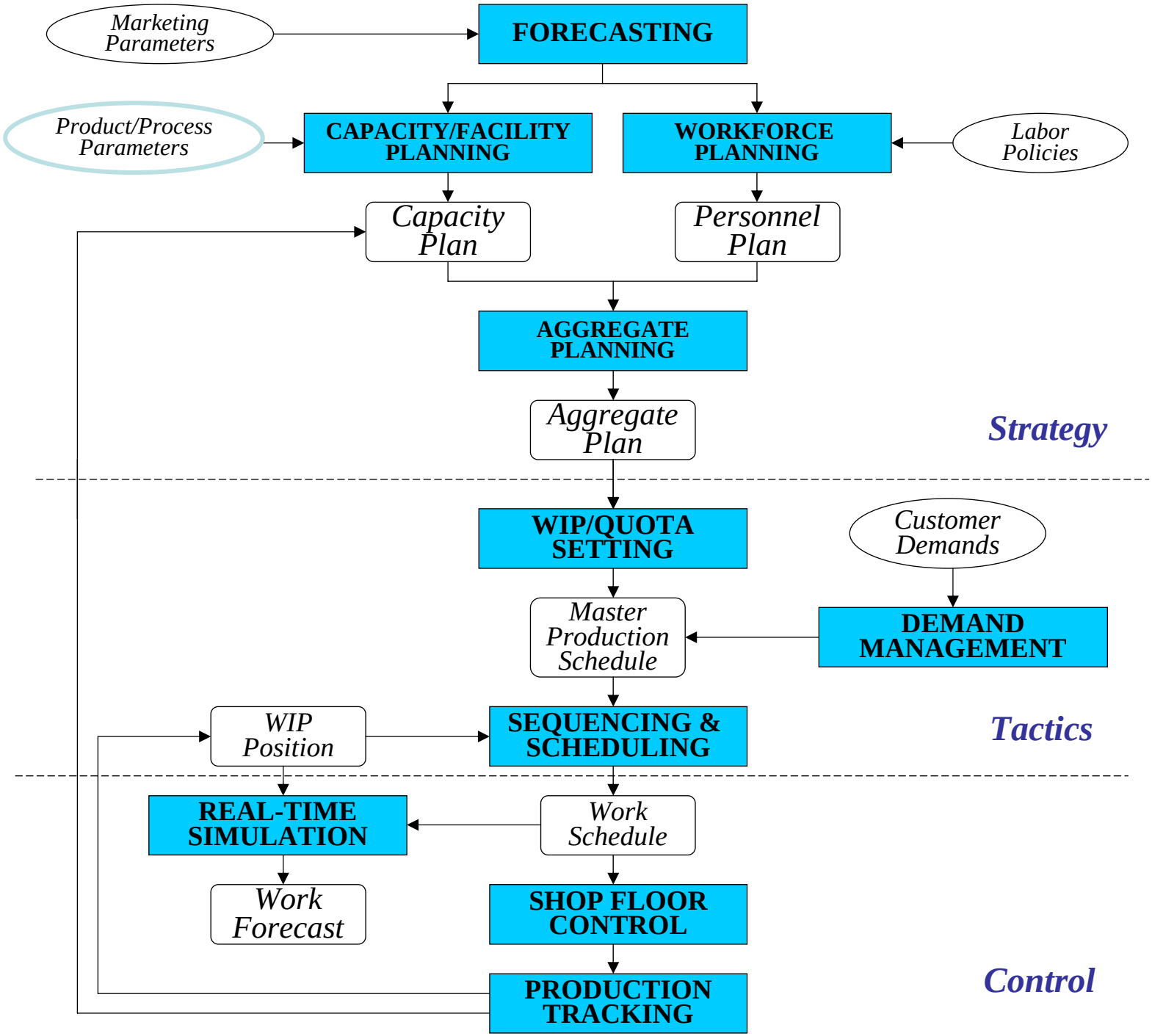
# Chapter 5

# Production Planning & Control Hierarchy

# Objectives

1. Outline of Planning Hierarchy
2. Forecasting
3. Capacity/Facility Planning
4. Workforce Planning
5. Aggregate Planning
6. Quota Setting
7. Scheduling
8. Shop Floor Control

# 1. Planning Hierarchy

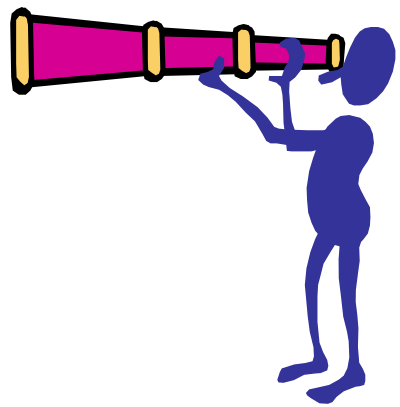


# Aggregating Planning by Time Horizon

| Time Horizon | Length | Representative Decisions |
|---|---|---|
| Long-Term<br>(Strategy) | year – decades | Financial Decisions<br>Marketing Strategies<br>Product Designs<br>Process Technology Decisions<br>Capacity Decisions<br>Facility Locations<br>Supplier Contracts<br>Personnel Development Programs<br>Plant Control Policies<br>Quality Assurance Policies |
| Intermediate-Term<br>(Tactics) | week – year | Work Scheduling<br>Staffing Assignments<br>Preventive Maintenance<br>Sales Promotions<br>Purchasing Decisions |
| Short-Term<br>(Control) | hour – week | Material Flow Control<br>Worker Assignments<br>Machine Setup Decisions<br>Process Control<br>Quality Compliance Decisions<br>Emergency Equipment Repairs |

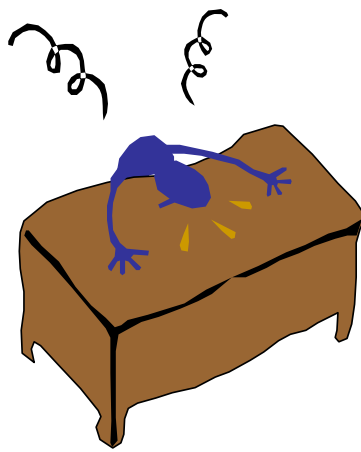
# 2. Forecasting

- Basic Problem: **predict demand for planning purposes.**
- Laws of Forecasting:
  1. ***Forecasts are always wrong!***
  2. ***Forecasts always change!***
  3. ***The further into the future, the less reliable the forecast will be!***
- Forecasting Tools:
  - ***Qualitative*:**
    - Delphi
    - Analogies
    - Many others
  - ***Quantitative*:**
    - Causal models (e.g., regression models)
    - Time series models



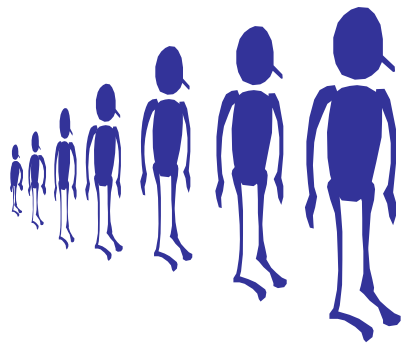
# 3. Capacity/Facility Planning

- Basic Problem: how much and what kind of physical equipment is needed to support production goals?
- Issues:
  - ***Basic Capacity Calculations***: stand-alone capacities and congestion effects (e.g., blocking)
  - ***Capacity Strategy***: lead or follow demand
  - ***Make-or-Buy***: vending, long-term identity
  - ***Flexibility***: with regard to product, volume, mix
  - ***Speed***: scalability, learning curves



# 4. Workforce Planning

- Basic Problem: how much and what kind of labor is needed to support production goals?
- Issues:
  - ***Basic Staffing Calculations***: standard labor hours adjusted for worker availability.
  - ***Working Environment***: stability, morale, learning.
  - ***Flexibility/Agility***: ability of workforce to support plant's ability to respond to short and long term shifts.
  - ***Quality***: procedures are only as good as the people who carry them out.



# Workforce Planning

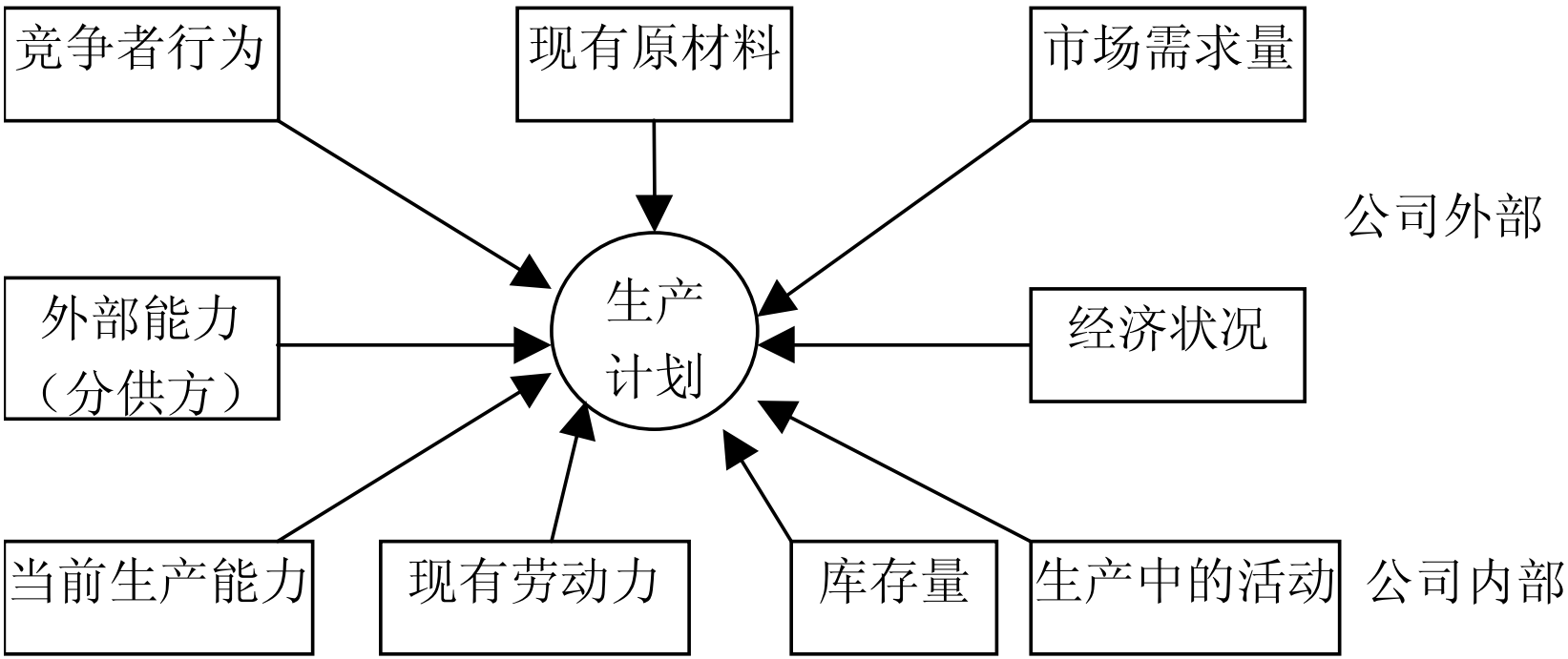
- **Problem:** determine most profitable production and hiring/firing policy over planning horizon.
- **Motivation for Study:**
  - hiring/firing vs. overtime vs. Inventory Build tradeoff
  - iterative nature of optimization modeling.
- **Inputs:**
  - demand forecast (assume single product for simplicity)
  - unit hour data
  - labor content data
  - capacity constraints
  - hiring/ firing costs
  - overtime costs
  - holding costs
  - unit profit

# 5. Aggregate Planning

- Basic Problem: generate a long-term production plan that establishes a rough product mix, anticipates bottlenecks, and is consistent with capacity and workforce plans.
- Issues:
  - ***Aggregation***: product families and time periods must be set appropriately for the environment.
  - ***Coordination***: AP is the link between the high level functions of forecasting/capacity planning and intermediate level functions of quota setting and scheduling.
  - ***Anticipating Execution***: AP is virtually always done deterministically, while production is carried out in a stochastic environment.
  - ***Linear Programming***: is a powerful tool well-suited to AP and other optimization problems.

# Aggregate Planning

- 中期生产计划的环境与输入



# Basic Aggregate Planning

- Problem: project production of single product over planning horizon.
- Motivation for Study:
  - mechanics and value of LP as a tool
  - intuition of production smoothing
- Inputs:
  - demand forecast (over planning horizon)
  - capacity constraints
  - unit profit
  - inventory carrying cost rate

# Product Mix Planning

- Problem: determine most profitable mix over planning horizon
- Motivation for Study:
  - linking marketing/promotion to logistics.
  - Bottleneck identification.
- Inputs:
  - demand forecast by product (family?) -may be ranges
  - unit hour data
  - capacity constraints
  - unit profit by product
  - holding cost

# Aggregate Planning Conclusions

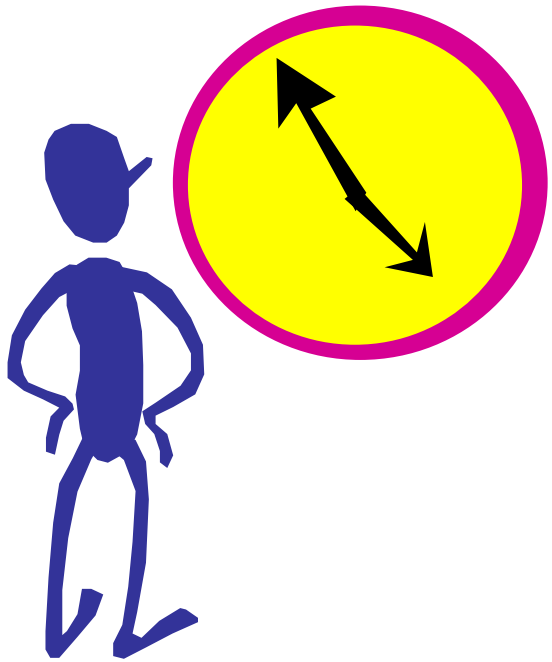
- No single AP model is right for every situation
- Simplicity promotes understanding
- Linear programming is a useful AP tool
- Robustness matters more than precision
- Formulation and Solution are not separate activities.

# 6. Quota Setting

- Basic Problem: **set target production quota for pull system**
- Issues: **Larger quotas yield**

***Benefits:***

- Increased throughput.
- Increased utilization.
- Lower unit labor hour.
- Lower allocation of overhead.



***Costs:***

- More overtime.
- Higher WIP levels.
- More expediting.
- Increased difficulties in quality control.

# 7. Goals of Production Scheduling

- High Customer Service: **on-time delivery**
- Low Inventory Levels: **WIP and FGI**
- High Utilization: **of machines**

# Meeting Due Dates – Measures

- Service Level:
  - Used typically in ***make to order*** systems.
  - Fraction of orders which are filled on or before their due dates.
- Fill Rate:
  - Used typically in ***make to stock*** systems.
  - Fraction of demands met from stock.
- Lateness（延期）:
  - Used in shop floor control.
  - Difference between order due date and completion date.
  - ***Average*** lateness has little meaning.
  - Better measure is lateness ***variance***.
- Tardiness（延误）:
  - Used in shop floor control.
  - Is equal to the lateness of a job if it is late and zero, otherwise.
  - ***Average tardiness*** is meaningful but unintuitive.

# Classic Scheduling

- MRP/ERP:
  - **Benefits –** Simple paradigm, hierarchical approach.
  - **Problems –**
    - MRP assumes that lead times are an attribute of the part, independent of the status of the shop.
    - MRP uses pessimistic lead time estimates.
- Classic Scheduling: **(only classic in academia)**
  - **Benefits –** “Optimal” schedules
  - **Problems –** Bad assumptions.
    - All jobs available at the start of the problem.
    - Deterministic processing times.
    - No setups.
    - No machine breakdowns.
    - No preemption.
    - No cancellation.

# Classic Single Machine Results

- Minimizing Average Cycle Time:
  - Minimize by performing in “shortest process time” (SPT) order.
  - Makespan is not affected.
- Minimizing Maximum Lateness (or Tardiness):
  - Minimize by performing in “earliest due date” (EDD) order.
  - Makespan is not affected.
  - If there exists a sequence with no tardy jobs, EDD will do it.
- Minimizing Average Tardiness:
  - No simple sequencing rule will work. Problem is ***NP Hard***.
  - Makespan is not affected.

# Classic Multi Machine Results

- Minimizing “Makespan” on Two Machines: given a set of jobs that must go through a sequence of two machines, what sequence will yield the minimum makespan?
  - Mapespan is sequence dependent.
  - Simple algorithm (Johnson 1954)
- Optimal Schedules: **Impossible to find for most real problems.**
- Dispatching（调度）: **sorts jobs as they arrive at a machine.**
- Dispatching rules:
  - FIFO – simplest, seems “fair”.
  - SPT – Actually works quite well with tight due dates.
  - EDD – Works well when jobs are mostly the same size.
  - Many (100?) others.
- Problems with Dispatching:
  - Cannot be optimal (can be bad).
  - Tends to be myopic.

# Implications for Real Problems

- Computation: NP algorithms are slow to use.
- No Technology Fix: Faster computers don't help on NP algorithm.
- Scheduling is Hard: Real scheduling problems tend to be NP Hard.
- Scheduling is Big: Real scheduling problems also tend to be quite large; impossible to solve optimally.
- Robustness? NP hard problems have many solutions, and presumably many "good" ones.
- Role of Heuristics: Polynomial algorithms can be used to obtain "good" solutions. Example heuristics include:
  - Simulated Annealing
  - Tabu Search
  - Genetic Algorithms

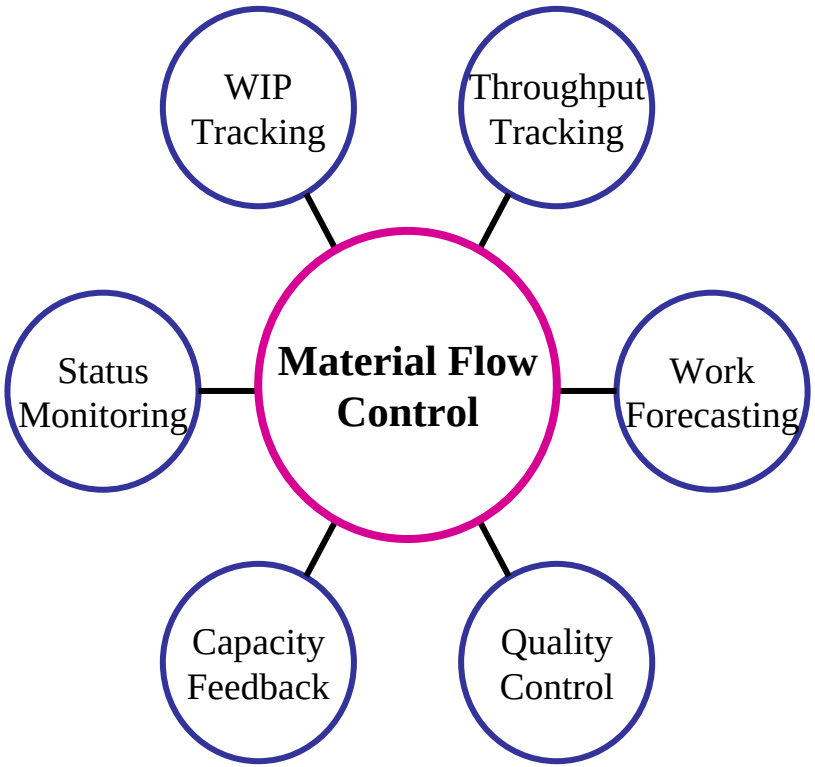
# Scheduling Software Approaches

- Fixed leadtime backward scheduling (MRP)
- Rule based forward scheduling (FACTOR)
- AI/Expert System approaches (MIMI)
- Bottleneck scheduling (OPT)
- Heuristics (MADEMA/PROMIS)
- Diagnostic (backward) scheduling (MRP-C)
- Perturbation scheduling (developmental)

# 8. What is Shop Floor Control?

- Definition: *Shop Floor Control (SFC)* **is the process by which decisions directly affecting the flow of material through the factory are made.**

- Functions:



# Planning for SFC

- Gross Capacity Control: **Match line to demand via:**
  - Varying staffing (no. shifts or no. workers/shift)
  - Varying length of work week (or work day)
  - Using outside vendors to augment capacity
- Bottleneck Planning:
  - Bottlenecks can be designed
  - Cost of capacity is key
  - Stable bottlenecks are easier to manage
- Span of Control:
  - Physically or logically decompose system
  - Span of labor management (10 subordinates)
  - Span of process management (related technology?)

# Question Bowl

1. 对于采用Make-to-Stock生产方式的企业，反映其服务水平的适当指标是：

A. 生产周期小于提前期的概率　B. 需求被立即满足的比率

C. 定单不被拖延的概率　D. 生产计划不被延误的比率

2. 制造型企业的计划层级中，下列哪一种计划是企业制造功能与市场需求的界面（指反映市场需求的最低层次的计划）？

A. 长期资源计划　B. 中期生产计划

C. 主生产进程　D. 物料需求计划