Aggregate Planning

Coca Cola

- Coca-Cola produces nearly 40% of the beverages consumed in the U.S.
- Matches fluctuating demand by brand to specific plant, labor, and inventory capacity
- High facility utilization requires
  - meticulous cleaning between batches
  - effective maintenance
  - efficient employees
  - efficient facility scheduling

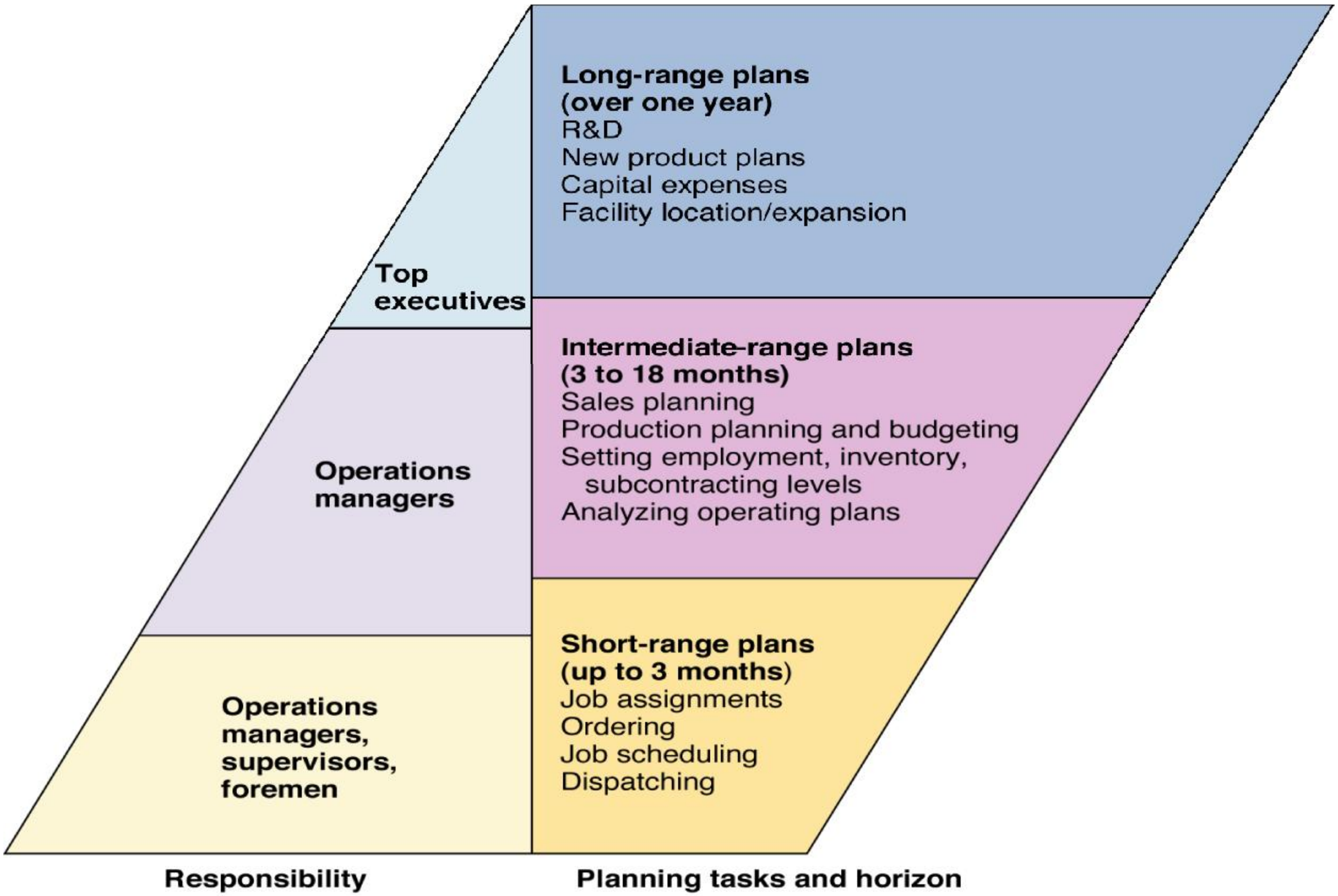
Aggregate Planning Requires

- Logical overall unit for measuring sales and outputs
- Forecast of demand for intermediate planning period in these aggregate units
- Method for determining costs
- Model that combines forecasts and costs so that planning decisions can be made

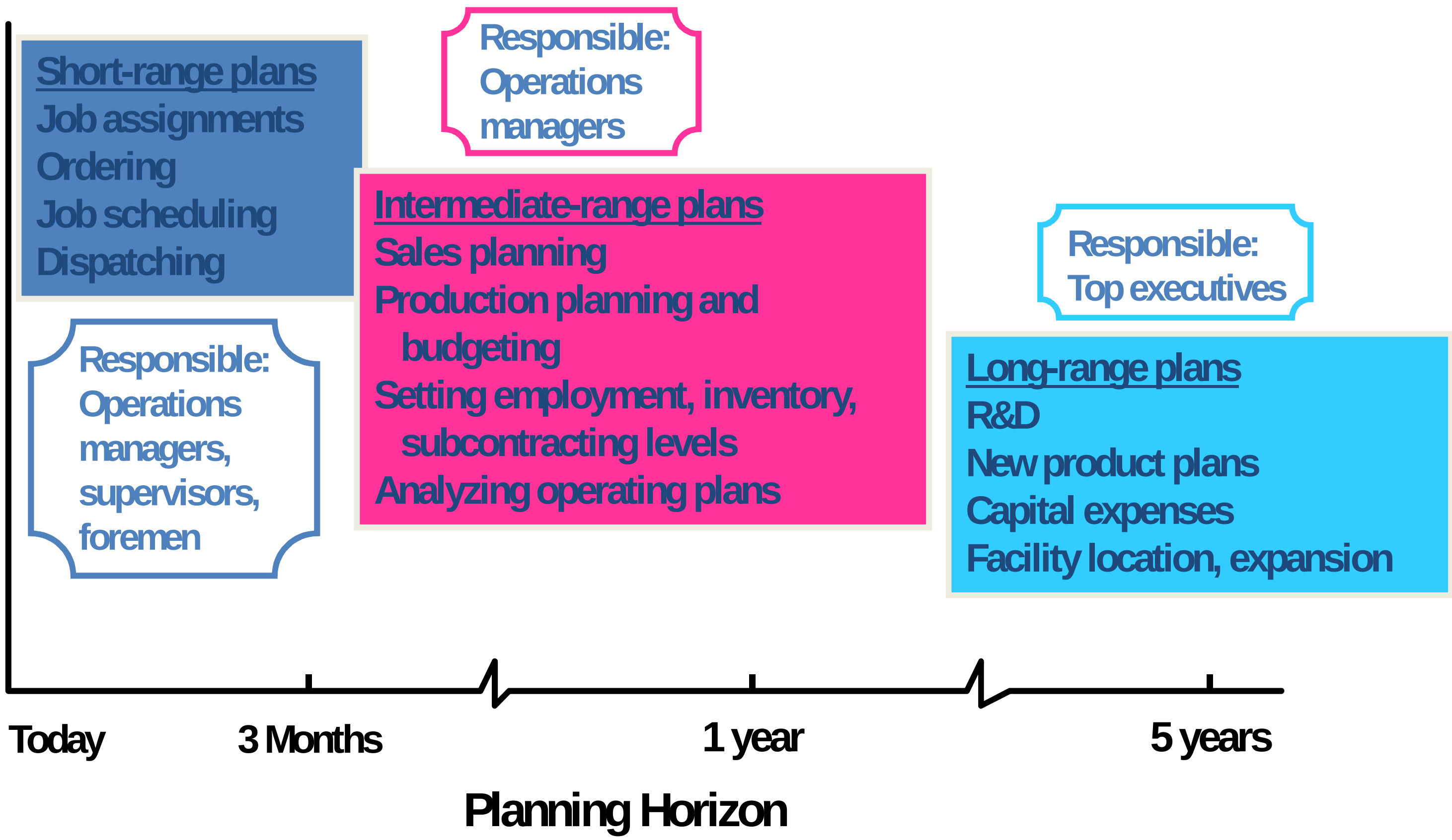
Planning

- Setting goals & objectives
  - Example: Meet demand within the limits of available resources at the least cost
- Determining steps to achieve goals
  - Example: Hire more workers
- Setting start & completion dates
  - Example: Begin hiring in Jan.; finish, Mar.
- Assigning responsibility

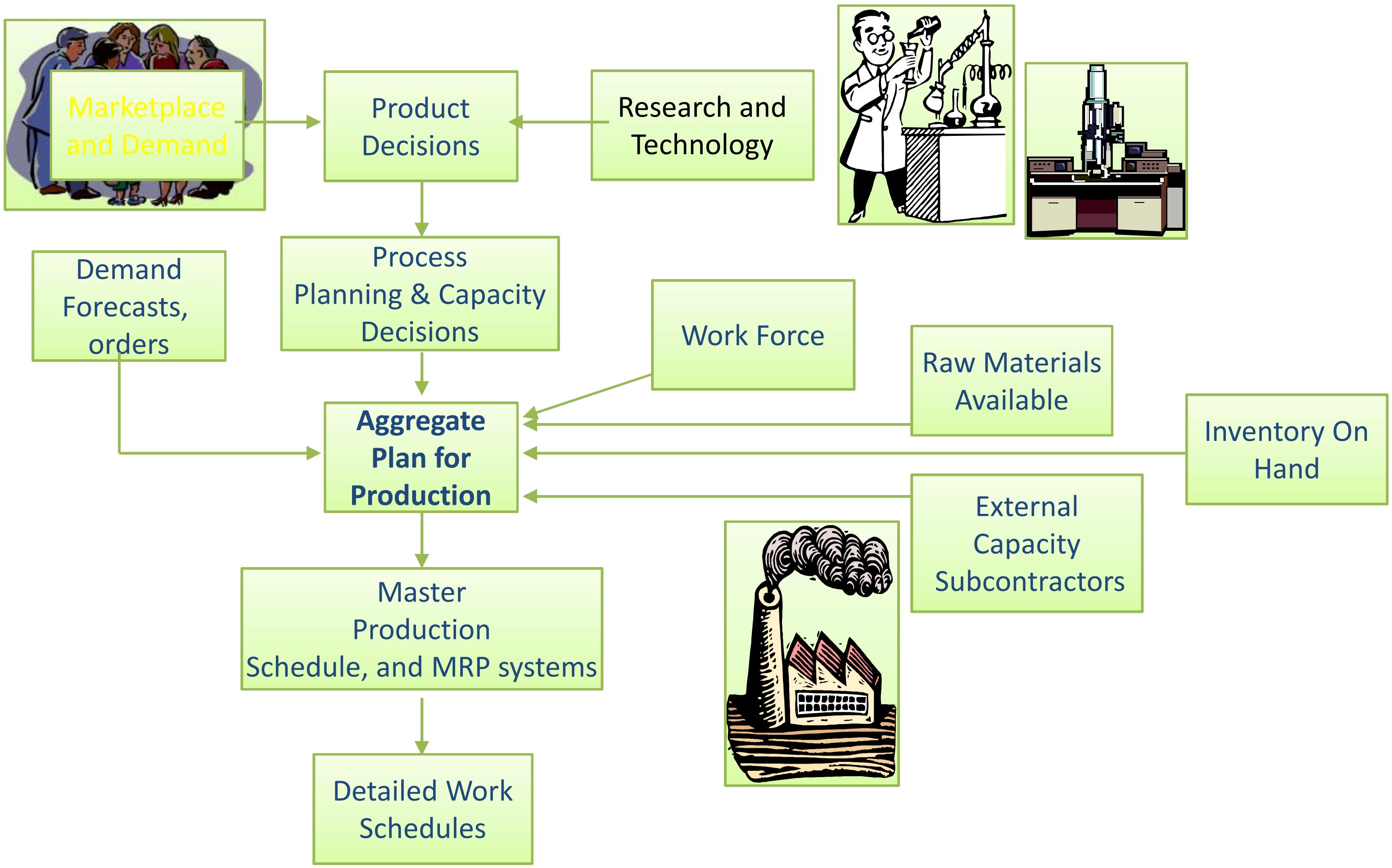
Planning Tasks and Responsibilities



Planning Horizons



Relationships of the Aggregate Plan



What’s Needed for Aggregate Planning

A mathematically based aggregate planning model requires considerable:

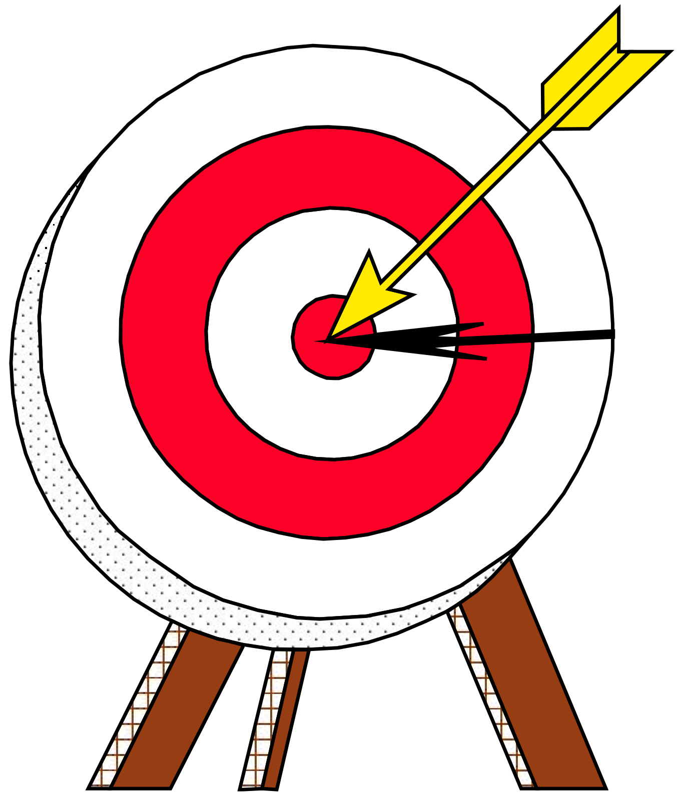
- time
  - problem definition
  - model development
  - model verification
  - model application
- expertise
  - people who understand the problem
  - people who understand both the modeling process, and the specific model
- money
  - money to pay for all of the above
  - often requires funding for several people for several months!

Aggregate Planning

- Provides the quantity and timing of production for intermediate future
  - Usually 3 to 18 months into future
- Combines (‘aggregates’) production
  - Often expressed in common units
    - Example: Hours, dollars
- Involves capacity and demand variables

Aggregate Planning Goals

- Meet demand
- Use capacity efficiently
- Meet inventory policy
- Minimize cost
  - Labor
  - Inventory
  - Plant & equipment
  - Subcontract



Aggregate Planning Strategies
Pure Strategies

- Capacity Options — change capacity:
  - *changing inventory levels*

    there are variations in demand over planning horizon. There are two types of time periods;

    Slack months: The months when demand is low

    Peak months: The months when demand is high.

    One planning-thumb-rule is;

    Produce excess than demand during Slack months. Keep the excess production in stock (inventory). Since, there will be shortage during "peak" months, overcome the shortage in "peak" periods from the inventory."

Aggregate Planning Strategies
Pure Strategies

- Capacity Options — change capacity:
  - ***varying work force size by hiring or layoffs***

    The utility of work-force increases or decreases with an organization's work load. During "peak" period, organization requires more and more work force. However, the large pool of work force remains under-utilized in "slack" period. In order to keep tight control over expenses, organizations should employ matching number of workers in "peak" as well as in "slack" periods. This implies that large work force should be employed ("hired") in peak period and, excess work force should be laid-off ("fired") in "slack period".

Aggregate Planning Strategies
Pure Strategies

- Capacity Options — change capacity:
  - ***varying production capacity through overtime or idle time***

    If frequent hiring/firing is not feasible, then organizations will have a constant pool of work force of adequate size. In "slack periods", some of the work force will remain under-utilized. However, some portion of the work force will be engaged in over time as well during "peak" period. This strategy is far better than frequent hiring and firing of the work force.

Aggregate Planning Strategies
Pure Strategies

- Capacity Options — change capacity:
  - ***Subcontracting***

    If some portion of the work order is technically complex and, requires special expertise. Also, this work is not of repetitive nature, then organization can award the work to some 3rd party (subcontracting)
  - ***using part-time workers***

    If organization's regular work force is too much occupied with work loads, some portion of work may be assigned to part-time workers.

Aggregate Planning Strategies
Pure Strategies

- Demand Options — change demand:
  - *influencing demand*

    demand rises and goes down because of buying trend of the consumer. Offer special discounts during low-demand periods so as to increase sales.
  - *backordering during high demand periods*

    since capacity is limited and all the demand cannot be met on-time, get permission from customer to deliver the products at a later time; e.g., meeting January demand by producing in March (Late delivery)
  - *counterseasonal product mixing*

    some organizations are engaged in producing more than two products. One product has high demand in winter , and, the other product has demand in summer.

Aggregate Scheduling Options - Advantages and Disadvantages

Option	Advantage	Disadvantage	Some Comments
Changing inventory levels	Changes in human resources are gradual, not abrupt production changes	Inventory holding costs; Shortages may result in lost sales	Applies mainly to production, not service, operations
Varying workforce size by hiring or layoffs	Avoids use of other alternatives	Hiring, layoff, and training costs	Used where size of labor pool is large

Advantages/Disadvantages - Continued

Option	Advantage	Disadvantage	Some Comments
Varying production rates through overtime or idle time	Matches seasonal fluctuations without hiring/training costs	Overtime premiums, tired workers, may not meet demand	Allows flexibility within the aggregate plan
Subcontracting	Permits flexibility and smoothing of the firm's output	Loss of quality control; reduced profits; loss of future business	Applies mainly in production settings

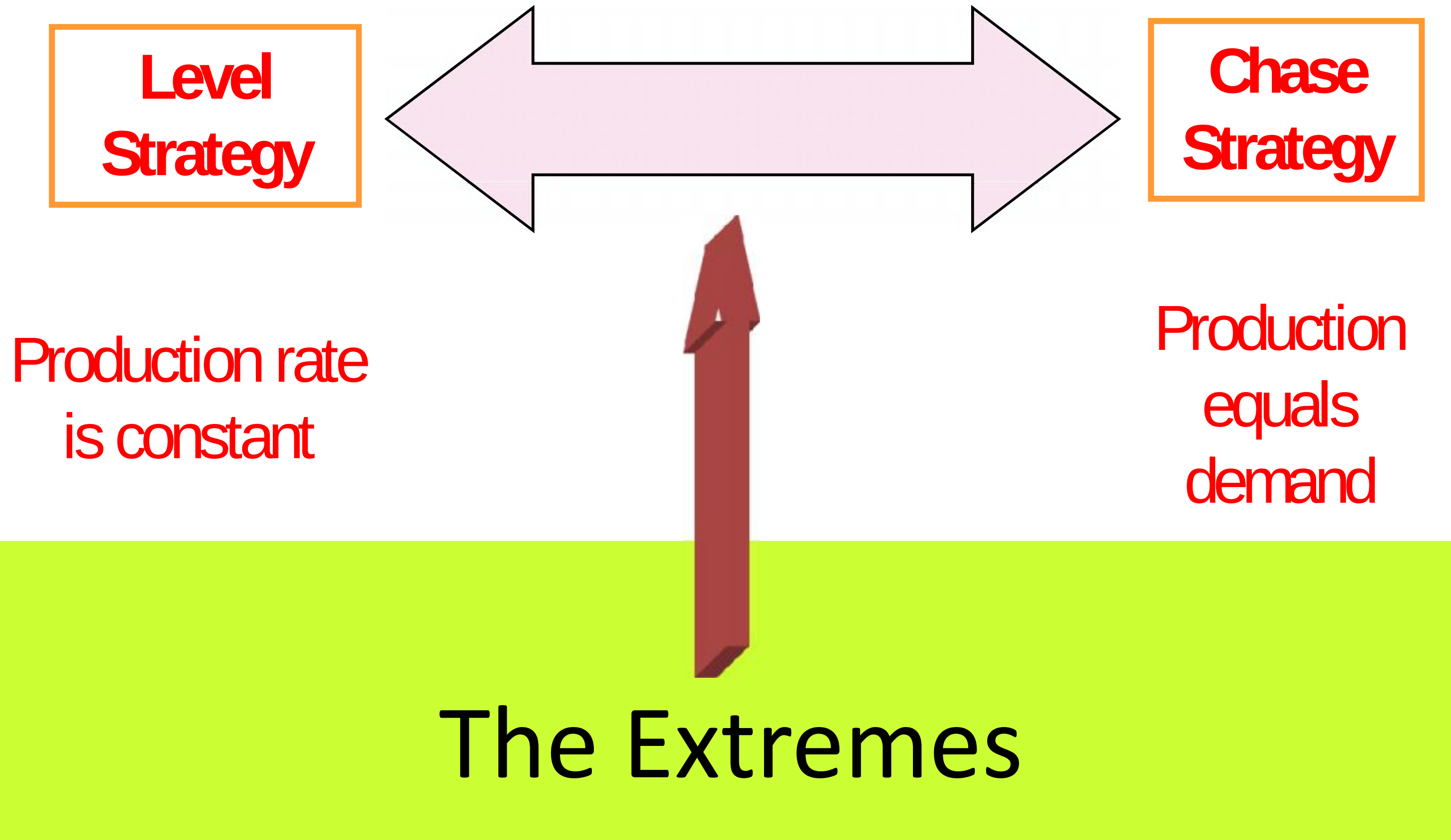
Advantages/Disadvantages - Continued

Option	Advantage	Disadvantage	Some Comments
Using part-time workers	Less costly and more flexible than full-time workers	High turnover/training costs; quality suffers; scheduling difficult	Good for unskilled jobs in areas with large temporary labor pools
Influencing demand	Tries to use excess capacity. Discounts draw new customers.	Uncertainty in demand. Hard to match demand to supply exactly.	Creates marketing ideas.

Advantage/Disadvantage - Continued

Option	Advantage	Disadvantage	Some Comments
Back ordering during high-demand periods	May avoid overtime. Keeps capacity constant	Customer must be willing to wait, but goodwill is lost.	Many companies backorder.
Counterseasonal products and service mixing	Fully utilizes resources; allows stable workforce.	May require skills or equipment outside a firm's areas of expertise.	Difficult finding products or services with opposite demand patterns.

Aggregate Planning Strategies



Aggregate Planning Strategies

- **Mixed strategy**
  - Combines 2 or more aggregate scheduling options
  - uses alternatives mixing inventory, back order, capacity change, work force change, etc
- **Level scheduling strategy**
  - Produce *same amount* of products every day
  - Keep *work force* level constant
  - Vary *non-work force* capacity or demand options
  - Often results in *lowest production* costs

Aggregate Planning Methods

- Graphical & charting techniques
  - Popular & easy-to-understand
  - Trial & error approach
- Mathematical approaches
  - Transportation method
  - Linear decision rule
  - Management coefficients model
  - *Linear Programming*
  - Simulation

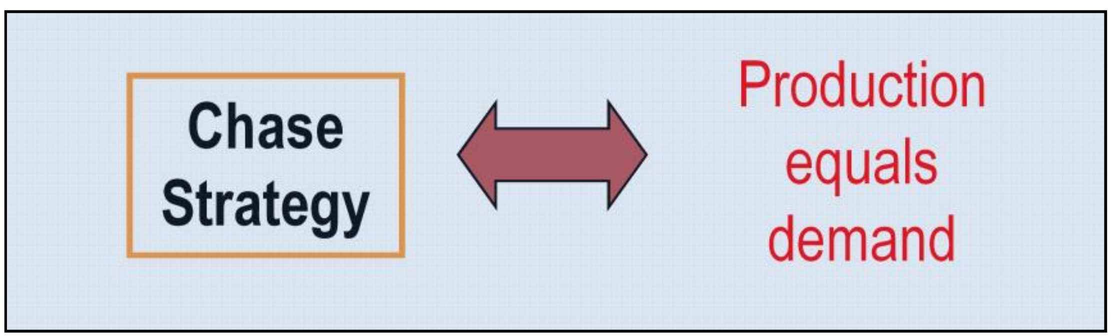
The Graphical Approach to Aggregate Planning

- Forecast the demand for each period
- Determine the capacity for regular time, overtime, and subcontracting, for each period
- Determine the labor costs, hiring and firing costs, and inventory holding costs
- Consider company policies which may apply to the workers or to stock levels
- Develop alternative plans, and examine their total costs

Data for a 6-month production planning problem is given below:

Month	Working Days	Demand per day
Jan	22	41
Feb	18	40
Mar	21	39
Apr	21	57
May	22	68
Jun	20	54

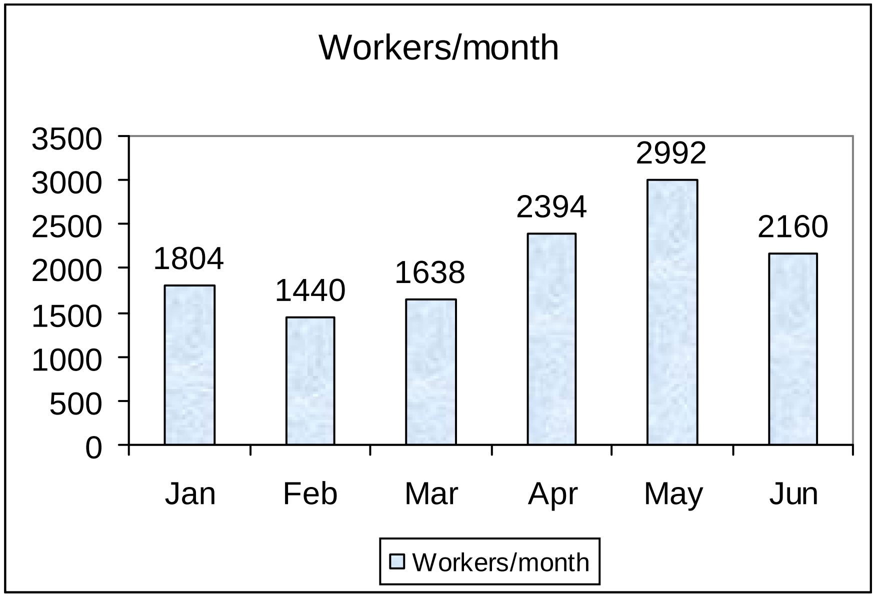
Suppose, "*chase strategy*" is to be adopted. ***Two workers are required to produce one unit***. Propose a feasible plan. Is the plan acceptable?



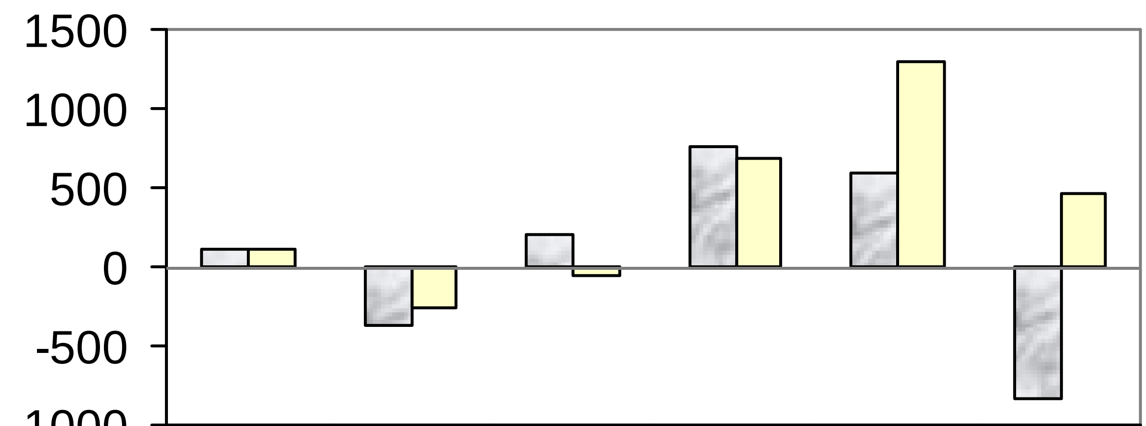
Employ an exact number of workers so that number of units produced per month is equal to number of units demanded

Work Force Requirements & Changes/Month

Month	Days/ month (A)	Demand/ day (B)	Units/ month C=(AxB)	Workers/ month **D=2C**	Change/ month
Jan	22	41	902	1804	0
Feb	18	40	720	1440	-364
Mar	21	39	819	1638	198
Apr	21	57	1197	2394	756
May	22	68	1496	2992	598
Jun	20	54	1080	2160	-832



Beginning Work Force Level = 1700 workers



	Jan	Feb	Mar	Apr	May	Jun
Change/Month	104	-364	198	756	598	-832
Cum Changes	104	-260	-62	694	1292	460

Abrupt Employment (hiring) and Layoff from job (firing) at mass-scale is not acceptable (why)?

Consider 6-month production planning problem once again.

Month	Working Days	Demand per day
Jan	22	41
Feb	18	40
Mar	21	39
Apr	21	57
May	22	68
Jun	20	54

Suppose, "*level strategy*" is to be adopted. Find a constant production rate so that no shortage occurs

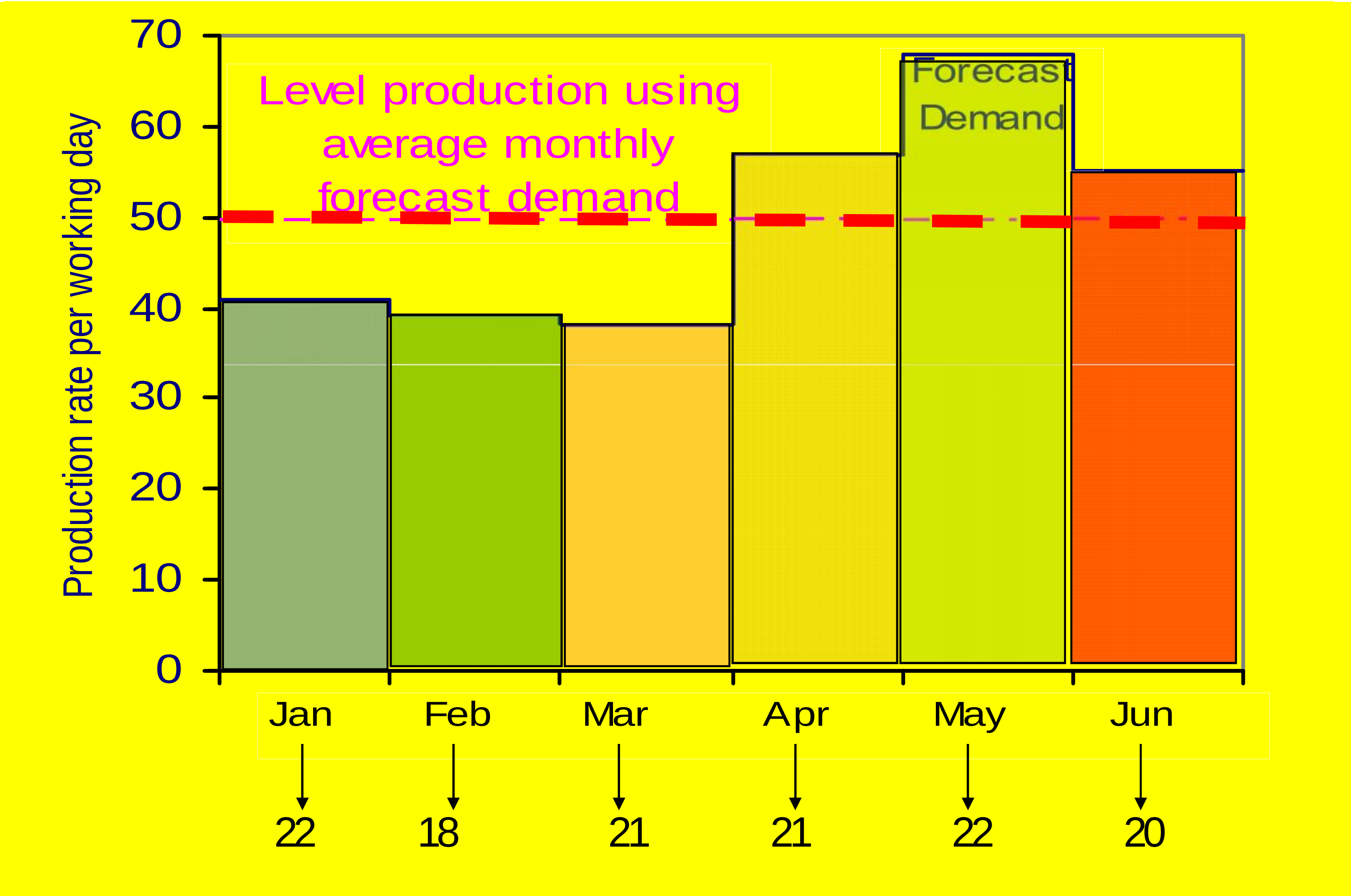
Level Strategy ⟷ Production rate is constant

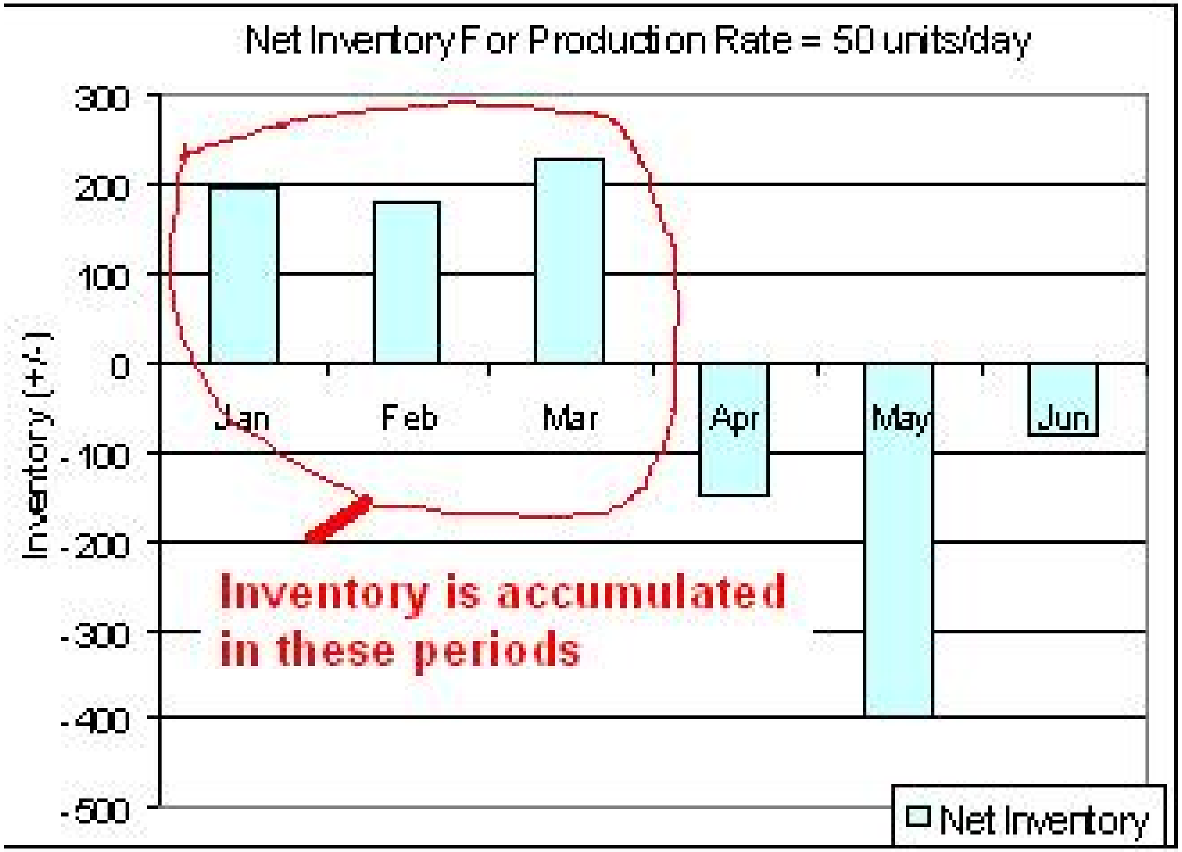
To find daily production rate so that no shortage occurs;

Divide total demand by total number of days.

Production rate = 6214/124 = 50 units (app)

Forecast and Average Forecast Demand

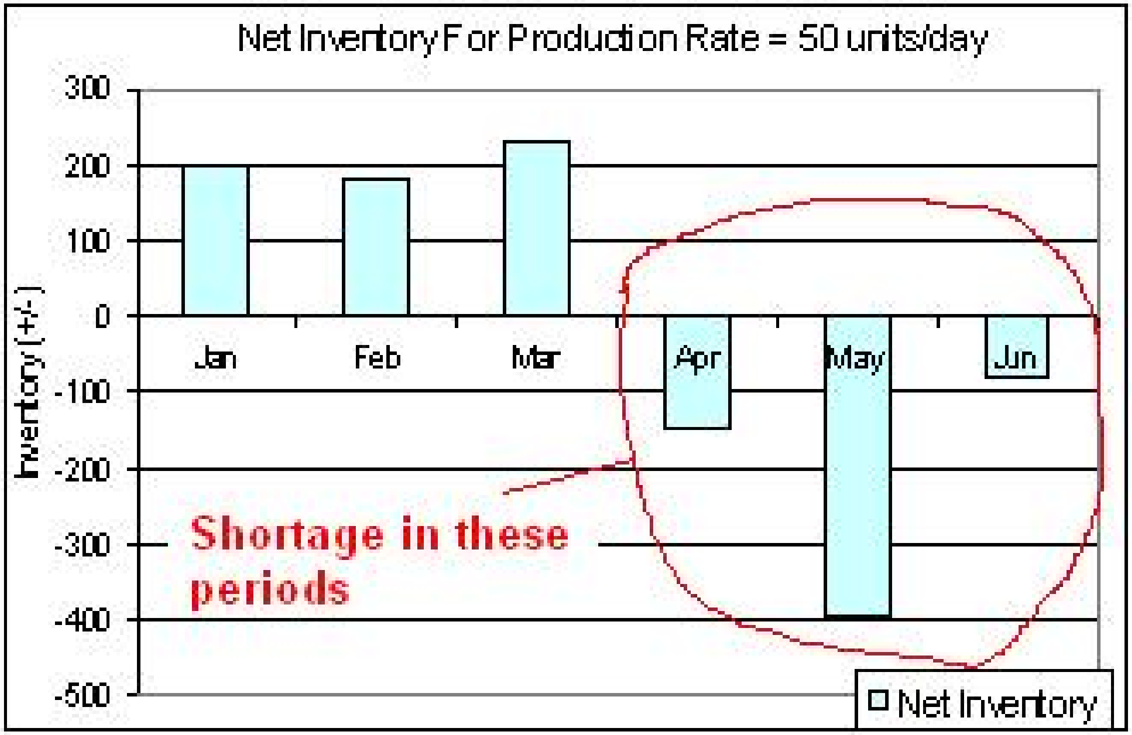




Inventory is accumulated

Because Demand < Production during Jan, Feb, Mar.

Month	Working Days	Demand per day	Production per day	Inventory (+/-)	Cumm Inventory
Jan	22	41	50	198	198
Feb	18	40	50	180	378
Mar	21	39	50	231	609
Apr	21	57	50	-147	462
May	22	68	50	-396	66
Jun	20	54	50	-80	-14



						Cumm Inventory
						198
						378
						609
						462
						66
Jun	20		54	50	-80	-14

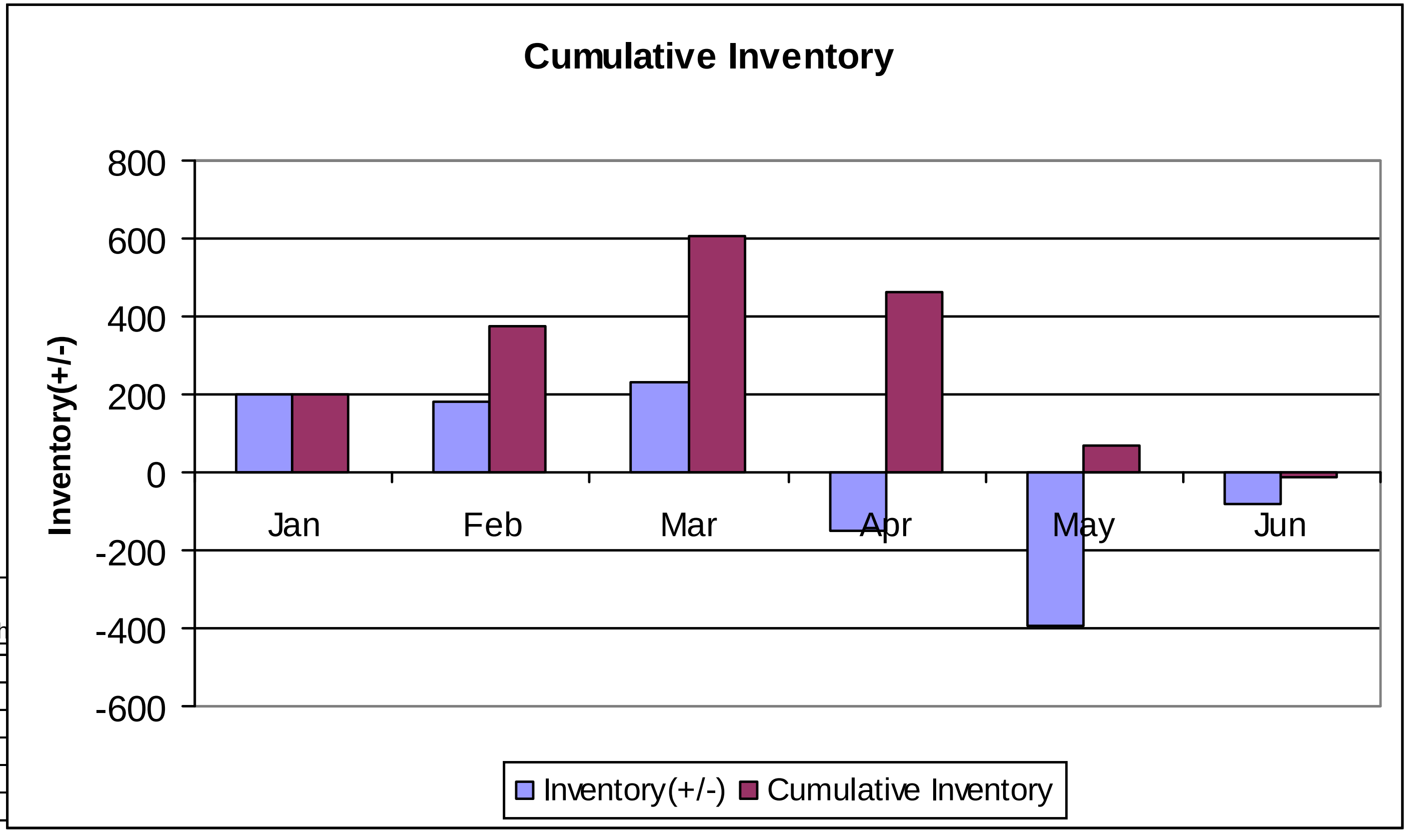
Shortage Created

Because

demand> Production

in Apr, May and Jun

Month
Jan
Feb
Mar
Apr
May
Jun

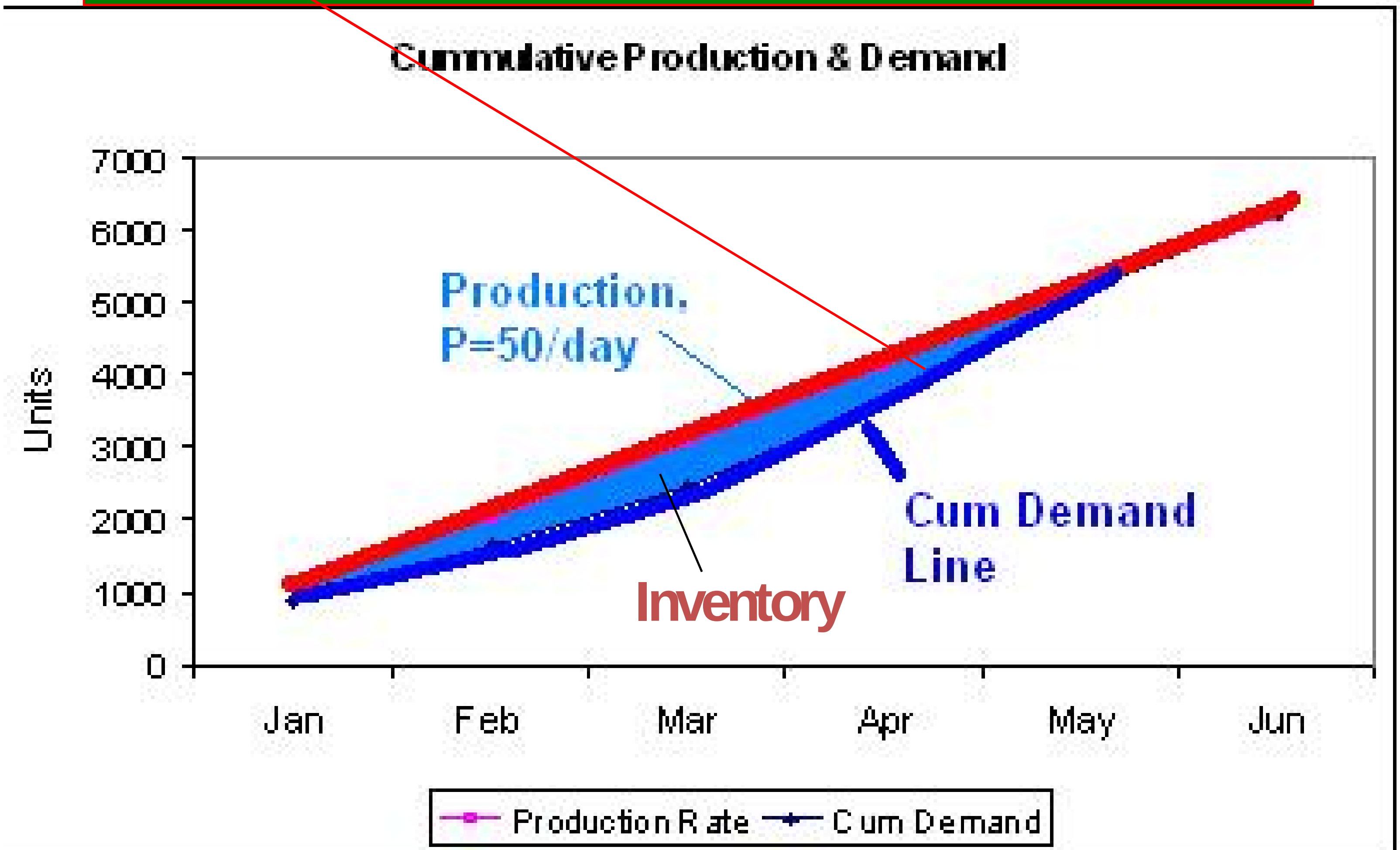


Cumulative Inventory

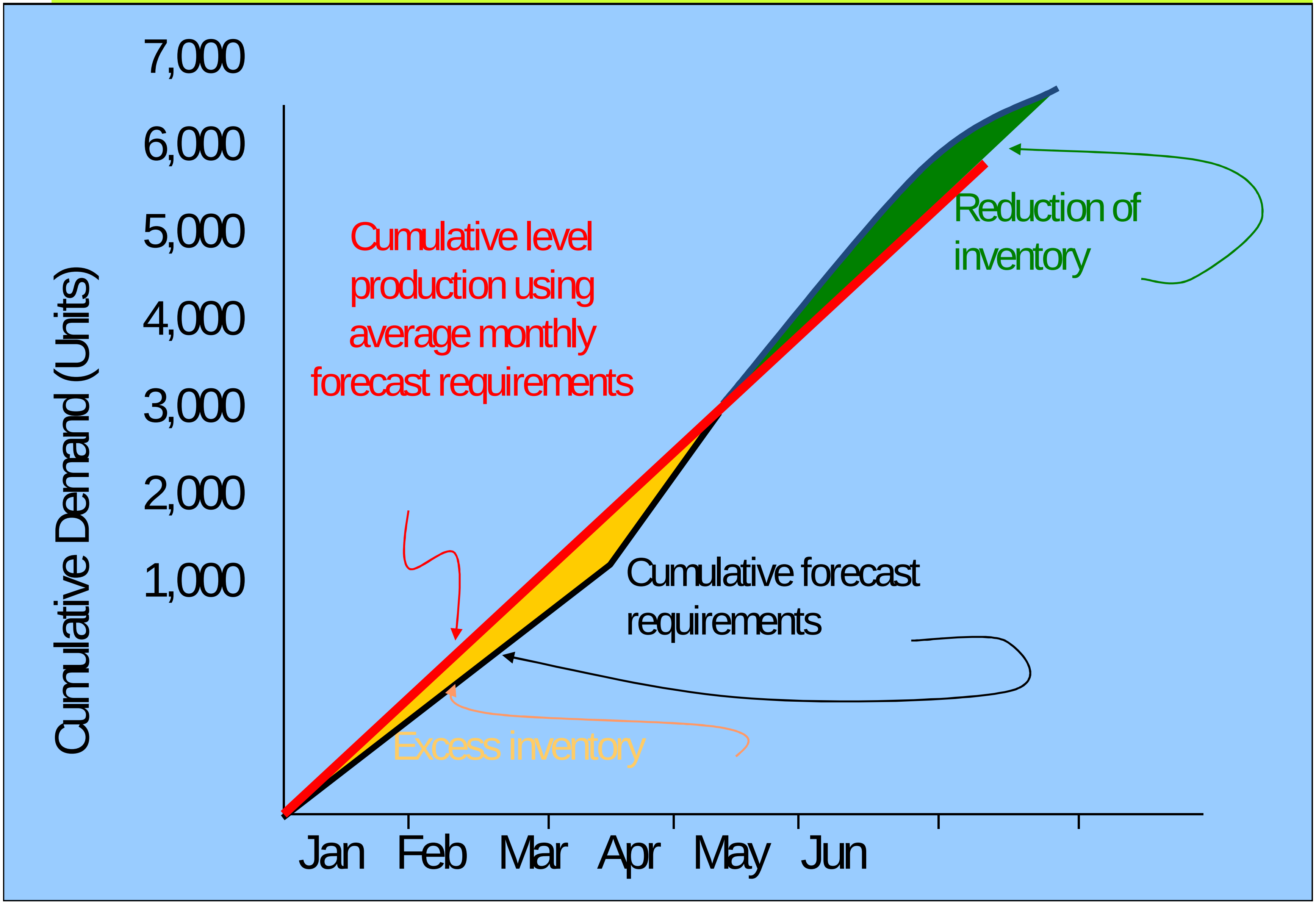
This inventory shows the overall total inventory at the end of each period

Cumulative Production & Demand Graph

The region between production line and demand line shows inventory.



Cumulative Demand Graph for Plan 1



Transportation Method

Transportation Method of Planning

- Each row in transportation table represents a production period
- Each column in the table represents a demand period
- Each cell in the table represents cost of production and inventory holding cost.

	Demand Period 1	Demand Period 2	Demand Period 3	Capacity/ Supply
Production Period 1	c_{11}	c_{12}	c_{13}	P_1
Production Period 2	**	c_{22}	c_{23}	P_2
Production Period 3	**	**	c_{33}	P_3
Demand→	D_1	D_2	D_3	

Transportation Method of Planning

- Suppose we have three month planning problem: { Jan , Feb , Mar }
  Demands for Jan, Feb and Mar are : { 40,50,50}
  Production capacity for Jan, Feb and Mar are : { 50,50,40}
  Production cost = $10/unit. Inventory holding cost = $2/unit/period
  $c_{11} = c_{22} = c_{33} = \$10$, $c_{12} = 10 + 2 = \$12$, $c_{13} = 10 + 2 + 2 = \$14$
  $c_{23} = 10 + 2 = \$12$.

Entering the data; Transportation Table will look like as follows:

	Demand Jan	**Demand Feb**	**Demand Mar**	**Capacity/ Supply**
Produce in Jan	10	12	14	50
Produce in Feb	**	10	12	50
Produce in Mar	**	**	10	40
Demand→	40	50	50	

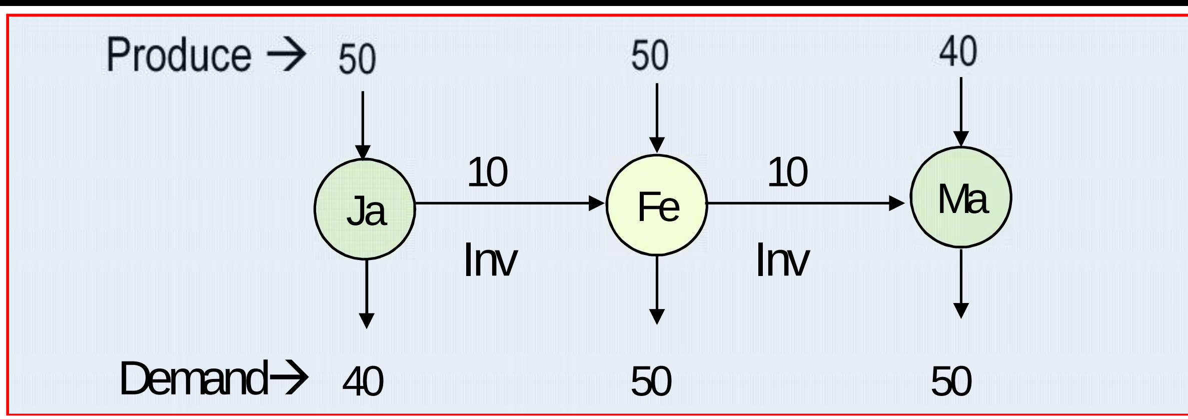
LINEAR PROGRAM OF THE PROD PLANNING PROBLEM

```
MIN= 10 * ( X1 + X2 + X3) + 2 * (I1 + I2 + I3 );

! Demand Data;
D1 = 40; D2 = 50; D3 = 50;

! Capacity Data;
P1 = 50; P2 = 50; P3 = 40;

! Subject to;

[Unused_Capacity_For_Period_1]   X1 <= P1;
[Unused_Capacity_For_Period_2]   X2 <= P2;
[Unused_Capacity_For_Period_3]   X3 <= P3;

! Inventory Balance Constraints;

I0 = 0;
I1 = I0 + X1 - D1;
I2 = I1 + X2 - D2;
I3 = I2 + X3 - D3;
```

Transportation Method of Planning

- Least cost solution;

	Demand Jan	Demand Feb	Demand Mar	Capacity/ Supply
Produce in Jan	40 10	12	10 14	50
Produce in Feb	**	50 10	12	50
Produce in Mar	**	**	40 10	40
Demand→	40	50	50	



Production Plan

- Optimal solution for by LP;

```
Global optimal solution found.
Objective value:                              1440.000
Infeasibilities:                              0.000000
Total solver iterations:                             0
```

Variable	Value	Reduced Cost
X1	50.00000	0.000000
X2	50.00000	0.000000
X3	40.00000	0.000000
I1	10.00000	0.000000
I2	10.00000	0.000000
I3	0.000000	16.00000

Multiple Production Source Problem

- Solve three month planning problem: { Mar, Apr, May }

Demands for Mar, Apr and May are : { 800,1000,750}

Production is to be carried out in Mar, Apr and May.

There are three sources of Production in each month.

Regular Time, Overtime and Subcontract

Capacity for each source in each month is :

Regular time = 700 units

Overtime = 50 units

Subcontract = 150 units

Production cost in each month:

Inventory holding cost = $2/unit/period

There are 100 units in inventory at the beginning of Mar.

Use Transportation Problem and develop a Production Plan.

Transportation Table

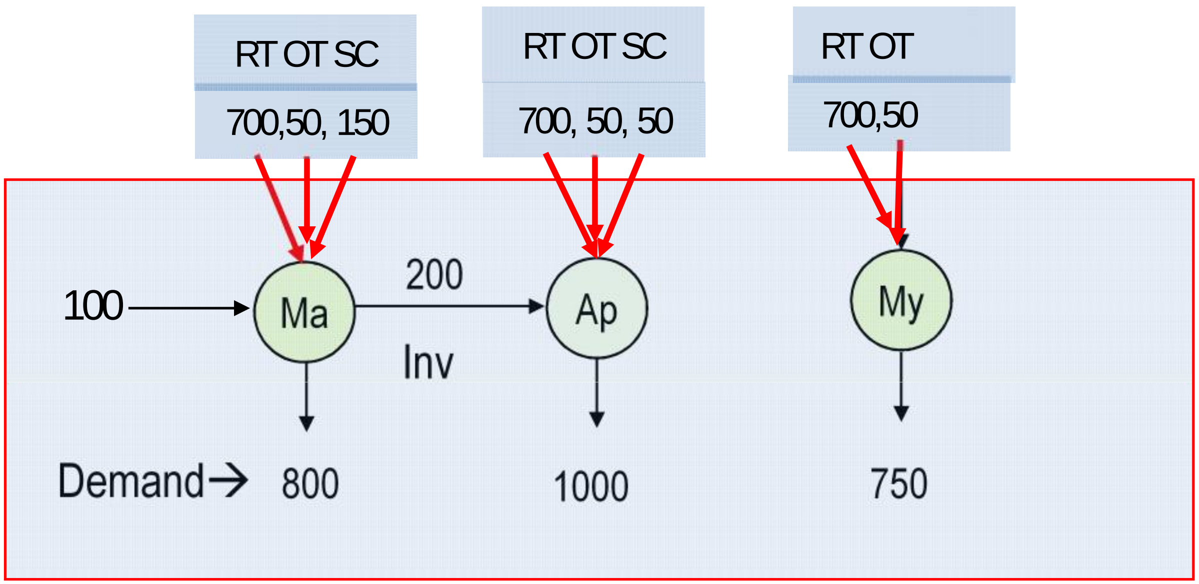
		Period 1 (Mar)	Period 2 (Apr)	Period 3 (May)	Unused Capacity (Dummy)	Total Capacity Available (Supply)
	Beginning Inventory	0 / 100	2	4	0	100
Period 1	Regular	40 / 700	42	44	0	700
	Overtime	50	52 / **50**	54	0	50
	Subcontract	70	72 / **150**	74	0	150
Period 2	Regular	X	40 / **700**	42	0	700
	Overtime	X	50 / **50**	52	0	50
	Subcontract	X	70 / **50**	72	0 / **100**	150
Period 3	Regular	X	X	40 / **700**	0	700
	Overtime	X	X	50 / 50	0	50
	Subcontract	X	x	70	0 / 150	150
	Total Demand	**800**	**1000**	**750**	250	2800

Transportation Table

		Period 1 (Mar)	Period 2 (Apr)	Period 3 (May)	Unused Capacity (Dummy)	Total Capacity Available (Supply)
	Beginning Inventory	0 **100**	2	4	0	100
Period 1	Regular	40 **700**	42	44	0	700
	Overtime	50	52 **50**	54	0	50
	Subcontract	70	72 **150**	74	0	150
Period 2	Regular	X	40 **700**	42	0	700
	Overtime	X	50 **50**	52	0	50
	Subcontract	X	70 **50**	72	0 **100**	150
Period 3	Regular	X	X	40 **700**	0	700
	Overtime	X	X	50 **50**	0	50
	Subcontract	X	x	70	0 **150**	150
	Total Demand	800	1000	750	250	2800

Cost of solution:

700*40+52*50+150*72+700*40+50*50+70*50+40*700+50*50=$105,900



Solution by Transportation Model

Comparison of Three Major Aggregate Planning Methods

Techniques	Approaches	Aspects
Charting/graphical methods	Trial and error	Simple to understand, easy to use. Many solutions; one chosen may not be optimal
Transportation method	Optimization	LP software available;permits sensitivity analysis and constraints. Linear function may not be realistic
Management coefficient model	Heuristic	Simple, easy to implement; tries to mimic manager's decision process; uses regression