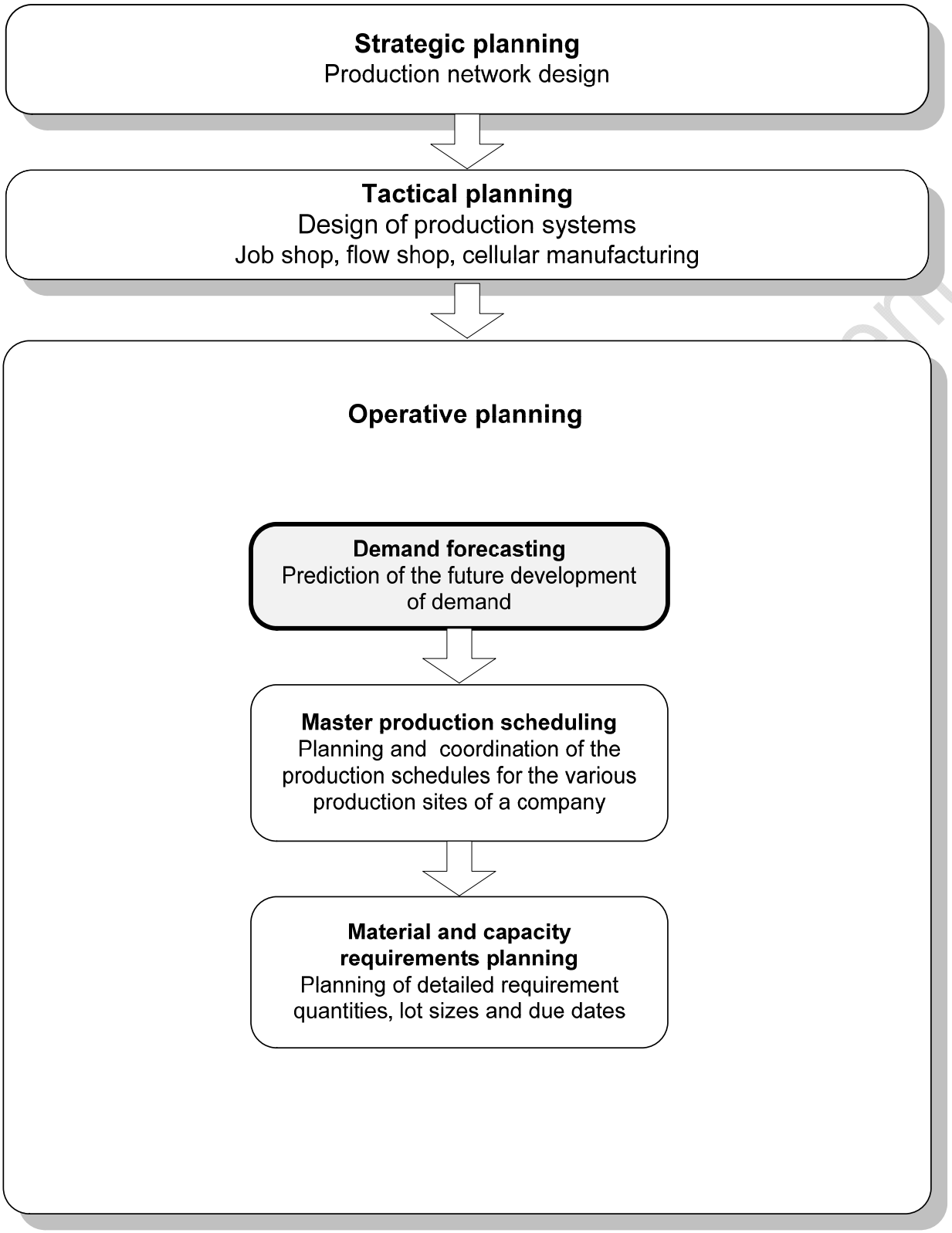
4. Demand forecasting


Strategic planning
Production network design
Tactical planning
Design of production systems
Job shop, flow shop, cellular manufacturing
Operative planning
Demand forecasting
Prediction of the future development of demand
Master production scheduling
Planning and coordination of the production schedules for the various production sites of a company
Material and capacity requirements planning
Planning of detailed requirement quantities, lot sizes and due dates

- **Purpose and contents of the operational planning level**

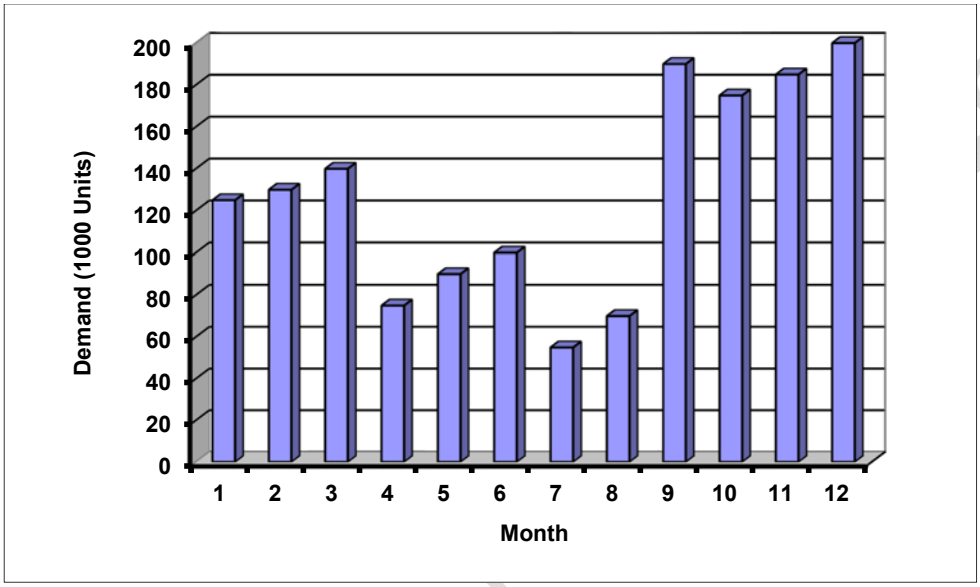
  ⇒ Smoothing of **seasonal variations** of capacity requirements and available capacity

  ⇒ Determination of the **master production schedule**: Which **products** shall be produced in which quantities in the various periods during the planning horizon?

  ⇒ **Procurement planning**: Which quantities of the **input materials** (raw materials, supplied part and in-house sub-assemblies) are needed for the fulfilment of the master schedule?

- **Smoothing of demand and production based on forecasts**

Example: Demand of a consumer electronics product in Europe



Which measures can be taken to match production and demand?

- Overtime / Extra shifts
- Outsourcing
- Rent machinery

Which are the pros and cons of a "chase demand" vs. a "level production" strategy?

CHASE DEMAND	LEVEL PRODUCTION
- Lower inventory cost	- less dependant on supply chain

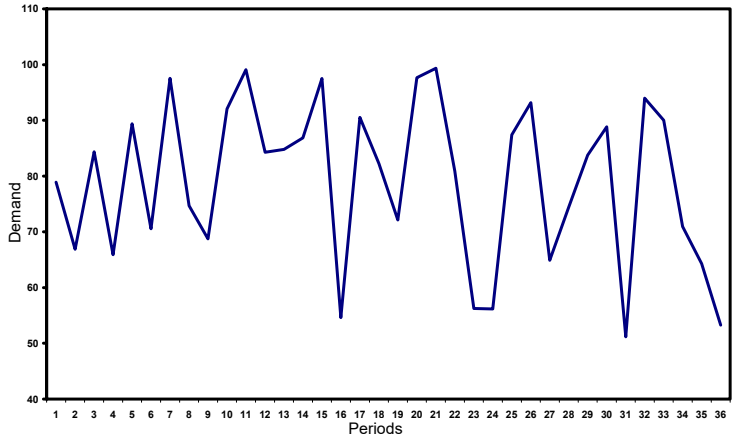
4. Demand forecasting

⇒ Prediction of future values of a time series under uncertainty (based on historical values)

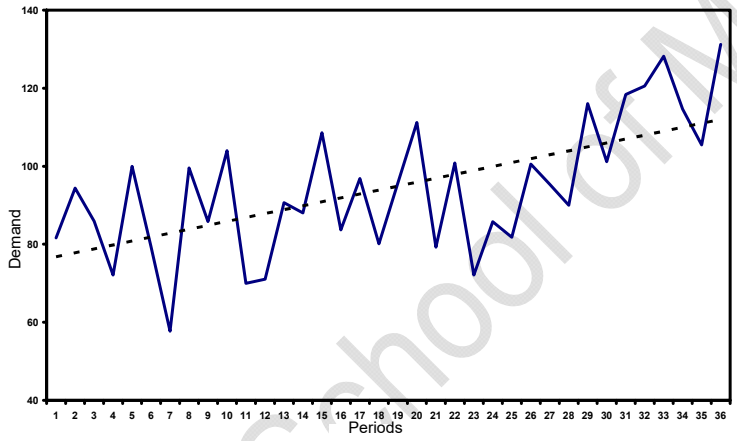
⇒ Forecast horizon depends on the particular application

- **Types of time series**

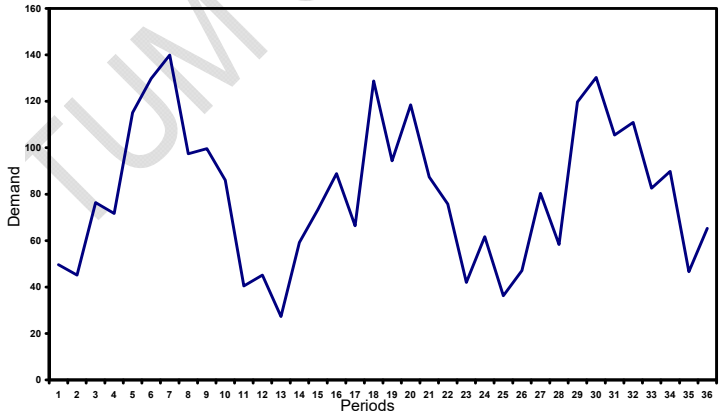
⇒ Level demand



⇒ Linear trend



⇒ Seasonal variation



Procedure of time series based forecasting

1. Analysis of the **characteristics of a time series**

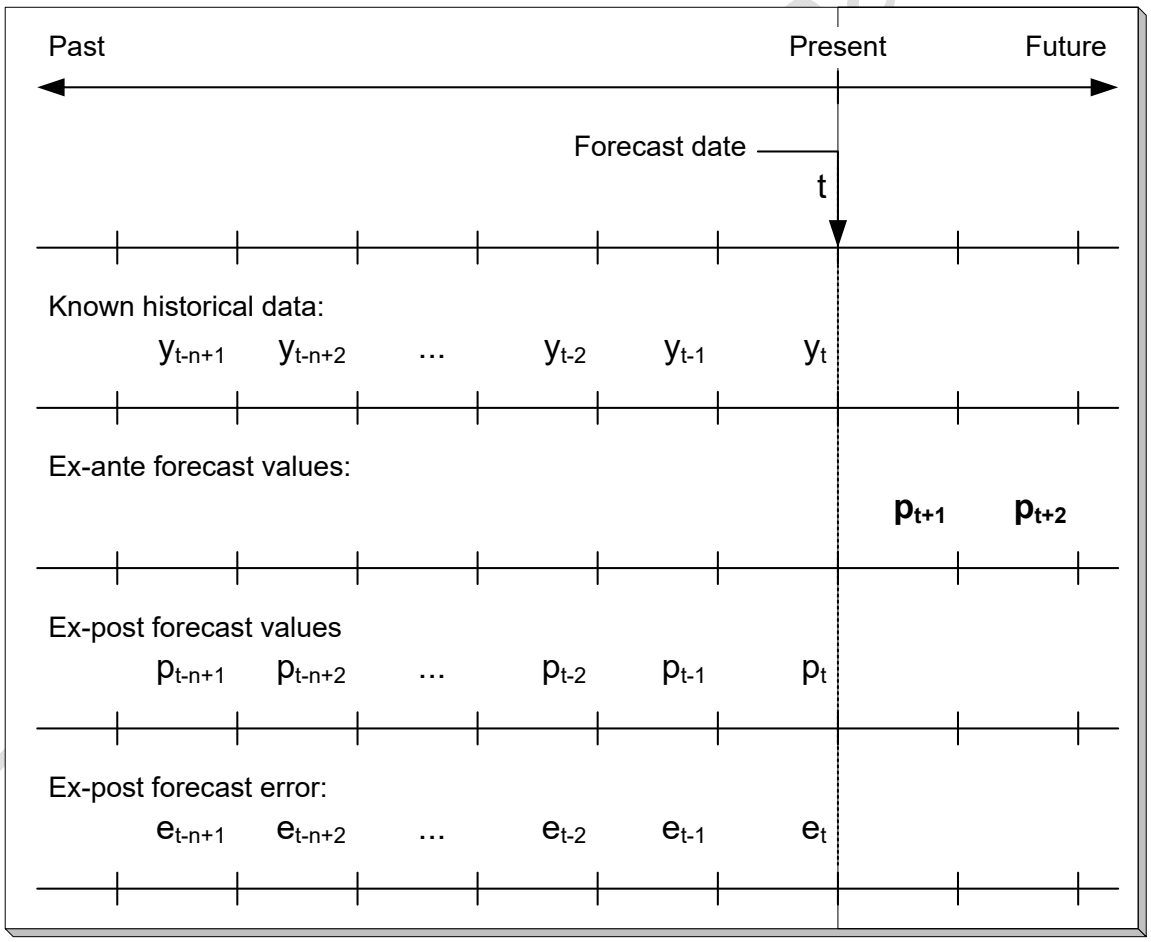
   ⇒ Long-term **trend**

   ⇒ Mid-term **cyclical variations** (e.g. economic cycles, product lifecycle)

   ⇒ **Seasonal fluctuations** (e.g. annual seasons)

   ⇒ Random **variations**
2. Selection of an appropriate **forecast model**
3. Estimation of the **coefficients** of the forecast model
4. **Application** of the forecast model (calculation of forecast values)
5. Monitoring and analysis of the **forecast accuracy** over time

- **Data structure of demand forecasts**



- **Simple exponential smoothing**

  ⇒ Assumed demand process: random variations around a **constant demand level**

  ⇒ Forecast

$$P_{t+1} =$$

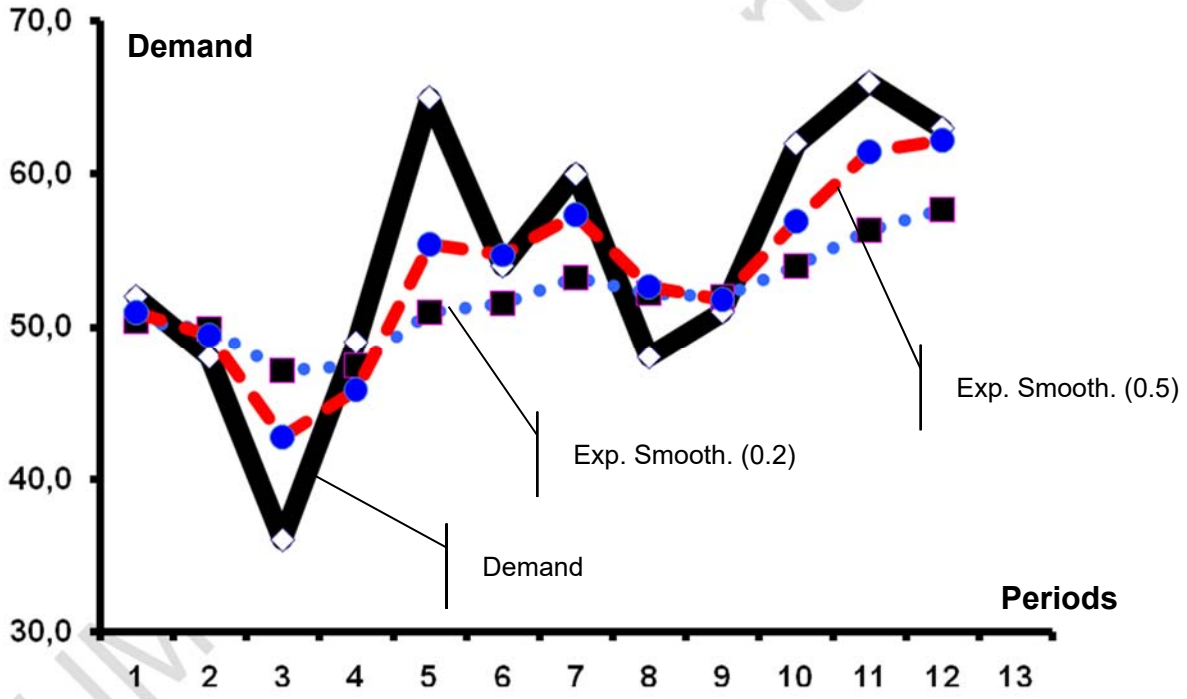
$y_t =$ observed demand in period t

$P_{t+1} =$ forecast for period $t+1$

$\alpha =$ smoothing parameter (generally $0.1 \leq \alpha \leq 0.3$)

⇒ **Initialization**: Before the first forecast,(for $t=1$) an adequate initial value P_o has to be determined (estimate of the level demand); often y_o is chosen.

⇒ **Smoothing parameter** α: determines the strength of the smoothing effect



Simple exponential smoothing

For a specific product the historical demand process was analyzed at the end of period 0. The analysis showed that demand fluctuated randomly around a mean of 80. Hence, simple exponential smoothing was chosen as a forecasting method with smoothing parameter α=0.2. The historical demand value observed for period 0 was 90 units.

a) Calculate the demand forecast for t=1.

b) In period t=1, a demand of y_1 = 50 was observed. Calculate the demand forecast for t=2.

c) In period t=2, a demand of y_2 = 120 was observed. Calculate the demand forecast for t=3.

d) In period t=3, a demand of y_3 = 70 was observed. Calculate the demand forecast for t=4.

e) In period t=4, a demand of y_4 = 80 was observed. Calculate the demand forecast for t=5.

f) In period t=5, a demand of y_5 = 100 was observed. Calculate the demand forecast for t=6.

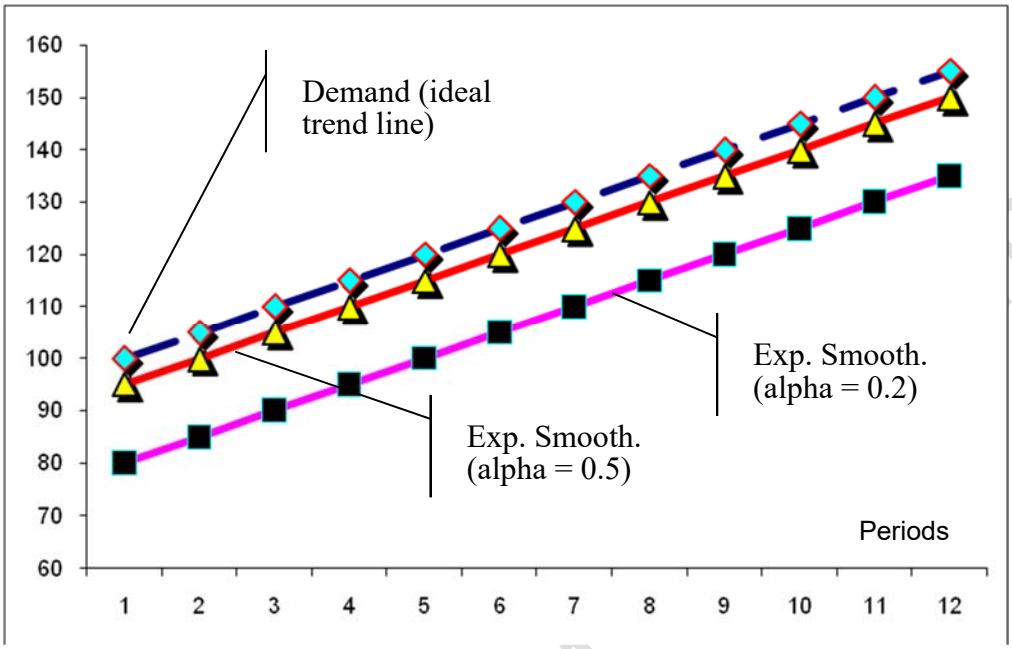
(1) There was a demand of 100 product units in period t=5. Which is the value of the forecasted demand for period t=6?
   a. 81.27
   b. 100.6
   c. 84.33
   d. 85.02

(2) The company wants to calculate in period t=5 a demand forecast for period t=7. What is the value for the forecast?
   a. 85.02
   b. 84.48
   c. 84.33
   d. 100.00

- **Exponential smoothing with trend adjustment**

  ⇒ Assumed demand process: random variations around a **linear trend**, i.e. a time series of the type $y_t = A + B \cdot t + \varepsilon_t$ is assumed

  ⇒ Application of the simple exponential smoothing method to a linear trend time series causes a **systematic error**



⇒ **Trend adjustment** (correction factor) $\frac{1-\alpha}{\alpha} \cdot b$

where

b = trend increase per period

α = smoothing parameter

⇒ **Update of level demand** at the end of period t

$$a_t = \alpha \cdot y_t + (1-\alpha) \cdot a_{t-1}$$

⇒ **Update of trend** at the end of period t

$$b_t = \alpha \cdot (a_t - a_{t-1}) + (1-\alpha) \cdot b_{t-1}$$

⇒ **Forecast determination** for periods t+1, t+2, …, t+n

$$P_{t+\tau} = a_t + b_t \cdot \frac{1-\alpha}{\alpha} + \tau \cdot b_t \qquad \tau = 1,2,...,n$$

⇒ **Initialization**: Before the first forecast determination (for $t=1$) adequate initial values a_o and b_o have to be determined, e.g. through linear regression

$$a_0 = y_0 - \frac{1-\alpha}{\alpha} \cdot b_0$$

Exponential smoothing with trend adjustment

At the end of period t=0 the historical demand of a product was analyzed showing that the development of demand was characterized by a linear trend according to $y = 18 + 2 \cdot t$, i.e. level demand was estimated in t=0 as 18 and trend increase per period as 2 units.

a) Demand has to be forecasted by use of exponential smoothing with trend adjustment using α=0.2. Determine the initial value of level demand.

$a_0 = 18 - \frac{1-0.2}{0.2} \cdot 2 = 10$

b) Determine demand forecasts at the end of period t=0 for the subsequent periods t=1 and t=2.

$P_1 = 10 + \frac{1-0.2}{0.2} \cdot 2 + 1 \cdot 2 = 20$

$P_2 = 10 + \frac{1-0.2}{0.2} \cdot 2 + 2 \cdot 2 = 22$

c) Determine demand forecasts at the end of period t=1 for the subsequent periods t=2 and t=3. In period t=1 a demand of y_1 = 18 units was observed.

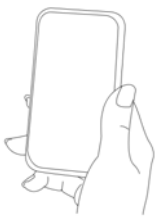
$a_1 = 0.2 \cdot 18 + 0.8 \cdot 10 = 11.6$

$a_2 = 0.2 (11.6 - 10) + 0.8 \cdot 2 = 1.92$

$P_2 = 11.6 + \left(\frac{1-0.2}{0.2}\right) \cdot 1.92 + 1 (1.92) = 21.2$

$P_3 = 11.6 + \left(\frac{1-0.2}{0.2}\right) \cdot 1.92 + 2 (1.92) = 23.12$

d) In period t=2, a demand of y_2 = 23 units was observed. Determine demand forecasts at the end of period t=2 for the subsequent periods t=3 and t=4.



a. P_3 = 25.04, P_4 = 26.96
b. P_3 = 23.84, P_4 = 23.84
c. P_3 = 23.84, P_4 = 25.83
d. a_2 = 13.88, b_2 = 1.992