BUSI4496 Supply Chain and Operations Planning

Aggregate Planning

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Today's Content

1. Learning Objectives
2. Introduction to Aggregate Planning
3. The Aggregate Planning Process
    I. Units of production,
    II. Problem overview
    III. Aggregate planning strategies
4. Aggregate Planning Worked Example

1. Learning Objectives

01

Understand the importance of aggregate planning

02

Identify when to apply different aggregate planning techniques

03

Apply aggregate planning techniques and interpret the output of different strategies

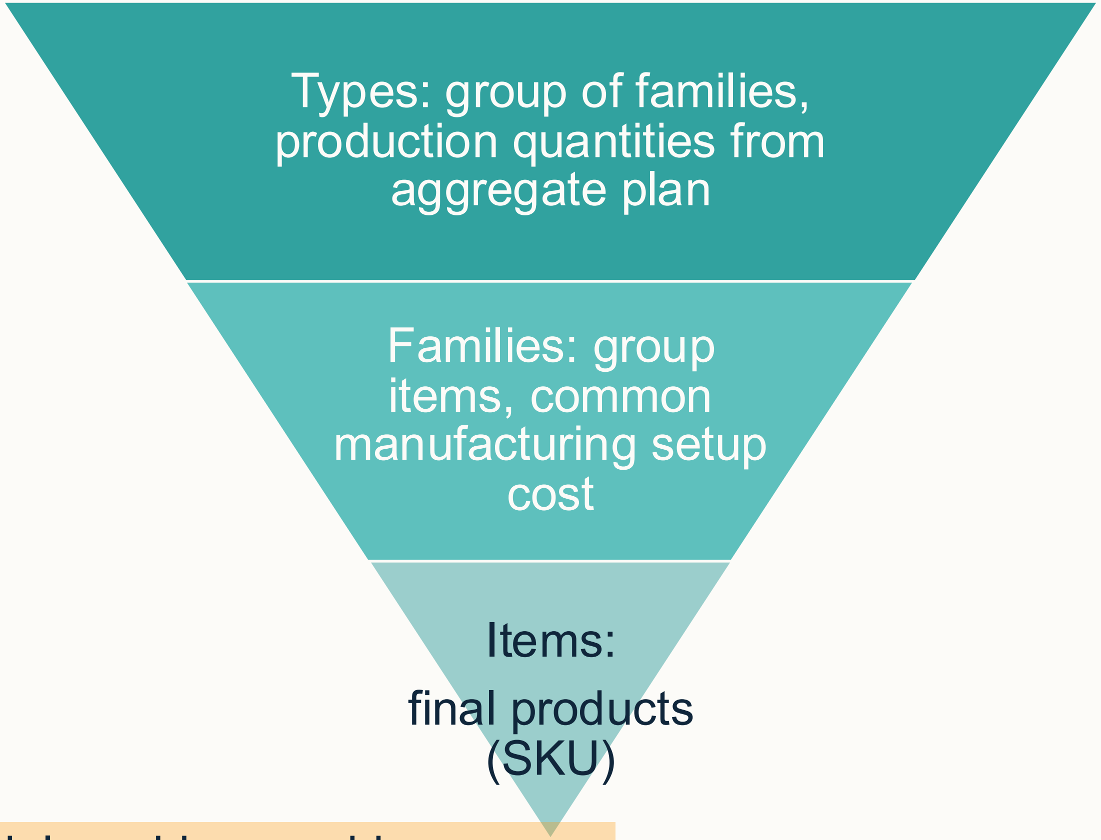
Introduction to Aggregate Planning

Intro to aggregate planning

Intro to aggregate planning

Key concept: manage groups of items rather than single items – aggregate units of production

- Aggregate planning is closely related to **hierarchical production planning** (HPP) (Hax & Meal, 1975).
- HPP considers workforce sizes and production rates at several levels of the firm.



Example: Items = individual model washing machine; Family = all washing machines; Type = large appliance

Intro to aggregate planning

Typically works at **product level**
Working with groups of items as opposed to individual item

Is based on **likely demand** and **response policy**

Considers known **constraints** on major **facilities** or **resources** (aka bottlenecks)

Not only important for manufacturing industries but also useful in service industries
Here the focus is on **staffing requirements**

Intro to aggregate planning

The main purpose of an aggregate plan is to specify the optimal combination of		
Production rate	Workforce level	Inventory on hand

As such there are trade offs to be made…

Ability to react quickly to changes: hiring and firing of workforce

Associated costs with varying capacity!

Stability: build up of inventory during demand period

Maximising profit: balancing cost of carrying inventory vs lost sales

The Aggregate Planning Process

The Aggregate Planning Process

Hierarchy of production planning decisions:

Forecast of aggregate demand for t period horizon

↓

Aggregate Production Plan

Determination of aggregate production and workforce levels for t period planning horizon

↓

Master Production Schedule (MPS)

Production levels by item by time period

↓

Materials Requirements Planning System (MRP)

Detailed timetable for production and assembly of components and subassemblies

Aggregate planning: units of production

Aggregate planning assumes the existence of aggregate units of production

how to define is not always straightforward…

‘average unit’

(in case types of items are similar)

aggregate units in terms of weights (tonnes of steel), volume, amount of work required, sales £ volume … for different types of items

Aggregate planning: units of production

Example: Suppose you work for a company that produces different varieties of granola, with the following characteristics: labour hours, sales price, market share (sales volume)

Type	# Working hours	Price (£)	Sales volume (%)
Nut	3.4	1.20	31
Blueberry	3.9	4.50	18
Strawberry	4.1	316	15
Raisin	4.2	340	17
Original	4.3	420	12
Mized	4.6	580	7

Aggregate planning: units of production

Possible aggregation schemes:

Aggregate unit = one £ of output

(***but*** selling prices are **not** proportional with worker hours required to produce each type of washing machine)

If sales volumes (%) are fairly constant over time:

Define an average unit:

fictitious variety requiring average labour time:

= (3.4*0.31) + (3.9*0.18) + (4.1*0.15) + (4.2*0.17) + (4.3*0.12) + (4.6*0.07)

= 3.923 hours of labour time.

What if sales volume (%) changes over time?

No direct link with revenue anymore!

Aggregate unit = worker hours

Aggregate planning: problem overview

Aggregate planning will translate aggregate demand forecast into a blueprint for planning staffing and production over a certain horizon.

We need to know:

- Demand (aggregate forecasts): assumption ‘known’ → focus is on predictable changes in demand pattern
- Aggregate units: considered ‘available’
- Planning horizon (6-12 months) / periods (1 month)
- Constraints (e.g. bottlenecks, max capacity etc)
- Costs

Aggregate planning: problem overview

Costs in aggregate planning
• Smoothing cost: Hiring c_H & Firing c_F • Holding (inventory) cost: c_I • Backordering (shortage) cost: c_P • Regular time (labour) cost: c_R • Overtime and subcontracting cost: c_O and c_S • Idle cost per unit of production (underutilisation): c_U

System parameters
• K = # of agg. units produced by one worker/day • n_t = # of production days in period t

Assume all costs are linear

Aggregate planning: Strategies

1 **Chase strategy**: using capacity to meet demand

- Varying machine capacity
- Hiring/firing workers
- Low levels of inventory

2 **Constant workforce:** using scheduling (of workforce/production) to meet demand

- Maintain constant workforce/machine capacity
- Fluctuation of inventory levels

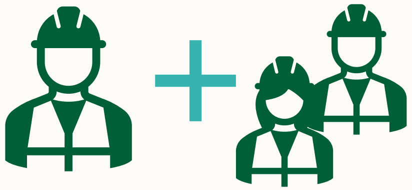
3 **Mixed strategy:** using capacity and inventory to meet demand

- Variations in workforce
- Outsourcing of production
- Fluctuation in inventory levels

Now, let's go through an example

Aggregate planning: an example

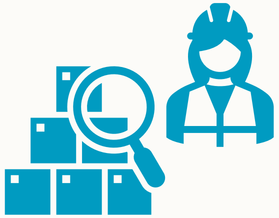
So, we have three different strategies meet our aggregate plan...



Chase strategy

(Zero inventory plan): change workforce **each** month and produce just enough to meet demand

Constant workforce plan: maintain minimum constant workforce to satisfy demand



Mixed strategy

Use a combination of inventory and workforce change to satisfy demand

Aggregate planning: an example

A company produces two products (P1 and P2), they operate with a 6-month planning horizon and a one-month planning period.
Forecasts for P1 and P2 are given as:

Product 1	1100	600	900	1200	2000	1300
Product 2	500	500	600	400	600	800

The company starts with initial inventory of 200 and 100 units of P1 and P2 respectively and always holds 300P1 and 200P2 units in inventory at the end of the planning horizon.

Currently 45 employees are employed, working 8 hours per day
The production rate per worker for P1 is 5 hours, and P2 is 6 hours

Here we assume no underutilisation

Costs:
Cost of hiring = c_H = £500
Cost of firing = ; c_F = £1000
Inventory holding cost c_I = £2 **per aggregate unit of production** per month
Shortages are not permitted
Production days per month n_t: 20, 24, 20, 25, 21, 16

charged on inventory at end of each period

Aggregate planning: an example

First, let's calculate net demand:

- Calculate net demand: subtract initial inventory from demand in first period; add ending inventory to demand last period
- Aggregate units = working hours
- Demand (in hours) = 5*net demand P1 + 6*net demand P2

Month	P1	P1 Net demand	P2	P2 Net demand	Aggregate units (working hours)	Cumulative
	Initial inventory = 200		Initial inventory = 100			
1	1100	1100-200=900	500			
2	600	600	500			
3	900	900	600			
4	1200	1200	400			
5	2000	2000	600			
6	1300	1300+300=1600	800			
	End inventory = 300		End inventory = 200			

Aggregate planning: an example

Chase strategy

(1) Calculate number of workers hired / fired each month: compare each month demand forecast with productivity

Month	Demand (Aggregate units)	Working days	Hours per worker	Workers required	Workers (rounded)	Workers hired	Workers fired
1	6900	20					
2	6000	24					
3	8100	20					
4	8400	25					
5	13600	21					
6	1400	16					
					Total	**87**	**22**

Aggregate planning: an example

Chase strategy

- **(2) Production and inventory levels**

Inventory(t) = Inventory(t-1) + Production(t) – Demand(t)

Month	Demand (Aggregate units)	Hours per worker	Workers (rounded)	Production	Inventory
1	6900	160	44		
2	6000	192	32		
3	8100	160	51		
4	8400	200	42		
5	13600	168	81		
6	1400	128	110		
				Total	**1896**

Aggregate planning: an example

Chase strategy

In a chase strategy (zero inventory plan), the production curve should (almost) coincide with the demand curve

Costs:

(Correction for ending inventory of P1 and P2 see slide 11)

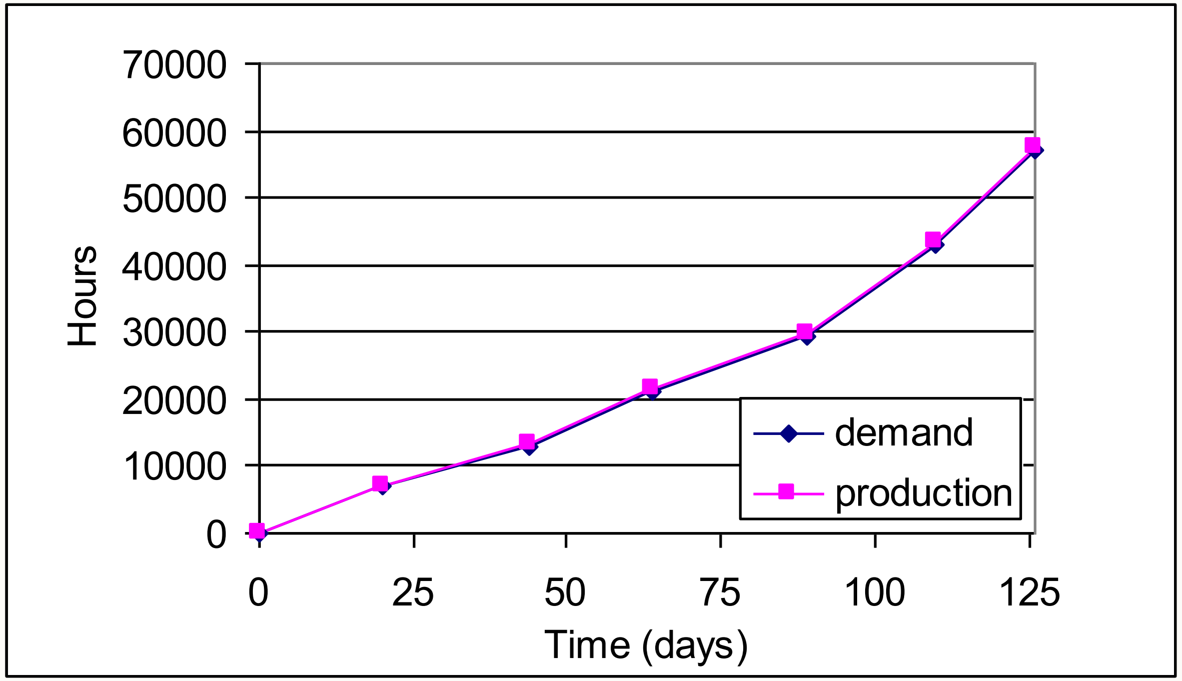
Hiring: 87*£500 = £43500

Firing: 22*£1000 = £22000

Inventory holding = £2*(1896 + 5*300 + 6*200) = £9138

Total = £74638

Note: Assume inventory holding cost is £2 per hour of production per month)



Aggregate planning: an example

Minimum constant workforce

(1) Calculate minimum number of workers required: compare cumulative demand forecast with cumulative productivity

Month	Cumulative demand	Days	Days cumulative	Hours per worker (cumulative)	Minimum workers required
1	6900	20	20		
2	12900	24	44		
3	21000	20	64		
4	29400	25	89		
5	43000	21	110		
6	57000	16	126		

We need 57 workers

Current worker level: 45 so we need to hire 12 workers

Look for the maximum to find how many workers we need

Aggregate planning: an example

Minimum constant workforce

(2) Production and inventory levels

Inventory(t) = Inventory(t-1) + Production(t) – Demand(t)

Month	Demand (Aggregate units)	Hours per worker	Workers	Production	Inventory
1	6900	160	57		
2	6000	192	57		
3	8100	160	57		
4	8400	200	57		
5	13600	168	57		
6	1400	128	57		
				Total	**36368**

Aggregate planning: an example

Minimum constant workforce

Evaluation of strategy

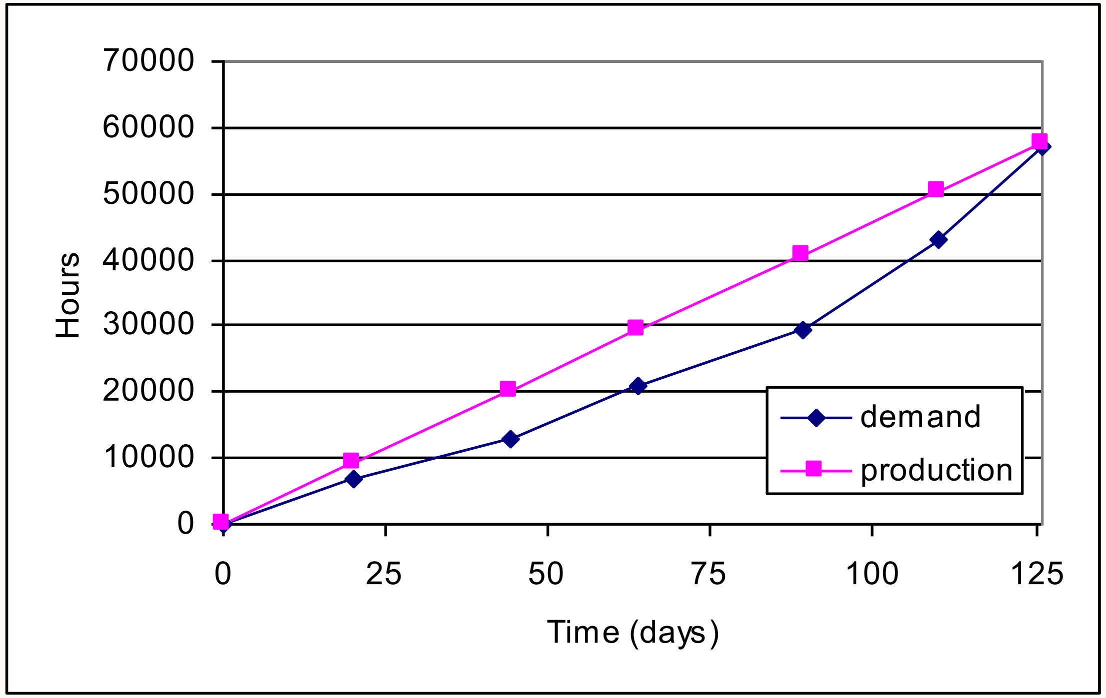
Costs:

Hiring: 12*£500 = £6000

Firing: 0

Inventory holding = £2*(36368 + 5*300 + 6*200) = £78136

Total = £84136

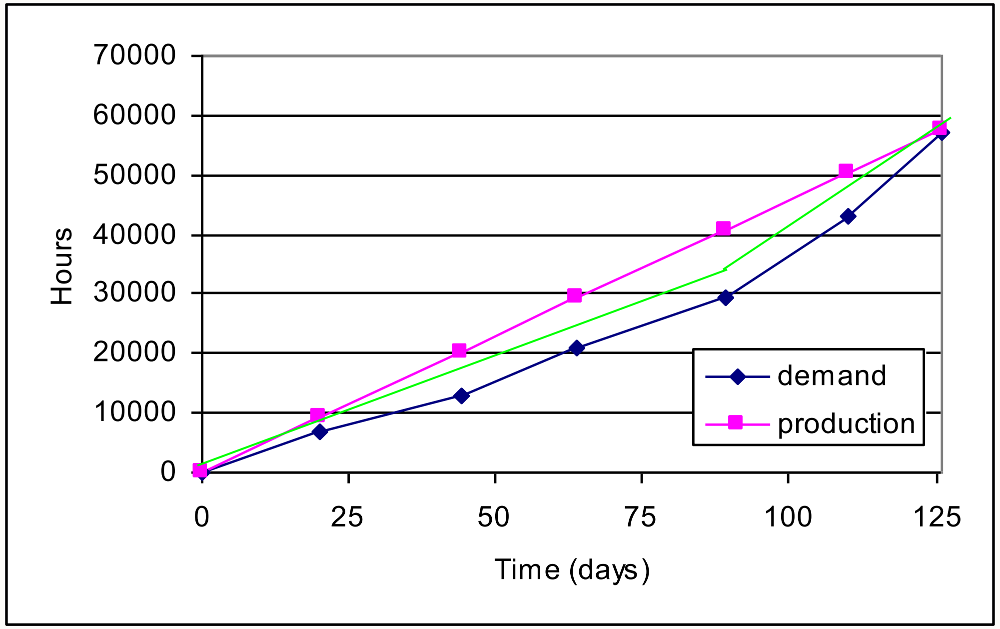


In constant workforce plan, the production curve plots as a straight line (if time is measured on a continuous scale)

Aggregate planning: an example

Mixed strategies

- Small changes to pure strategies may dramatically reduce costs
- Typically solved via Linear Programming (exact solution)
- Graphical representation may help to provide insight e.g. what if you change workforce level only once – how to reduce inventory?



Inventory = area between cum. production and cum. demand curves

(assume cum. prod >= cum. demand)

Reduce area (no shortages):

Approach the cumulative demand curve by two straight lines: keep workforce at 45 until month 4; then change to 85.

Aggregate planning: an example

Mixed strategies

- Evaluation of mixed strategy:

Month	Demand (aggr. units)	# hours per worker	# workers (rounded)	Production	Inventory
1	6900	160	45	7200	300
2	6000	192	45	8640	2940
3	8100	160	45	7200	2040
4	8400	200	45	9000	2640
5	13600	168	85	14280	3320
6	14000	128	85	10880	200
				Total	11440

Costs

Hiring: 40*£500 = £20000

Firing: 0

Inventory holding = £2*(11440 + 5*300 + 6*200) = £28280

Total = £48280

Other strategies

- In previous examples we illustrated a chase strategy by changing the ‘permanent’ workforce level (hiring and firing workers).

  Other ways to achieve more flexibility could be:

  - workers work 8h per day (regular time) but they can work overtime (if required) - specify regular labour cost and overtime labour cost
  - instead of adjusting the permanent workforce level you may hire temporary workers (again at a specific rate)
  - you may outsource part of the production (if it cannot be met by regular time labour)
  - any combination of the above

Practice makes perfect

- Worksheets provide you with an opportunity to work through aggregate planning questions
- The additional material will provide cover a worked example

Thank you

See you next week!