KS SUPPLY CHAIN FUNDAMENTALS

03 Forecasting

SS 2025

JKU
PLM Institute of
Production and
Logistics Management

Learning goals

Being able to ...

- ... list features common to all forecasts.
- ... list elements of a good forecast.
- ... outline the steps of the forecasting process.
- ... compute forecast errors and error measures.
- ... define the difference between a qualitative and a quantitative forecasting method.
- ... employ the naive method to make a forecast and three basic methods: moving average, weighted average, and exponential smoothing.

Literature

Stevenson, WJ: Operations Management. McGraw-Hill Education Ltd; latest edition - Chapter 3

Acknowledgements: icons are by fontawsome (latex) or by Pixelmeetup from www.flaticon.com

Forecasts ...

- ... are a **basic input** in the decision processes of operations and supply chain management because they provide information on future demand.
- ... are essential to determine how much capacity or supply will be needed to meet demand (main objective of OM: **match supply and demand**).
- ... are especially important, if there are no orders at the time of planning. Most of the time, a **combination of orders and forecast demand** is used.
- ... consist of two important elements: the **expected** level of **demand** and the degree of **accuracy** (forecasting error).
- ... are made with reference to a specific **time horizon**. Short-term forecasts pertain to ongoing operations. Long-term forecasts can be an important strategic planning tool.

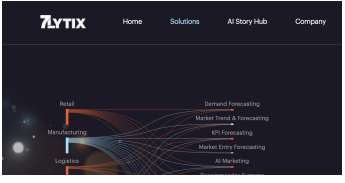
Walt Disney World employs 20 people in the forecasting department.

Forecasts ...

- ... are the **basis** for budgeting, capacity planning, sales, production and inventory, personnel, purchasing, and more.
- ... affect decisions and **activities throughout an organization**, in accounting, finance, human resources, marketing, and management information systems (MIS),...

Here: **Focus on forecasting the demand**, but a wide variety of things may be forecast (profits, revenues, costs, productivity changes, price and availability of energy and raw materials, interest, ...)

Example: AI based demand prediction:
`https://www.7lytix.com/`



Features common to all forecasts

1. Assumption, that the same underlying causal system that existed in the past will continue to exist in the future.
2. Forecasts are not perfect; actual results usually differ from predicted values; the presence of randomness precludes a perfect forecast.
3. Forecasts for groups of items tend to be more accurate than forecasts for individual items.
4. Forecast accuracy decreases as the time period covered by the forecast - the time horizon - increases.
5. Forecasts should not be used instead of available information.

Important: Managers should not use models alone. Events not covered by the forecasting model may have a large influence on future demand!

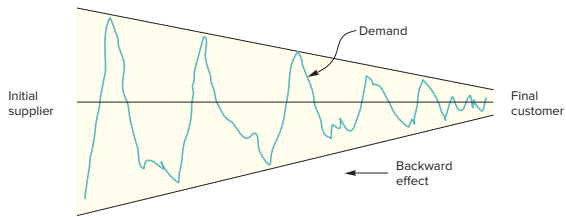
Elements of a good forecast

- Forecasts should be timely.
- Forecasts should be accurate.
- Forecasts should be reliable.
- Forecasts should be made using meaningful units.
- Forecasts should be in writing.
- The forecasting technique should be simple to understand and use.
- Forecasts should be cost-effective.

Forecasting and the supply chain (1)

- Inaccurate/wrong forecasts can lead to shortages and excesses throughout the supply chain.
- Negative effect may not only affect customer service, but can also affect profits.
- Wrong forecasts can lead to a temporary increase or reduction in orders, which can mislead the entire supply chain.

Bullwhip Effect



Source: Stevenson (2021)

Forecasting and the supply chain (2)

This problem can be addressed as follows:

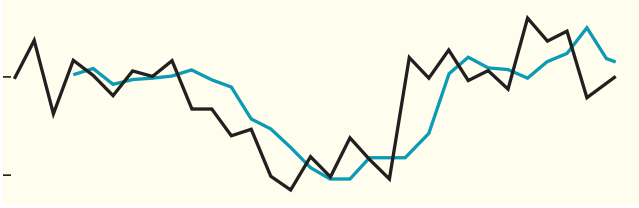
- Try to develop the best possible forecast.
- **Collaborative planning and forecasting** together with important partners in the supply chain.
- **Information sharing** with the partners.
- **Increase in supply chain visibility** (real-time access to sales and inventory information for partners)
- Rapid communication of bad forecasts and other incidents.

https://www.relexsolutions.com/resources/customer-voice-ica-sweden-shares-order-forecasts-with-suppliers-to-improve-collaboration/

The forecasting process

1. Determine the **purpose** of the forecast: detail, resource usage, accuracy.
2. Establish a **time horizon**.
3. Obtain, clean, and analyze appropriate **data**.
4. Select a **forecasting technique**.
5. Make the **forecast**.
6. Monitor the **forecast errors**.

Forecast quality



D_t	Demand at time t
F_t	forecast demand at time t
e_t	forecast error at time t
$e_t = D_t - F_t$	

$e_t < 0$ Forecast is too high

$e_t > 0$ Forecast is too low

Measuring forecast quality

Mean absolute deviation

$$\text{MAD} = \frac{1}{n} \sum_{t=1}^{n} |e_t|$$

Mean squared error

$$\text{MSE} = \frac{1}{n} \sum_{t=1}^{n} e_t^2 \text{ or } (\frac{1}{n-1} \sum_{t=1}^{n} e_t^2)$$

Mean absolute percentage error

$$\text{MAPE} = [\frac{1}{n} \sum_{t=1}^{n} \frac{|e_t|}{D_t}] \times 100$$

Example

	A	B	C	D	E	F	G
1	Period t	Demand D_t	Forecast F_t	e_t = D_t - F_t	|e_t|	e_t^2	|e_t|/D_t
2	1	217	215	2	2	4	0.009
3	2	213	216	-3	3	9	0.014
4	3	216	215	1	1	1	0.005
5	4	210	214	-4	4	16	0.019
6	5	213	211	2	2	4	0.009
7	6	219	214	5	5	25	0.023
8	7	216	217	-1	1	1	0.005
9	8	212	216	-4	4	16	0.019

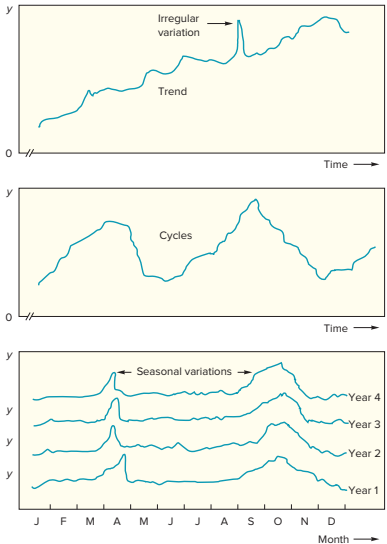
Calculate MAD, MSE und MAPE.

Forecasting methods

Subjective methods vs. Objective methods

- **Qualitative methods**
  - Surveys
  - Expert Panels
  - Executive Opinions
  - Salesforce Opinions
  - Delphi Method (iterative process based on surverys until a consensus is found)
- **Quantitative methods**
  - Based on time-series data (moving average, weighted average, exponential smoothing, Holt, Winters)
  - Regression
  - Simulation

Analyzing time series data



- Stationary
- Trend
- Seasonality
- Cycle
- Irregular variation
- Random variations

Naive method

- **Constant demand** the latest value of the time series is used as forecast for the next. ($F_t = D_{t-1}$)
- **Seasonal demand** the value of the time series corresponding to the same period of the last season is used as forecast for the next. Assumption: p periods per season. ($F_t = D_{t-p}$)
- **Trend** the difference between the latest two periods is added to the most recent value. ($F_t = D_{t-1} + T_0$, $T_0 = (D_{t-1} - D_{t-2})$)

Example

Period t	Demand D_t	T_0	Forecast
1	50		
2	53	+3	
3			53+3 =56

Averaging past demand

- Moving average
- Weighted moving average
- Exponential smoothing

Stevenson (2021)

→ Works well for stationary demand: $D_t = \mu + \epsilon_t$
with μ being a constant, ϵ_t being a random error with mean 0 und variance σ^2

Moving average

$$F_t = (1/n) \sum_{i=t-n}^{t-1} D_i = (1/n)(D_{t-1} + D_{t-2} + \ldots + D_{t-n})$$

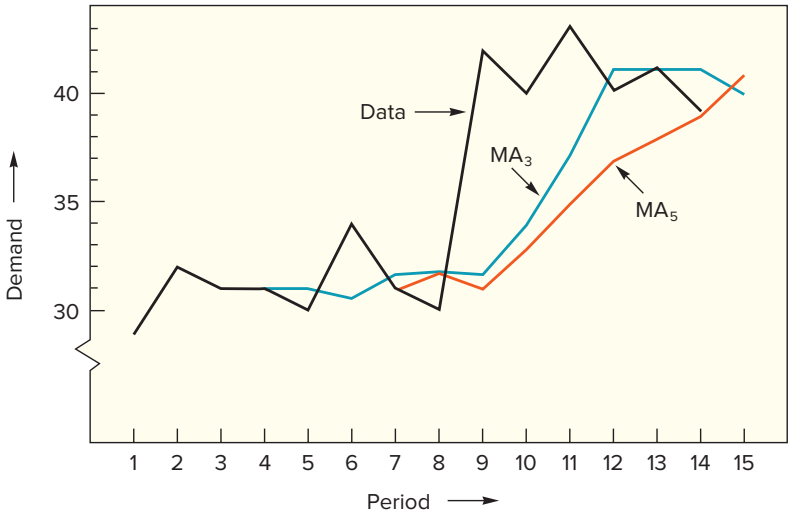
Example

Compute the demand for period 6 using the moving average of the last three periods.

Period t	Demand D_t
1	42
2	40
3	43
4	40
5	41

$$F_6 = (D_5 + D_4 + D_3)/3 = (41 + 40 + 43)/3 = 41.3$$

Moving average reacts slowly



Stevenson (2021)

Weighted moving average

$F_t = w_{t-n}(D_{t-n}) + ... + w_{t-2}(D_{t-2}) + w_{t-1}(D_{t-1})$ und $\sum_{i=1}^{n} w_{t-i} = 1$

Example

Compute the demand for period 6 using weighted moving average over 4 periods with weights $w_{t-1} = 0.4$, $w_{t-2} = 0.3$, $w_{t-3} = 0.2$ and $w_{t-4} = 0.1$

Period t	Demand D_t
1	42
2	40
3	43
4	40
5	41

$$F_6 = w_2 D_2 + w_3 D_3 + w_4 D_4 + w_5 D_5 =$$
$$= 0.1 \times 40 + 0.2 \times 43 + 0.3 \times 40 + 0.4 \times 41 = 41$$

Exponential smoothing

$$F_t = \alpha D_{t-1} + (1-\alpha)F_{t-1} = F_{t-1} + \alpha(D_{t-1} - F_{t-1}) = F_{t-1} + \alpha e_{t-1}$$

Example

Compute the demand for period 6 using exponential smoothing with ($\alpha = 0.1$) and $F_2 = D_1$

Period t	Demand D_t
1	42
2	40
3	43
4	40
5	41

$$F_3 = \alpha D_2 + (1-\alpha)F_2 = 0.1 \times 40 + 0.9 \times 42 = 41.8$$

$$\dots$$

$$F_6 = \alpha D_5 + (1-\alpha)F_5 = 41.66$$

Summary and outlook

- (Weighted) average based methods are slow to adjust to a trend.
- For time series data including an obvious **trend**, a method should be chosen that takes this trend into account (eg Holt's method or linear regression).
- For data sets that include **seasonal variability**, a method should be chosen that takes this seasonality into account (eg Winter's method, correction by including seasonality factors)
- If other/multiple factors should be considered to estimate demand, **regression analysis** can be chosen.
- Methods using **data mining** and **machine learning** are becoming more and more important in forecasting (not just the demand is predcited, but also eg probability of a customer extending their contract due to a tailored offer).