Formula: E = (∑ i=1k ti / Nactual × C) × 100
- **Balance Delay / Idle Time Percentage (D_B):** Formula: DB = 100% - E = ((Nactual × C) - ∑ ti / Nactual × C) × 100

Systematic Layout Planning (SLP) & Muther's Closeness Grid: In process layouts, Richard Muther's Systematic Layout Planning (SLP) utilizes a Relationship Chart (REL Chart) with standardized closeness priority ratings:

- **A (Absolutely Necessary):** , Foundry and Pouring floor).
- **E (Especially Important):** High inter-departmental paperwork or personnel movement.

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- **I (Important):** Moderate operational coordination.
- **O (Ordinary Closeness):** Normal interaction.
- **U (Unimportant):** Negligible relationship.

MODULE II

CAPACITY PLANNING, MEASUREMENT METRICS & EXPANSION STRATEGIES

Capacity Planning, Measurement Metrics & Expansion Strategies: Capacity Planning is the strategic determination of the maximum production rate or workload that an operational facility, manufacturing line, or service delivery system can sustain over a defined planning horizon.

Core Mathematical Performance Metrics: Utilization and Efficiency: To quantify capacity performance, operations managers compute two distinct percentage ratios:

- **Capacity Utilization Rate:** Measures the proportion of theoretical design capacity actually achieved: Formula: Utilization = (Actual Output / Design Capacity) × 100
- **Operating Efficiency Rate:** Measures actual output as a percentage of effective capacity, isolating operational execution from engineering design constraints: Formula: Efficiency = (Actual Output / Effective Capacity) × 100
- **Formula:** Utilization = (Actual Output / Design Capacity) × 100
- **Formula:** Efficiency = (Actual Output / Effective Capacity) × 100

Strategic Capacity Expansion Strategies: When forecasting long-term demand growth, organizations deploy three distinct timing strategies:

- **Capacity Lead Strategy(Aggressive Expansion):** ; High capital carrying costs; severe risk of asset underutilization if market growth forecasts fail.
- **Capacity Lag Strategy(Conservative Expansion):** ; Lost sales during stockout periods; customer defection to competitors; overtime labor cost spikes.
- **Tracking / Match Strategy(Incremental Expansion):** ; Frequent construction and tooling disruptions; higher cumulative engineering setup costs.

Aggregate Production Planning (APP) Strategies & Modeling: Aggregate Production Planning (APP) is the tactical operational process of determining the overall production rates, workforce staffing levels, inventory buffer investments, and subcontracting commitments across an intermediate planning horizon (typically 3 to 18 months).

Solved Numerical Problem: Level versus Chase Cost Evaluation: Business Scenario: A manufacturing firm forecasts quarterly demand for its primary product family across a 4-quarter planning cycle: Q1: 1,000 units, Q2: 1,400 units, Q3: 1,800 units, Q4: 1,000 units (Total Annual Demand = 5,200 units).

- Hire 3 workers at start of Q1 (from 10 to 13 workers): Cost = 3×Rs.
- Q1: Produce 1,300; Demand 1,000; Ending Inventory = 300 units.
- Q2: Produce 1,300; Demand 1,400; Ending Inventory = 300+1,300−1,400=200 units.
- Q3: Produce 1,300; Demand 1,800; Ending Inventory = 200+1,300−1,800=−300 (Shortage of 300 units, backordered).
- Q4: Produce 1,300; Demand 1,000; Covers 300 backorder; Ending Inventory = 0 units.

Master Production Scheduling (MPS) & Material Requirements Planning (MRP): The transition from aggregate production plans to detailed operational shop-floor execution is achieved through Disaggregation.

Solved Numerical Problem: MRP Record Computational Grid: Business Scenario: Component Part C-101 has an initial On-Hand Inventory of 25 units, a Safety Stock requirement of 10 units, a vendor Lead Time L=2 weeks, and orders are placed using Lot-for-Lot (L4L) sizing.

- **Week 1:** Beginning inventory = 25.
- **Week 2:** Beginning inventory = 15.
- **Planned Order Release = 40 in Week 1:** Week 3: Gross demand = 40.
- **Planned Order Release = 30 in Week 2:** Week 4: Gross demand = 30.
- **Planned Order Release = 50 in Week 3:** Week 5: Gross demand = 50.

Capacity Requirements Planning (CRP) & Work Center Load Profiles: While basic MRP I calculates component part requirements assuming infinite production capacity, Capacity Requirements Planning (CRP) translates planned order releases into required machine and labor hours across individual work centers:

- **Rough-Cut Capacity Planning (RCCP):** Evaluates whether high-level Master Production Schedules violate critical bottleneck resource capacities prior to detailed BOM explosion.
- **Detailed CRP Load Profiling:** Multiplies planned order releases by routing data standards (setup time + run time per unit) to compute weekly machine hour load for every work center.
- **Managing Work Center Overload / Underload:** If Overloaded: Planners adjust capacity via overtime, temporary worker reassignments, alternative routing to secondary machines, or subcontracting.
- **If Underloaded:** Work orders scheduled for future weeks are pulled forward (infinite vs finite forward loading) to maintain steady machine utilization.

Quantitative Performance Evaluation of Dispatching Rules: To evaluate priority sequencing rules, operations managers compute three objective metrics:

- **Average Flow Time:** $F^{-}=(\sum FlowTimeofalljobs/NumberofJobs)$
- **Average Number of Jobs in the System (WIP):** WIP= $(\sum TotalFlowTime/TotalMakespan)$
- **Average Job Tardiness:** $T^{-}=(\sum Tardinessofalljobs/NumberofJobs)$ (where Tardiness = max(0,CompletionTime−DueDate)).

Two-Machine Job Sequencing: Johnson's Rule (Johnson's Algorithm): , all jobs must be turned on Machine 1, and then ground on Machine 2 in the same order), Johnson's Rule mathematically identifies the sequence that minimizes the total Makespan (total elapsed time to complete all jobs across both machines) and minimizes idle time on Machine 2.

- **Step 1:** List all jobs along with their processing t × on Machine 1 (t_{i1}) and Machine 2 (t_{i2}).
- **Step 2:** Scan all remaining processing t × across both machines and find the single smallest processing time.
- **Step 3:** If the smallest time occurs on Machine 1, schedule that job as EARLY as possible in the empty sequence (from left to right).
- **Machine 2:** If the smallest time occurs on , schedule that job as LATE as possible in the empty sequence (from right to left).
- **Step 4:** Remove the scheduled job from further consideration.

MODULE III

WORK STUDY CONCEPTS, OBJECTIVES & SYSTEMATIC PROCEDURE

Work Study Concepts, Objectives & Systematic Procedure: Work Study is the systematic examination of methods of conducting operational activities so as to optimize the effective utilization of enterprise resources—including human labor, machine capital, physical materials, and floor space—and to establish verifiable standards of operational performance.

Core Objectives and Economic Benefits of Work Study: Enterprises deploy work study across shop-floor and service operations to achieve multiple operational objectives:

- **Standardization of Best Practices:** Eliminating arbitrary, individualized operator techniques in favor of scientifically validated, standardized standard operating procedures (SOPs).
- **Productivity Enhancement & Cost Compression:** Increasing unit output per labor hour without requiring substantial capital expenditure on expensive automated machinery.
- **Accurate Production Scheduling & Capacity Planning:** Providing realistic time standards that enable master schedulers to balance assembly lines, schedule machines, and estimate delivery lead t × accurately.
- **Equitable Wage Incentive Systems:** Establishing transparent, objective piece-rate or bonus incentive structures tied to verified standard performance.
- **Improving Worker Safety and Ergonomics:** Reducing physical fatigue, repetitive stress injuries, and awkward postures, thereby decreasing absenteeism and accident liabilities.

Human Factors, Hawthorne Studies & Labor Union Dynamics in Work Study: Work study is never a purely mechanical engineering exercise; it directly affects human employees' daily livelihoods, physical pacing, and psychological dignity:

- **Worker Anxieties and Rate-Cutting Fears:** Historically, unscrupulous managers used time study to increase production quotas and subsequently cut piece-rate wages (the "speed-up").
- **Consultative Union Engagement:** Best practices require joint union-management work study committees where shop stewards are trained in time study techniques, ensuring transparency and mutual trust in setting performance standards.

Standardized Recording Techniques: Process Charting: Industrial engineers record work processes using standardized American Society of Mechanical Engineers (ASME) process chart symbols:

- **Circle (○):** ; Turning a shaft on a lathe; drilling a hole; soldering a circuit; typing a customer invoice.
- **Square (□):** ; Checking component diameter with a micrometer; proofreading a financial contract; count auditing.
- **Arrow (→):** ; Forklift moving a pallet of parts; conveyor belt transport; operator walking to a tool crib.
- **D-Shape (D):** ; WIP batch waiting for an available machine; operator waiting for elevator; cooling after heat treatment.

Frank and Lillian Gilbreth's 18 Therbligs: The Gilbreths identified 18 fundamental elemental micro-motions (anagram of Gilbreth spelled backward, with 'th' transposed) that constitute all physical manual work:

- **Grasp (G):** ; Design objects and bins to allow immediate, effortless grasping.
- **Move (M):** ; Minimize transport distances; use gravity conveyors.
- **Position (P):** ; Use guide funnels, chamfered edges, and fixture stops.
- **Assemble (A):** ; Standardize fastenings; design modular snap-fits.

Work Measurement / Time Study, Performance Rating & Standard Time: Work Measurement is the application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance.

Performance Rating (Levelling) and The Qualified Worker: Because observed operators rarely work at exactly standard pace (some work faster, others slower), the analyst must assess the operator's speed and rhythm relative to the concept of a Standard Qualified Worker:

- **The Qualified Worker:** Defined by the ILO as one who is accepted as having the necessary physical attributes, intelligence, skill, and knowledge to carry out the work in hand to satisfactory standards of safety, quality, and quantity.
- **Standard Rating Scales:** The 100-Point British Standard Scale (BS 3138): 100 represents standard performance (defined as the walking speed of a brisk person unburdened at 4 miles per hour on level ground).
- **The 60-70-80 Bedaux Scale:** 60 represents normal base pace; 80 represents standard incentive pace.
- **Normal Time (Basic Time) Calculation:** Formula: Normal Time (NT) = Observed Time (OT) × (Performance Rating / 100)

Predetermined Motion Time Systems (PMTS) & Methods-Time Measurement (MTM): , during the design phase of a new factory before lines exist), engineers use Predetermined Motion Time Systems (PMTS):

- **The Core Premise:** All human work consists of combinations of basic physical motions (reaches, moves, turns, grasps, releases).
- **Methods-Time Measurement (MTM):** The global benchmark PMTS system.
- **Key Benefits of PMTS:** Establishes accurate labor standards and line balancing configurations before equipment is purchased; eliminates subjective performance rating disputes on the shop floor; and provides an objective benchmark for ergonomic tool comparison.

Work Sampling: Statistical Ratio-Delay Methodology: C. Tippett in 1934 in the British textile industry, Work Sampling is a statistical technique of taking a large number of instantaneous, random observations of workers or machines over an extended period.

- **Mathematical Determination of Sample Size (N):** Based on the normal approximation of the binomial distribution: Formula: N = (Z2 · p (1 - p) / s2) Where: N = Total number of random observations required.
- 0 for practical industrial studies).
- p = Estimated proportion of time spent in the state under study (expressed as a decimal fraction).
- 03 for ±3% absolute accuracy).

Ergonomics & Anthropometric Principles in Workstation Design: Ergonomics (derived from the Greek ergon meaning work and nomos meaning natural laws) is the scientific discipline concerned with the understanding of interactions among humans and other elements of an operational system, applying theoretical principles, data, and design methods to optimize human well-being and overall system performance.

- **Anthropometric Design(Physical Dimensions):** ; Design for Extreme (95th percentile): Clearances, door heights, legroom.
- **Biomechanics & Posture:** ; Eliminate prolonged static standing with anti-fatigue mats; provide armrests; position working plane at elbow height (5–10 cm below elbow for precision work).
- **Environmental Ergonomics:** ; Provide 500–1000 lux for precision visual tasks; maintain temperature at 20°C–24°C; dampen pneumatic tools to prevent Hand-Arm Vibration Syndrome (HAVS).

MODULE IV

INVENTORY MANAGEMENT CONCEPTS & SELECTIVE CONTROL TECHNIQUES

Inventory Management Concepts & Selective Control Techniques: Inventory Management is the operational discipline of planning, organizing, and controlling the stock of materials, assemblies, and finished products held within an enterprise.

Economic Structure of Inventory Costs: Optimal inventory policies minimize total cost across four fundamental economic cost components:

- **1. Purchase / Acquisition Cost (C):** The direct unit purchase price paid to the supplier, or direct variable manufacturing cost per unit.
- **2. Ordering / Setup Cost (S):** , purchase order administration, vendor communication, invoice processing, physical die changeovers, and trial run calibration).
- **3. Holding / Carrying Cost (H):** The expense of maintaining one unit of inventory in storage for one year.
- **Storage Space Costs:** Warehouse building depreciation, lease rents, lighting, heating, and cooling.
- **Inventory Service Costs:** Physical insurance premiums, property taxes, and inventory tracking software.

The ABC-VED 9-Box Matrix for Spare Parts Control: In manufacturing maintenance, combining monetary usage (ABC) with operational criticality (VED) yields a powerful 9-box decision matrix:

- **Category I (Critical Executive Oversight - AV, BV, CV, AE, AD):** Includes all Vital items regardless of cost, plus high-value Essential and Desirable items.
- **Category II (Moderate Tactical Control - BE, CE, BD):** Moderate value and criticality.
- **Category III (Routine Operational Control - CD):** Low value, low criticality parts (standard hardware, nuts, washers).

Mathematical Derivation of the EOQ Formula: Total Annual Inventory Cost TC(Q) is the Sum of of Annual Ordering Cost and Annual Holding Cost:

- **Annual Ordering Cost:** NumberofOrdersperYear×CostperOrder= (D/Q)S
- **Annual Holding Cost:** AverageInventoryLevel×AnnualHoldingCostperUnit=(Q/2)H
- **Formula:** Total Cost TC(Q) = (D / Q) S + (Q / 2) H
- **Formula:** (dTC / dQ) = -(DS / Q2) + (H / 2) = 0 ⇒ (H / 2) = (DS / Q2) ⇒ Q2 = (2DS / H)

Reorder Point (ROP) & Safety Stock under Uncertainty: The Reorder Point (ROP) determines the inventory level at which a new replenishment order must be placed:

- **Deterministic Case (Constant Demand & Lead Time):** Formula: ROP = d × L Where d is daily demand rate (d=D/Workdays), and L is lead time in days.
- **Formula:** ROP = (bard × L) + Safety Stock
- **Formula:** Safety Stock (SS) = Z × σ L = Z × σ d √(L)

Lean Manufacturing Systems, Just-In-Time (JIT) & Kanban Operations: Lean Manufacturing is an integrated socio-technical operational philosophy focused on the systematic identification and relentless elimination of non-value-adding operational waste (Muda) to deliver maximum customer value with minimum resources.

The Just-In-Time (JIT) Pull Philosophy & SMED: Unlike traditional MRP systems that "push" work through factories based on centralized schedules, Just-In-Time (JIT) operates on a Pull System: nothing is manufactured upstream until an explicit customer order "pulls" it from downstream.

- **Single-Minute Exchange of Die (SMED):** , bolting the new die onto the press).
- **External Setups:** , pre-heating dies, gathering tooling, staging raw material).
- **Conversion Process:** By systematically converting internal setups into external ones and standardizing fasteners, setup t × drop by 90%, enabling micro-batch production without cost penalties.

Solved Numerical Problem: Kanban Container Sizing: Business Scenario: A motorcycle assembly line consumes specialized clutch cables at a steady rate of 200 cables per hour.

- **6 Kanban containers:** Rounding up to the nearest integer, management must authorize exactly circulating between the workstations.

The Evolution of Industrial Maintenance Philosophies: Maintenance strategies evolved across four historical generations:

- **Breakdown / Corrective Maintenance (Run-to-Failure):** Repairing machinery only after catastrophic failure occurs.
- **Preventive Maintenance (Time-Based PM):** Servicing machinery, lubricating bearings, and replacing components at fixed calendar intervals or operating hours regardless of condition.
- **Predictive Maintenance (Condition-Based PdM):** Monitoring physical equipment telemetry (vibration analysis, thermography, acoustic ultrasound, lubricant wear particles) to service equipment immediately prior to functional failure.
- **Total Productive Maintenance (TPM):** A holistic human-centered paradigm that engages frontline machine operators directly in routine autonomous maintenance, transforming operators from passive machine users into active equipment caretakers.

Mathematical Formulation of Overall Equipment Effectiveness: Overall Equipment Effectiveness is computed as the composite product of Availability, Performance, and Quality:

- **Global World-Class OEE Benchmark:** 0%
- **Performance:** 0%
- **Quality Rate:** 9%
- **World-Class Composite OEE:** 0%

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