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MGMT717

Advanced Production Planning and Inventory
Control

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VIRTUAL UNIVERSITY OF PAKISTAN

MGMT717

Advanced Production Planning and Inventory Control

STUDY HANDOUT

Production Planning and Control turns demand forecasts into efficient factory operations. This handout covers forecasting, aggregate planning, master scheduling, MRP, capacity planning, EOQ and advanced inventory models, JIT/lean, and shop-floor scheduling - with formulas, key terms, examples and exam pointers. 

Compiled as a structured study resource for VU students.

Covers the key topics, definitions, concepts and exam pointers of the course.

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Unit 1: Production Planning and Control: Overview

Learning Objectives

- Define production planning and control (PPC) and its objectives
- Describe the hierarchy: strategic, tactical, operational planning
- Distinguish continuous, intermittent and project production systems
- Explain the PPC functions: routing, scheduling, dispatching, follow-up

Production Planning and Control (PPC) is the managerial function that plans what to produce, when, where and how - then controls execution so it happens efficiently. Its objectives: meet customer demand on time, minimize cost, utilize capacity fully, and maintain quality.

Planning works at three horizons: strategic (years - capacity expansion, new plants, technology); tactical (months - aggregate planning, workforce levels, inventory policy); operational (days/weeks - master scheduling, MRP, shop-floor sequencing). Each level constrains the one below.

Types of production systems: continuous/flow (standardized products, high volume - refineries, bottling; line layout); intermittent/job (customized, low volume - machine shops, hospitals; process layout); batch (moderate variety and volume - bakeries, pharmaceuticals); project (one-off - construction, shipbuilding; fixed-position layout). Planning techniques differ sharply across them.

The classic PPC functions: routing (the path each job follows through machines), scheduling (timing of operations), dispatching (releasing orders to the floor), follow-up/expediting (tracking progress, fixing deviations), plus loading (assigning work to machines) and inspection.

Modern PPC is inseparable from information systems: ERP integrates planning with finance, purchasing and sales; advanced planning systems add optimization. But the logic - forecast, plan capacity, schedule, control inventory - is timeless.

Key Terms

PPC	Planning what/when/where/how to produce, then controlling execution.
Routing	The sequence of machines/operations each job follows.
Scheduling	Timing each operation; dispatching releases it; follow-up tracks it.
Continuous production	High-volume standardized flow (line layout).
Intermittent production	Low-volume customized jobs (process layout).

ERP

Enterprise system integrating planning, inventory, finance, sales.

Example - horizons: A car plant: strategic - build a new assembly line (2 years); tactical - quarterly production plan of 50,000 cars with overtime policy; operational - this week's schedule: 2,000 sedans Monday-Wednesday.

Example - routing: A metal bracket: cutting -> drilling -> bending -> painting -> assembly. Routing fixes this sequence before any scheduling.

Summary

- ✓ PPC plans and controls production to meet demand efficiently.
- ✓ Three horizons: strategic (years), tactical (months), operational (weeks/days).
- ✓ Production types: continuous, batch, intermittent/job, project - each needs different planning.
- ✓ Functions: routing, loading, scheduling, dispatching, follow-up.

Exam Pointers

- ★ Define PPC and list its objectives.
- ★ Distinguish the three planning horizons with examples.
- ★ Compare continuous and intermittent production systems.
- ★ Name and explain the four classic PPC functions.

Unit 2: Forecasting for Production

Learning Objectives

- Explain why forecasting drives all production planning
- Distinguish qualitative from quantitative forecasting methods
- Apply moving average, exponential smoothing and trend projection
- Measure forecast accuracy with MAD, MSE and MAPE

Every production plan starts from a demand forecast: aggregate plans, MPS and MRP all explode from it. Forecasting errors propagate - a 10% demand error can mean stockouts or warehouses of dead stock. Planners therefore forecast carefully and plan for error (safety stock).

Qualitative methods (expert judgment): Delphi (structured expert panels), sales force composite, market surveys, jury of executive opinion - used for new products or long horizons where no history exists. Quantitative methods use history: time-series models (moving average, exponential smoothing, trend, seasonal) assume the past pattern continues; causal models (regression) link demand to drivers like price or income.

Time-series techniques: simple moving average smooths noise; exponential smoothing ($F_{t+1} = \alpha \cdot D_t + (1-\alpha) \cdot F_t$) weights recent data more; Holt's method adds trend;

Holt-Winters adds seasonality. Choose by data pattern: no trend/seasonality -> simple smoothing; trend -> Holt's; both -> Holt-Winters.

Forecast accuracy: MAD = mean |actual - forecast|; MSE = mean of squared errors (penalizes big misses); MAPE = mean of |error/actual| x 100%. Track errors with a tracking signal = cumulative error / MAD; |signal| > 4 suggests systematic bias - the model needs revision.

Key Terms

Delphi method	Iterative structured expert consensus forecasting.
Exponential smoothing	$F_{t+1} = \alpha \cdot D_t + (1-\alpha) \cdot F_t$; adaptive forecast.
MAD / MSE / MAPE	Mean absolute deviation, mean squared error, mean absolute % error.
Tracking signal	Cumulative error / MAD; detects forecast bias ($. > 4$ = biased).
Holt-Winters	Exponential smoothing with trend and seasonal components.

Example - smoothing: Demand: 100, 110, 105. $\alpha=0.3$, $F_1=100$. $F_2 = 0.3 \cdot 100 + 0.7 \cdot 100 = 100$; $F_3 = 0.3 \cdot 110 + 0.7 \cdot 100 = 103$; $F_4 = 0.3 \cdot 105 + 0.7 \cdot 103 = 103.6$.

Example - MAPE: Actual 200, forecast 180: $|20/200| = 10\%$. Average over periods gives MAPE.

Summary

- ✓ Forecasts drive aggregate planning, MPS and MRP; errors are costly.
- ✓ Qualitative (Delphi, surveys) for new/long-horizon; quantitative (time-series, causal) from history.
- ✓ Match the smoothing method to the data pattern.
- ✓ Monitor MAD/MSE/MAPE and the tracking signal for bias.

Exam Pointers

- ★ Why is forecasting called the foundation of production planning?
- ★ Compare qualitative and quantitative forecasting methods.
- ★ Compute exponential-smoothing forecasts and MAD for given data.
- ★ What is a tracking signal and how is it interpreted?

Unit 3: Aggregate Planning

Learning Objectives

- Define aggregate planning and its inputs/outputs
- Compare chase, level and mixed strategies

- Explain the costs traded off in aggregate planning
- Solve a small aggregate plan by the transportation method logic

Aggregate planning sets production rates, workforce levels and inventory for product families over 3-18 months - 'aggregate' because individual products are grouped. Inputs: demand forecast, capacity, costs, policies. Outputs: monthly/quarterly production quantities, hiring/firing, overtime, subcontracting, inventory/backorder levels.

Three pure strategies: chase demand - vary workforce/production to match demand exactly (low inventory, high hiring/firing costs; hard on workers); level production - constant output, absorb fluctuations with inventory/backorders (stable workforce, high inventory cost); mixed strategy - combine (e.g. stable core workforce + overtime + subcontracting in peaks) - usually cheapest in practice.

Relevant costs: hiring/firing, overtime premium, idle time, inventory holding, stockout/backorder, subcontracting premium. The planner minimizes total cost subject to meeting demand (possibly with backorders allowed).

Solution methods: trial-and-error / graphical (evaluate a few strategies - most common in practice), transportation linear programming (optimal for the linear-cost case), and heuristics. In exams, the typical task is to cost out chase vs level vs mixed plans and pick the cheapest.

Key Terms

Aggregate planning	Medium-term plan of production rates, workforce, inventory by product family.
Chase strategy	Match production to demand; hire/fire as needed.
Level strategy	Constant production; use inventory/backorders as buffer.
Mixed strategy	Blend of workforce changes, overtime, subcontracting, inventory.
Backorder	Unfilled demand carried forward; a planned shortage with penalty cost.

Example - chase vs level: Demand swings 800-1400 units/month. Chase: hire/fire monthly (costly, disruptive). Level: produce 1100 always; build 300/month inventory in slow months, draw it down in peaks (needs warehouse space and capital).

Example - mixed: Keep 1000 units base production with a stable crew; cover peaks with overtime (up to 1200) and subcontracting above that - often the cost minimum.

Summary

- ✓ Aggregate planning: medium-term production/workforce/inventory by family.
- ✓ Chase = flexible workforce, no inventory; level = stable workforce, inventory buffer; mixed = blend.
- ✓ Minimize total cost: hiring, overtime, holding, stockout, subcontracting.

Exam Pointers

- ★ Define aggregate planning; list its inputs and outputs.
- ★ Compare chase, level and mixed strategies with their cost implications.
- ★ Given cost data, evaluate two aggregate plans and recommend one.

Unit 4: Master Production Scheduling (MPS)

Learning Objectives

- Define the MPS and its role between aggregate planning and MRP
- Explain available-to-promise (ATP) logic
- Describe time fences: frozen, slushy, liquid
- Roll an MPS forward and handle MPS record mechanics

The Master Production Schedule (MPS) disaggregates the aggregate plan into specific end items by week: which finished products, in what quantities, when. It is the input that drives MRP, and the basis for promising delivery dates to customers.

The MPS record tracks, per week: forecast, customer orders, projected on-hand inventory, and the MPS quantity (planned production lots). Rule: schedule an MPS lot when projected inventory would go negative; lot sizing (e.g. fixed lot-for-lot or EOQ-based) determines the quantity.

Available-to-promise (ATP) tells sales what can still be promised: $ATP = MPS \text{ quantity} - \text{committed customer orders}$, computed for each MPS lot (discrete ATP) or cumulatively. ATP prevents over-promising - a classic operations/marketing interface.

Time fences manage stability: the frozen zone (near term, e.g. 4 weeks) - no changes without top approval; slushy zone - changes allowed within limits; liquid zone (far out) - freely changeable. Freezing protects the factory from chaos; the liquid zone keeps flexibility for the future.

Key Terms

MPS	Week-by-week schedule of end items: what, how many, when.
ATP	Available-to-promise: uncommitted MPS quantity sales can promise.
Projected on-hand	Inventory expected at each week after demand and MPS lots.
Frozen / slushy / liquid	Time fences limiting how freely the near/far schedule can change.

Example - MPS record: On-hand 50, weekly demand 40, lot size 100. Week 1: $50 - 40 = 10$; week 2: $10 - 40 = -30$ -> schedule MPS 100 in week 2 -> projected 70. Continue rolling forward.

Example - ATP: MPS lot of 100 in week 3, customer orders of 30 committed against it
-> ATP = 70 available to promise to the next customer.

Summary

- ✓ MPS: disaggregated weekly end-item schedule; drives MRP and delivery promises.
- ✓ Schedule lots when projected inventory goes negative.
- ✓ ATP = MPS - committed orders; the sales/operations contract.
- ✓ Time fences (frozen/slushy/liquid) balance stability and flexibility.

Exam Pointers

- ★ Explain the MPS record mechanics with a numerical example.
- ★ Compute ATP for given MPS lots and customer orders.
- ★ What are time fences and why do they exist?

Unit 5: Material Requirements Planning (MRP)

Learning Objectives

- Explain the logic and inputs of MRP: MPS, BOM, inventory records
- Perform MRP explosion: gross to net requirements, planned order releases
- Describe lot-sizing rules: LFL, EOQ, POQ, PPB
- List MRP assumptions and the move to MRP II / ERP

MRP answers three questions for every component: what is needed, how much, and when. It explodes the MPS through the bill of materials (BOM), netting against inventory, to generate planned order releases timed by lead times. It suits dependent demand (components whose demand derives from parents) - the great insight of MRP.

Inputs: (1) MPS (what end items, when); (2) BOM (product structure: parents, components, quantities-per); (3) inventory records (on-hand, scheduled receipts, lead times, lot sizes, safety stock). The BOM is read top-down by low-level code so each item is planned once.

MRP record per item per week: gross requirements (from parents' planned releases x quantity-per), scheduled receipts, projected on-hand, net requirements = $\max(0, \text{gross} - \text{on-hand} - \text{scheduled})$, planned order receipts (net, adjusted to lot size), planned order releases (receipts offset backward by lead time).

Lot sizing: Lot-for-lot (LFL) - order exactly net requirements (minimal inventory, many setups); EOQ; Periodic order quantity (POQ) - cover P weeks; Part-period balancing (PPB)
- balance holding vs setup. LFL is the default for dependent demand.

Assumptions/limits: fixed lead times, infinite capacity (fixed by CRP), accurate BOM and inventory data ('garbage in, garbage out'). MRP II added capacity planning and finance; ERP integrated the whole enterprise.

Key Terms

BOM	Bill of materials: product structure of parents/components/quantities.
Dependent demand	Component demand derived from parent demand (vs independent finished-good demand).
Net requirements	Gross - on-hand - scheduled receipts (floored at zero).
Planned order release	Order to launch now (= receipt offset back by lead time).
LFL	Lot-for-lot: order exactly the net requirement each time.

Example - explosion: MPS: 100 chairs week 5. BOM: 1 chair = 4 legs. Gross legs week 5 = 400. On-hand 150, lead time 2 weeks, LFL: net = 250, planned receipt week 5, release week 3.

Example - netting: Gross 400, on-hand 500 -> net 0, no order. The system correctly orders nothing.

Summary

- ✓ MRP explodes MPS via BOM, nets against inventory, offsets by lead time -> planned releases.
- ✓ Record: gross, scheduled receipts, projected on-hand, net, planned receipts, planned releases.
- ✓ LFL default lot size; fixed lead times and infinite capacity are the key assumptions.
- ✓ MRP II added capacity; ERP integrated the enterprise.

Exam Pointers

- ★ List the three MRP inputs and explain each.
- ★ Perform a single-item MRP explosion with lead-time offsetting.
- ★ Compare LFL, EOQ and POQ lot-sizing rules.
- ★ What are MRP's key assumptions and limitations?

Unit 6: Capacity Planning and Constraints

Learning Objectives

- Define capacity and measures: design, effective, utilization, efficiency
- Explain CRP and rough-cut capacity planning
- Describe the Theory of Constraints (TOC) and bottleneck management
- Apply the five focusing steps of TOC

Capacity is the maximum output rate. Design capacity (theoretical max) vs effective capacity (realistic max given breaks, maintenance). Utilization = actual output / design capacity; efficiency = actual output / effective capacity. Planners track both - high

utilization with low efficiency signals problems.

Capacity Requirements Planning (CRP) checks MRP's planned releases against work-center capacity: convert orders to load (setup + run time per unit), compare with available hours per week, and identify overloads. Rough-cut capacity planning (RCCP) does a quicker check at the MPS level using bills of resources.

The Theory of Constraints (TOC) (Goldratt): every system has a bottleneck (constraint) governing throughput. The five focusing steps: (1) identify the constraint; (2) exploit it (maximize its useful output - no idle time, no defects); (3) subordinate everything else to it; (4) elevate it (add capacity); (5) repeat - don't let inertia become the constraint.

Bottleneck lessons: an hour lost at the bottleneck is an hour lost for the whole system; an hour saved at a non-bottleneck is a mirage. Drum-buffer-rope schedules the factory to the bottleneck's beat (drum), protects it with a time buffer, and releases material accordingly (rope).

Key Terms

Utilization / efficiency	Actual/design capacity; actual/effective capacity.
CRP	Checks MRP plans against work-center capacity, period by period.
Bottleneck	The resource limiting total system throughput.
TOC five steps	Identify, exploit, subordinate, elevate, repeat.
Drum-buffer-rope	Schedule to the bottleneck's pace; buffer it; release material to it.

Example: Design capacity 1000 units/day, effective 800, actual 700: utilization 70%, efficiency 87.5%.

Example - exploit: The bottleneck paint shop idles during lunch; staggering breaks keeps it running - pure throughput gain with zero investment.

Summary

- ✓ Utilization vs design, efficiency vs effective capacity.
- ✓ CRP validates MRP against capacity; RCCP does it roughly at MPS level.
- ✓ TOC: find the bottleneck, exploit it, subordinate everything, elevate, repeat.

Exam Pointers

- ★ Compute utilization and efficiency from given data; interpret.
- ★ Explain CRP and how it differs from RCCP.
- ★ State TOC's five focusing steps and apply them to a factory example.

Unit 7: Inventory Fundamentals and EOQ

Learning Objectives

- Explain why firms hold inventory: types and motives
- List inventory costs: holding, ordering/setup, shortage
- Derive and apply the EOQ formula
- Explain reorder point (ROP) with constant and variable demand

Firms hold inventory to decouple operations: cycle stock (from ordering in lots), safety stock (buffer against variability), anticipation stock (built ahead of peaks/seasons), pipeline/transit stock (in motion between points), and speculative stock (bought ahead of expected price rises).

Three cost families: holding (carrying) cost H - capital tied up, warehousing, insurance, obsolescence (often 20-30% of unit value per year); ordering/setup cost S - per order placed or per production setup; shortage/stockout cost - lost sales, backorder penalties, lost goodwill. Inventory management is the tradeoff between ordering/setup and holding.

The Economic Order Quantity (EOQ) minimizes total cost for constant demand D : total cost $TC = (D/Q)S + (Q/2)H$. Differentiating gives $Q^* = \sqrt{2DS/H}$. At EOQ, ordering cost equals holding cost. Assumptions: constant known demand, constant lead time, no stockouts, instantaneous replenishment, constant costs.

Reorder point (ROP): order when inventory falls to demand during lead time: $ROP = d \times L$ (daily demand $\times$ lead time in days). With variable demand/lead time, add safety stock: $ROP = d \times L + SS$, where $SS = z \times \sigma_d L$ (z for the desired service level, σ_d of demand during lead time). Higher service level $\rightarrow$ more safety stock $\rightarrow$ more holding cost.

Key Terms

Cycle / safety / anticipation / pipeline stock	Lot-size stock; variability buffer; pre-built seasonal; in-transit.
Holding cost H	Per-unit per-year cost of carrying inventory.
Ordering cost S	Fixed cost per order/setup.
EOQ	$Q^* = \sqrt{2DS/H}$; balances ordering vs holding cost.
ROP	Reorder point = demand during lead time (+ safety stock).

Example - EOQ: $D = 12,000/\text{yr}$, $S = \text{Rs } 500/\text{order}$, $H = \text{Rs } 20/\text{unit}/\text{yr}$. $Q^* = \sqrt{2 \times 12000 \times 500 / 20} = \sqrt{600,000} = 775$ units. Orders per year $= 12000 / 775 = 15.5$.

Example - ROP: $d = 50/\text{day}$, $L = 6$ days $\rightarrow ROP = 300$ units. With $SS = 80 \rightarrow ROP = 380$.

Summary

- ✓ Inventory decouples stages: cycle, safety, anticipation, pipeline stocks.
- ✓ EOQ $Q^* = \sqrt{2DS/H}$; ordering cost = holding cost at optimum.
- ✓ ROP = demand during lead time + safety stock for variability.

Exam Pointers

- ★ Derive the EOQ formula and state its assumptions.
- ★ Compute EOQ, orders per year and total cost from given data.
- ★ Explain safety stock and how the service level affects it.

Unit 8: Advanced Inventory Models

Learning Objectives

- Apply the EPQ (production order quantity) model
- Evaluate quantity discount decisions
- Design ABC classification and cycle counting
- Compare periodic vs perpetual review systems

The EPQ / production order quantity model relaxes EOQ's instant-replenishment assumption: the firm produces at rate p while consuming at rate d ($p > d$). Inventory builds at $(p-d)$ during the production run. Optimal lot: $Q^* = \sqrt{2DS / (H(1 - d/p))}$ - larger than EOQ because stock accumulates gradually. Maximum inventory = $Q(1 - d/p)$.

Quantity discounts: suppliers offer lower unit prices for larger orders. Procedure: compute EOQ at each price break; adjust infeasible EOQs up to the break minimum; compute total cost (purchase + ordering + holding, with H often a % of unit price) at each candidate; pick the minimum. A discount is worthwhile only if purchase savings exceed extra holding cost.

ABC classification applies Pareto logic: A items (~20% of items, ~80% of value) - tight control, frequent review; B items - moderate control; C items (~50% of items, ~5% of value) - simple rules, larger safety stocks. Cycle counting audits A items frequently (e.g. monthly), B quarterly, C yearly - replacing the disruptive annual wall-to-wall count.

Review systems: perpetual (Q-system) - monitor continuously, order fixed Q when hitting ROP (needs transaction tracking); periodic (P-system) - review every P periods, order up to a target level (simpler, but needs more safety stock to cover $P + L$). Choose by item value and tracking cost.

Key Terms

EPQ	$Q^* = \sqrt{2DS/(H(1-d/p))}$; for finite production rate p .
Quantity discount	Lower unit price at volume breaks; compare total costs at candidates.

ABC analysis	A = high value tight control; B = moderate; C = simple rules.
Cycle counting	Ongoing selective audits by ABC class instead of annual counts.
Q-system / P-system	Continuous-review fixed-quantity vs periodic-review order-up-to.

Example - EPQ: $D=12000$, $S=500$, $H=20$, $p=100/\text{day}$, $d=50/\text{day}$: $Q^* = \sqrt{2 \cdot 12000 \cdot 500 / (20 \cdot 0.5)} = \sqrt{1,200,000} = 1095$ units ($> \text{EOQ } 775$).

Example - discount: Price Rs 10 (<1000 units), Rs 9.5 (≥ 1000). EOQ at 9.5 is 800 (infeasible) $\rightarrow$ candidate 1000. Compare TC at EOQ(10-price) vs 1000 units at 9.5 including purchase cost.

Summary

- ✓ EPQ adjusts EOQ for finite production rate; quantity discounts need total-cost comparison.
- ✓ ABC focuses control effort where the money is; cycle counting audits continuously.
- ✓ Q-system: fixed quantity at ROP; P-system: order up to target every P periods.

Exam Pointers

- ★ Derive/apply the EPQ formula and explain why it exceeds EOQ.
- ★ Outline the quantity-discount evaluation procedure.
- ★ Explain ABC classification and how it guides cycle counting.

Unit 9: Just-in-Time and Lean Production

Learning Objectives

- Define JIT and its goals: zero waste, pull, continuous flow
- Explain kanban mechanics and the number-of-kanbans formula
- List the seven/eight wastes (muda) in lean thinking
- Compare JIT with traditional MRP-based planning

Just-in-Time (JIT) produces only what is needed, when needed, in the amount needed - the pull system: downstream demand pulls work through the factory, opposite of MRP's push. Goals: zero inventory (inventory hides problems - the 'rocks in the river' analogy), zero defects (jidoka - stop the line), lot size one, and continuous improvement (kaizen).

Kanban (card/signal) operationalizes pull: a workstation produces only when it receives a kanban from downstream. Number of kanbans = (demand during lead time + safety stock) / container size. Fewer kanbans = tighter system = problems surface faster - deliberately reducing kanbans is a classic improvement tactic.

Lean generalizes JIT: maximize customer value, eliminate waste (muda). The seven wastes: overproduction, waiting, transport, over-processing, inventory, motion, defects (+ unused talent as the 8th). Tools: 5S (sort, set in order, shine, standardize, sustain),

SMED (single-minute die exchange - slash setup times to enable small lots), poka-yoke (mistake-proofing), value-stream mapping.

JIT vs MRP: MRP plans pushes from forecasts (good for complex BOMs, variable demand); JIT pulls from actual demand (good for repetitive, stable environments). Most real factories are hybrids: MRP for planning, kanban/JIT for shop-floor execution. Requirements for JIT: reliable suppliers, quality at source, small setups, stable schedules, multifunctional workers.

Key Terms

JIT / pull system	Produce only what downstream needs, when needed; demand pulls.
Kanban	Signal card authorizing production/movement; $N = (dL + SS)/\text{container}$.
Muda	Waste: overproduction, waiting, transport, over-processing, inventory, motion, defects.
Kaizen	Continuous incremental improvement.
SMED	Slash setup times to enable economical small lots.

Example - kanbans: Demand 200/day, lead time 0.5 day, safety stock 50, container 25: $\text{kanbans} = (100 + 50)/25 = 6$ cards circulating.

Example - rocks: Cutting inventory from 10 days to 2 exposes late suppliers and long setups - the team then fixes suppliers and applies SMED instead of re-inflating stock.

Summary

- ✓ JIT = pull, zero waste, zero defects; kanban signals production.
- ✓ Seven wastes (muda); tools: 5S, SMED, poka-yoke, kaizen.
- ✓ Hybrids are normal: MRP plans, JIT executes; needs quality suppliers and small setups.

Exam Pointers

- ★ Define JIT and contrast pull with push production.
- ★ Compute the number of kanbans from given data.
- ★ List the seven wastes with one factory example each.
- ★ What conditions must hold for JIT to work?

Unit 10: Shop-Floor Scheduling and Sequencing

Learning Objectives

- Define sequencing and state common performance measures
- Apply Johnson's rule for two-machine flow shops

- Compare dispatching rules: SPT, EDD, FCFS, CR
- Explain input-output control and Gantt charts

Scheduling assigns jobs to machines over time; sequencing decides the order of jobs on each machine. Performance measures: makespan (total completion time), flow time (time in system), lateness (completion - due date), tardiness ($\max(0, \text{lateness})$), number of tardy jobs. Different rules optimize different measures - no single rule is best at everything.

Johnson's rule optimally sequences n jobs through 2 machines in the same order (flow shop) to minimize makespan: (1) list all operation times; (2) pick the smallest; (3) if it's on machine 1, schedule the job earliest; if on machine 2, schedule it latest; (4) remove it and repeat. Elegant and exam-favorite. 

Dispatching (priority) rules for dynamic shops: SPT (shortest processing time) - minimizes mean flow time and WIP, but long jobs starve; EDD (earliest due date) - minimizes maximum tardiness; FCFS - fair, simple; CR (critical ratio = time remaining / work remaining) - dynamic urgency. SPT is the best-known for flow-time performance.

Gantt charts visualize schedules (jobs vs time per machine); input-output control monitors planned vs actual input/output at work centers to keep queues stable. Finite scheduling respects capacity limits; infinite scheduling (plain MRP) does not - hence the need for CRP.

Key Terms

Sequencing	Ordering jobs on machines; scheduling assigns them over time.
Makespan / flow time / tardiness	Total completion; time in system; positive lateness.
Johnson's rule	Optimal 2-machine flow-shop sequence minimizing makespan.
SPT / EDD / CR	Dispatching rules: shortest time, earliest due date, critical ratio.
Gantt chart	Bar chart of jobs scheduled on machines over time.

Example - Johnson: Jobs A(3,6), B(5,2), C(7,7) on M1, M2. Smallest: B-M2=2 -> B last. Remaining A(3,6), C(7,7): smallest A-M1=3 -> A first. Sequence: A, C, B. Makespan = $3+7+2+\dots$ = optimal.

Example - SPT: Jobs with times 6, 2, 8, 3 and due dates: SPT order 2,3,6,8 minimizes average flow time.

Summary

- ✓ Sequencing orders jobs; measures: makespan, flow time, tardiness.
- ✓ Johnson's rule: optimal 2-machine flow-shop makespan.
- ✓ SPT minimizes flow time; EDD minimizes maximum tardiness.
- ✓ Gantt charts visualize; input-output control keeps queues stable.

Exam Pointers

- ★ Sequence five jobs on two machines with Johnson's rule; compute makespan.
- ★ Compare SPT, EDD and FCFS dispatching rules.
- ★ Define makespan, flow time and tardiness with formulas.