ASPECTS OF AGGREGATE PLANNING

Aggregate planning focuses on intermediate-rang production planning problems.

The aggregate production plan states in general terms the total amount of output that is the responsibility of manufacturing to produce for each period in the planning horizon. It uses business plans, demand forecasts and current conditions as inputs.

The aggregate unit is defined by some measure common to all products, such as production hours or dollars. Factors of aggregate planning include capacity, production costs, capacity change costs, and inventory costs

Capacity

Capacity is how much a production system can make.
To satisfy demand, system capacity should exceed demand, at least over the long run. However, excess capacity is costly. Idle capacity represents wasted investment.

Aggregate Units

An aggregate product is expressed in terms of time or money. By doing so, different products can be aggregated using the same unit of measurement.

Products A, B, and C require 5, 2.5 and 0.75 hours.

If demand for A is 200 units, demand for B is 100, and demand for C is 1000, then an equivalent demand for production hours is:

$$5 \times 200 + 2.5 \times 100 + 0.75 \times 1000 = 2000 \text{ hours.}$$

Or the equivalent demand in gears is 1300 aggregate gears with a production time of 2000/1300 = 1.54 hrs per aggregate gear.

Capacity must be measured in the same units as the aggregate product.

Costs

Many costs affect the production plan: Production costs, inventory costs, and capacity change costs.

Production costs include materials, direct labor, and other costs attributed to producing a unit, e.g., overtime or subcontracting costs.

Inventory related costs are holding and shortage costs - neither of which is linear.

Capacity-change costs include hiring and training costs, and layoff costs.

We now look at two methods used for generating an aggregate production plan.

1. Spreadsheet methods
2. Quantitative methods.

1. SPREADSHEET METHODS

We examine a simple method that may not give the best solution but often provides good solutions. This method is a trial-and-error.

A **chase** (**zero inventory)** strategy produces exactly the demand for each period, which requires a fluctuating work force.
A **level production** strategy produces a constant amount each period. Variations in demand are accounted for by holding inventory.
A **mixed strategy** uses both inventory and changing work force.

Example:
Precision Gears Inc. produces 41,383 gears/year. There are 260 working days and 40 workers $\Rightarrow$ $\approx$ 4 gears/worker-day.

Production costs, excluding labor, do not change over the planning horizon and thus are ignored. A unit produced but not sold in a month is counted as inventory for that entire month (end-of-month inventory). End of the month inventory holding cost is $5 per gear per month. At the beginning of each month, new workers can be hired at a

cost of $450 per worker. Existing workers can be laid off at a cost of $600 per worker. Wages and benefits for a worker are $15 per hour, all workers are paid for eight hours per day, and there are currently 35 workers at Precision Inc.

Aggregate demand forecast for gears

Month	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**Total**
Demand	2760	3320	3970	3540	3180	2900	19,670

Chase strategy (Zero-Inventory Plan)

We develop a chase strategy (also called zero inventory plan or lot for lot plan): Each month we produce exactly the amount demanded, and no inventory is carried. Workers are added when demand increases and are laid off when demand decreases.

Workers needed = [demand/month] ÷
[(days/month) * (units/worker day)]

Aggregate demand forecast for gears:

Month	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**Total**
Demand	2760	3320	3970	3540	3180	2900	19,670
Days avail.	21	20	23	21	22	22	129
Workers need.	33	42	44	43	37	33	232

TABLE 5-2
Zero inventory plan

		January	February	March	April	May	June	Total
1	Days	21	20	23	21	22	22	129
2	Units/worker	84	80	92	84	88	88	516
3	Demand	2,760	3,320	3,970	3,540	3,180	2,900	19,670
4	Workers needed	33	42	44	43	37	33	232
5	Workers available	35	33	42	44	43	37	na
6	Workers hired	0	9	2	0	0	0	11
7	Hiring cost	0	4,050	900	0	0	0	4,950
8	Workers laid off	2	0	0	1	6	4	13
9	Lay-off cost	1,200	0	0	600	3,600	2,400	7,800
10	Workers used	33	42	44	43	37	33	232
11	Labor cost	83,160	100,800	121,440	108,360	97,680	87,120	598,560
12	Units produced	2,760	3,320	3,970	3,540	3,180	2,900	19,670
13	Net inventory	0	0	0	0	0	0	na
14	Holding cost	0	0	0	0	0	0	0
15	Backorder cost	0	0	0	0	0	0	0
16	Total cost	84,360	104,850	122,340	108,960	101,280	89,520	611,310

Production = four units/worker/day
Hiring cost = $450/worker
Holding cost = $5/unit/month
Wages and benefits = $120/worker/day
Firing cost = $600/worker
Backorder cost = $15/unit/month

Capacity in Jan. =

(# of workers in Jan.) x (# of days in Jan.) x (gears/worker-day)

= 33 x 21 x 4 = 2772.

But actually produced is 2760.

The plan ends with 33 workers employed and no inventory.

The total cost is $611,310.

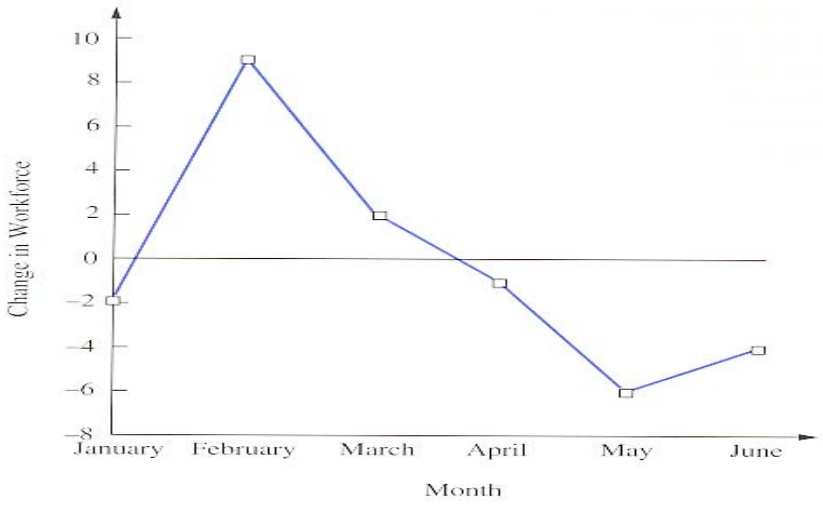

FIGURE 5-2
Zero inventory plan

Level Production (Work Force) Plan

Level production (work force) plan uses inventory produced in off peak periods to satisfy demand in peak periods and is called a *level production* or *constant work force* plan because the same number of workers is used in each period.

Average workers needed/day = [(total # of gears) ÷ [(total # of days) * (gear/worker-day)]

= [(19,670) ÷ (4x129)] = 38.12 workers.

$\Rightarrow$ 39 workers.

TABLE 5-3

Constant production: Backorders

		January	February	March	April	May	June	Total
1	Days	21	20	23	21	22	22	129
2	Units/worker	84	80	92	84	88	88	516
3	Demand	2,760	3,320	3,970	3,540	3,180	2,900	19,670
4	Workers needed	39	39	39	39	39	39	234
5	Workers available	35	39	39	39	39	39	na
6	Workers hired	4	0	0	0	0	0	4
7	Hiring cost	1,800	0	0	0	0	0	1,800
8	Workers laid off	0	0	0	0	0	0	0
9	Lay-off cost	0	0	0	0	0	0	0
10	Workers used	39	39	39	39	39	39	234
11	Labor cost	98,280	93,600	107,640	98,280	102,960	102,960	603,720
12	Units produced	3,276	3,120	3,588	3,276	3,432	2,978	19,670
13	Net inventory	516	316	−66	−330	−78	0	na
14	Holding cost	2,580	1,580	0	0	0	0	4,160
15	Backorder cost	0	0	990	4,950	1,170	0	7,110
16	Total cost	102,660	95,180	108,630	103,230	104,130	102,960	616,790

Production = four units/worker/day
Hiring cost = $450/worker
Holding cost = $5/unit/month
Wages and benefits = $120/worker/day
Firing cost = $600/worker
Backorder cost = $15/unit/month

The timing of peak demands was not considered in this approach. Cumulative production through March was less than cumulative demand. As a result, in March, inventory becomes -66.

Negative inventory, called **backorders**, will be made and delivered at a later date.

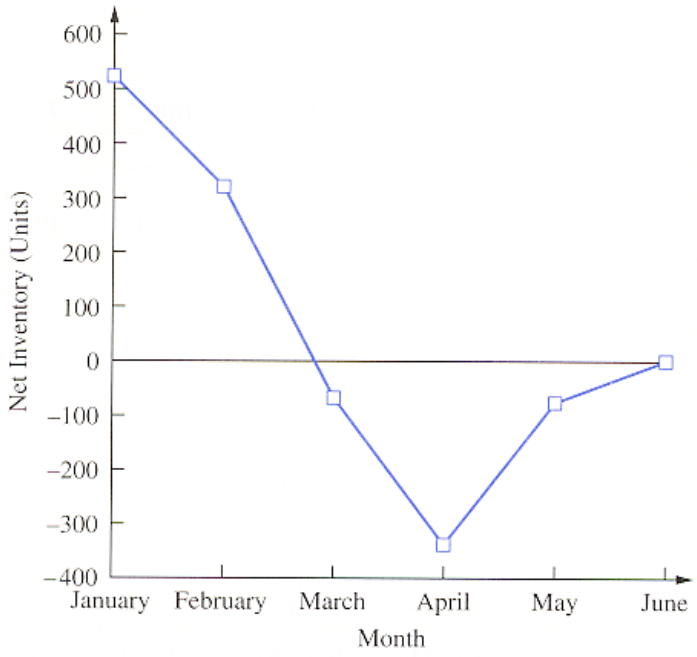

FIGURE 5-3
Constant production—backorders

The plan finishes with no inventory, 39 workers and a cost of $616,790. Unlike the zero inventory plan, this plan has a constant work force and varying inventory. It minimizes the hiring and firing costs, but increased holding and backorder costs.

What should we do if backorders are not allowed?

Aggregate demand forecast for gears:

Month	Jan	Feb	March	April	May	June	Total
Demand	2760	3320	3970	3540	3180	2900	19,670
Cumulative dem.	2760	6080	10050	13590	16770	19670	19,670
Days available	21	20	23	21	22	22	129
Cumulative days	21	41	64	85	107	129	
Workers needed	33	42	44	43	37	33	232
Cumulative wrk.	33	38	40	40	40	39	39

Therefore, a constant workforce of 40 is needed in each month.

TABLE 5-5
Constant production: No backorders

		January	February	March	April	CMay	June	Total
1	Days	21	20	23	21	22	22	129
2	Units/worker	84	80	92	84	88	88	516
3	Demand	2,760	3,320	3,970	3,540	3,180	2,900	19,670
4	Workers needed	40	40	40	40	40	40	240
5	Workers available	35	40	40	40	40	40	na
6	Workers hired	5	0	0	0	0	0	5
7	Hiring cost	2,250	0	0	0	0	0	2,250
8	Workers laid off	0	0	0	0	0	0	0
9	Lay-off cost	0	0	0	0	0	0	0
10	Workers used	40	40	40	40	40	40	234
11	Labor cost	100,800	90,600	110,400	100,800	105,600	105,600	619,200
12	Units produced	3,360	3,200	3,680	3,350	3,180	2,900	19,670
13	Net inventory	600	480	190	0	0	0	na
14	Holding cost	3,000	2,400	950	0	0	0	6,350
15	Backorder cost	0	0	0	0	0	0	0
16	Total cost	106,050	98,400	111,350	100,800	105,600	105,600	627,800

Production = four units/worker/day
Hiring cost = $450/worker
Holding cost = $5/unit/month
Wages and benefits = $120/worker/day
Firing cost = $600/worker
Backorder cost = $15/unit/month

Q: Why not produce 3360 in t=4 and 10 less in t=1?

At the end of June, there is no inventory, a work force of 40 people, and a six month cost of $627,800.

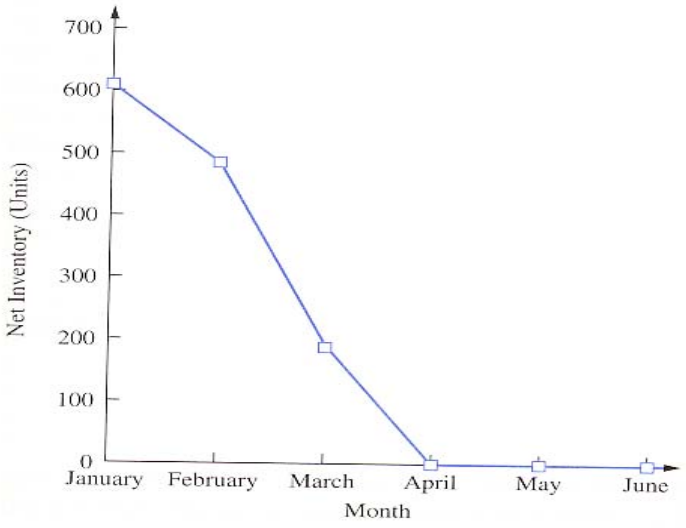

FIGURE 5-4
Constant production: No backorders

Mixed Plans

So far we have only considered pure strategies. Usually, mixed plans allowing inventory, backorders, and changing work force levels are superior to pure strategies.

The number of workers used in this plan is an educated guess based on the zero inventory and level workforce plans.

TABLE 5-6
A mixed plan

		January	February	March	April	May	June	Total
1	Days	21	20	23	21	22	22	129
2	Units/worker	84	80	92	84	88	88	516
3	Demand	2,760	3,320	3,970	3,540	3,180	2,900	19,670
4	Workers needed	38	38	42	42	35	35	230
5	Workers available	35	38	38	42	42	35	na
6	Workers hired	3	0	4	0	0	0	7
7	Hiring cost	1,350	0	1,800	0	0	0	3,150
8	Workers laid off	0	0	0	0	7	0	7
9	Lay-off cost	0	0	0	0	4,200	0	4,200
10	Workers used	38	38	42	42	35	35	230
11	Labor cost	95,760	91,200	115,920	105,840	92,400	92,400	593,520
12	Units produced	3,192	3,040	3,864	3,528	3,080	2,966	19,670
13	Net inventory	432	152	46	34	−66	0	na
14	Holding cost	2,160	760	230	170	0	0	3,320
15	Backorder cost	0	0	0	0	990	0	990
16	Total cost	99,270	91,960	117,950	106,010	97,590	92,400	605,180

Production = four units/worker/day
Hiring cost = $450/worker
Holding cost = $5/unit/month
Wages and benefits = $120/worker/day
Firing cost = $600/worker
Backorder cost = $15/unit/month

This mixed plan costs $605,180 and ends with 35 employees and no inventory.

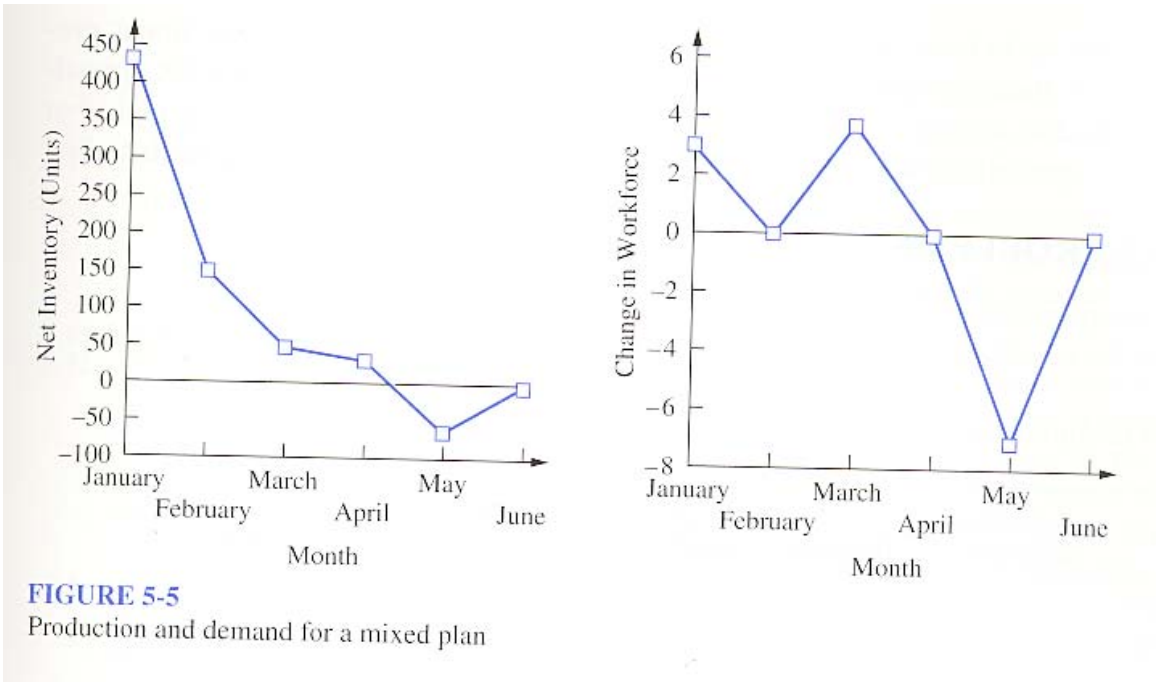

FIGURE 5-5
Production and demand for a mixed plan

Comparing Plans

We have examined four plans: zero inventory (**Zero Inventory**), constant work force with backorders (**Level/ BO**), constant work without backorders (**Level/ NBO**), and a mixed plan (**Mixed**).

	Zero Inventory	**Level/ BO**	**Level/ NBO**	**Mixed**
Hiring cost	4,950	1,800	2,250	3,150
Lay-off cost	7,800	0	0	4,200
Labour cost	59,856	603,720	619,200	593,520
Holding cost	0	4,160	6,350	3,890
Backorder cost	0	7,110	0	990
Total cost	611,310	616,790	627,800	**605,750**
Workers	33	39	40	35

The mixed plan is the least costly and will likely be preferred.