

Production Management (ME-419)

Module 2 – Demand Management

Holt-Winter Model

Amin Kaboli

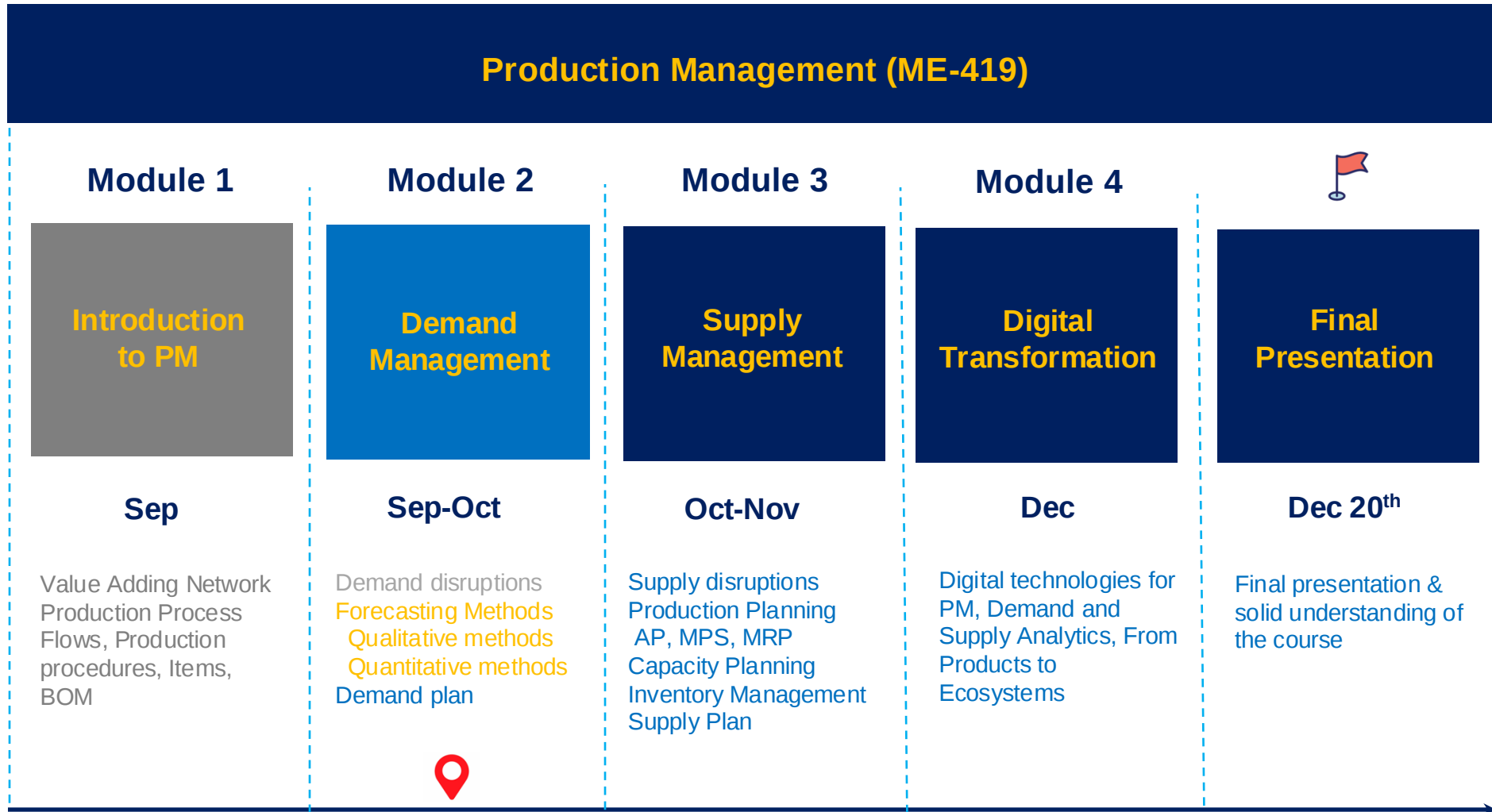
Week 5 – Session 1 – Oct 11th, 2024

Course Framework



Business plan

Strategic plan
Financial plan



Demand Management – Forecasting Steps



Demand forecast
at the item and
aggregate levels



Goal: What is the purpose of the forecast (Type of products, Granularity, Horizon)



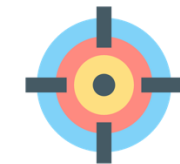
Data: Obtain, clean, and analyze appropriate data



Method: Select a forecasting method (Qualitative vs Quantitative)



Forecast: Make the forecast



Performance: Monitor the forecast errors

Demand Management – Forecasting Methods



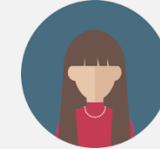
Demand forecast
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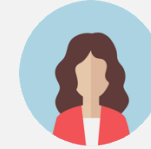
Forecasting
Methods



Qualitative methods



Executive
opinions



Salesforce
opinions



Customer
surveys



Delphi
method



Quantitative methods



Causal
models



Time
series



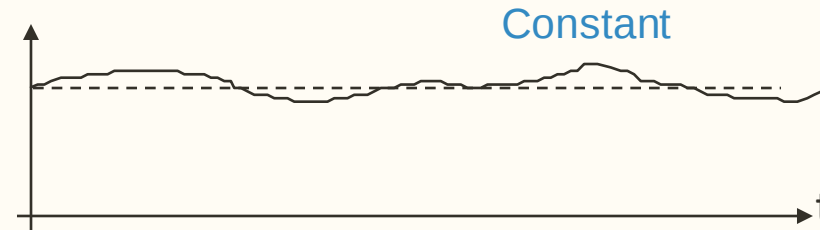
Machine
Learning

Time Series Models

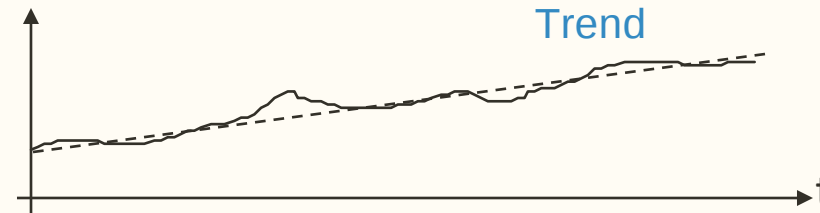


Time
Series

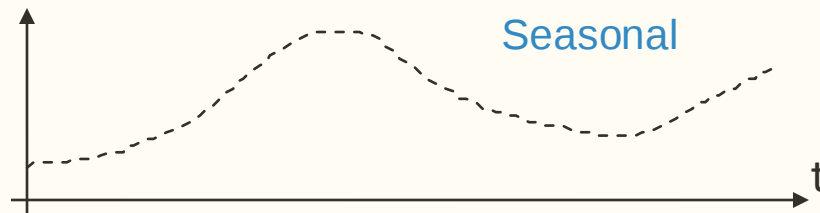
Stationary



Trend



Trend
+
Seasonality



Summary – Time Series – Stationary Models

1) Naïve:

$$F_{t+1} = Y_t$$

2) Simple mean:

$$F_{t+1} = \Sigma Y_t / n$$

3) Simple moving average:

$$F_{t+1} = \Sigma Y_t / n \quad \text{or} \quad F_{t+1} = \frac{1}{p} \sum_{i=0}^{p-1} [Y_{t-i}]$$

4) Weighted moving average:

$$F_{t+1} = \Sigma w_t * Y_t$$

5) Exponential Smoothing

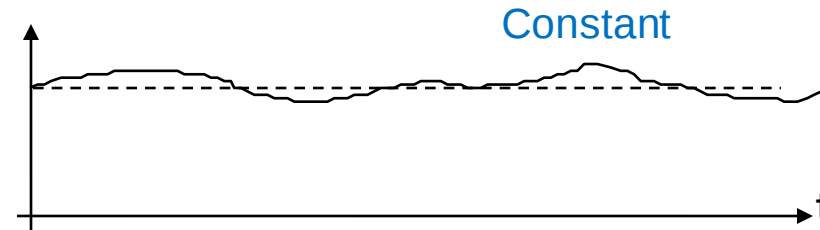
$$F_{t+1} = \alpha Y_t + (1 - \alpha) F_t$$

Time Series Models

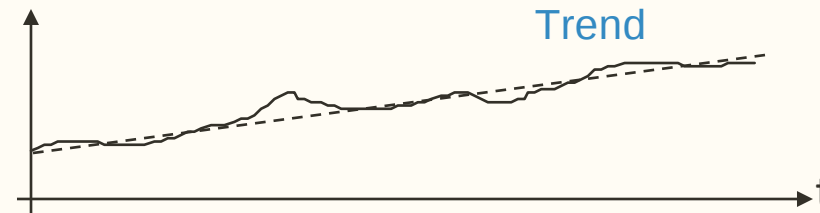


Time
Series

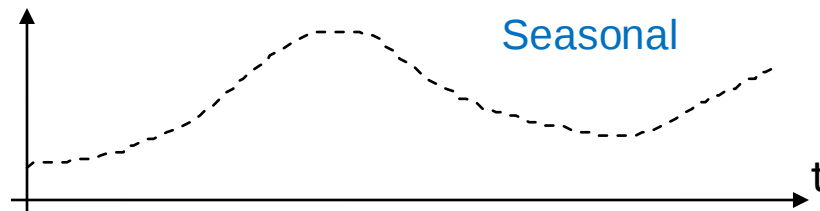
Stationary



Trend



**Trend
+
Seasonality**



Time Series – Trend (Holt Model)

An exponential smoothing model (with two smoothing equations) for data with trend:

Step 1) Forecast equation

$$F_{t+h} = B_t + hT_t \quad h = 1, 2, 3, \dots$$

Step 2) Level equation

$$B_t = \alpha Y_t + (1 - \alpha)(B_{t-1} + T_{t-1}) \quad 0 \leq \alpha \leq 1$$

Smoothing constant for the based level

Step 3) Trend equation

$$T_t = \beta (B_t - B_{t-1}) + (1 - \beta)T_{t-1} \quad 0 \leq \beta \leq 1$$

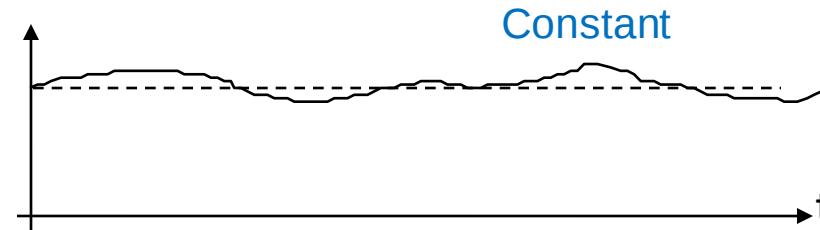
Smoothing constant for trend

Time Series Models

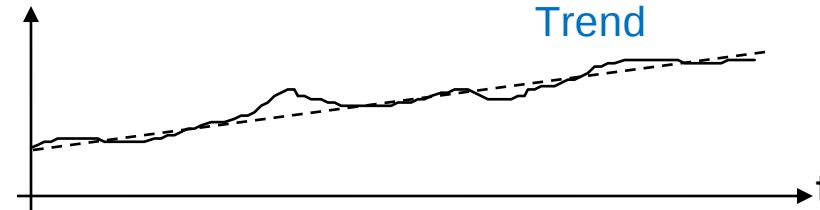


Time
Series

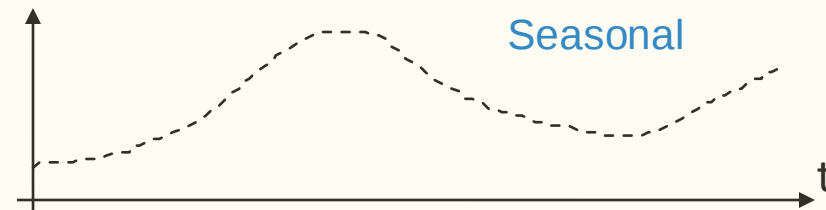
Stationary



Trend



Trend
+
Seasonality



Time Series – Trend & Seasonality (Holt-Winter Model)

An exponential smoothing model (with three smoothing equations) for data with trend + seasonality:

Step 1) Forecast equation

$$F_{t+h} = (B_t + hT_t) \times S_{t+h-c}$$

c: periodicity of the seasonal effect

Step 2) Level equation

$$B_t = \alpha \frac{Y_t}{S_{t-c}} + (1 - \alpha)(B_{t-1} + T_{t-1})$$

$$0 \leq \alpha \leq 1$$

Smoothing constant for the based level

Step 3) Trend equation

$$T_t = \beta (B_t - B_{t-1}) + (1 - \beta)T_{t-1}$$

$$0 \leq \beta \leq 1$$

Smoothing constant for trend

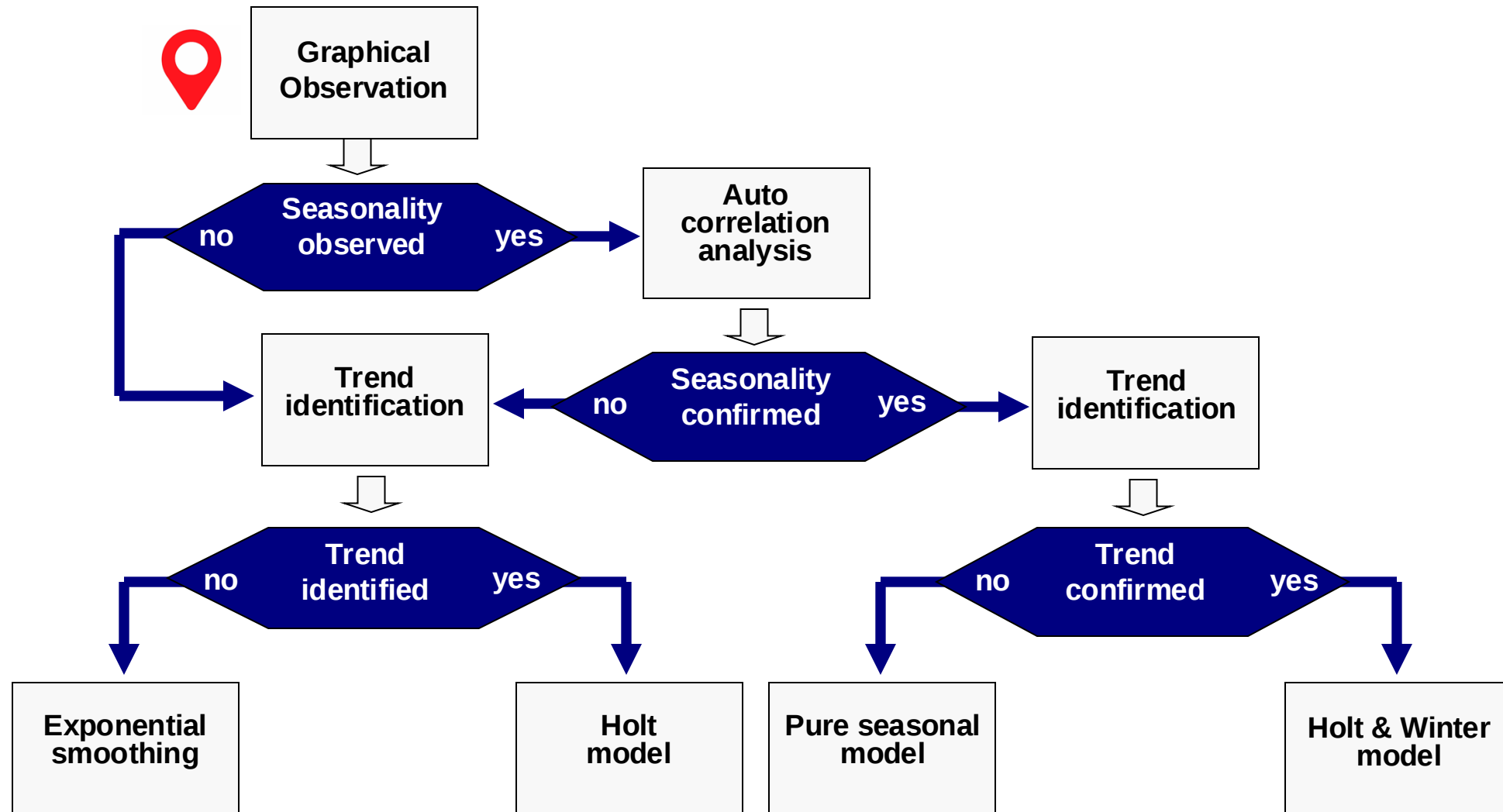
Step 4) Seasonality equation

$$S_t = \gamma \frac{Y_t}{B_t} + (1 - \gamma)S_{t-c}$$

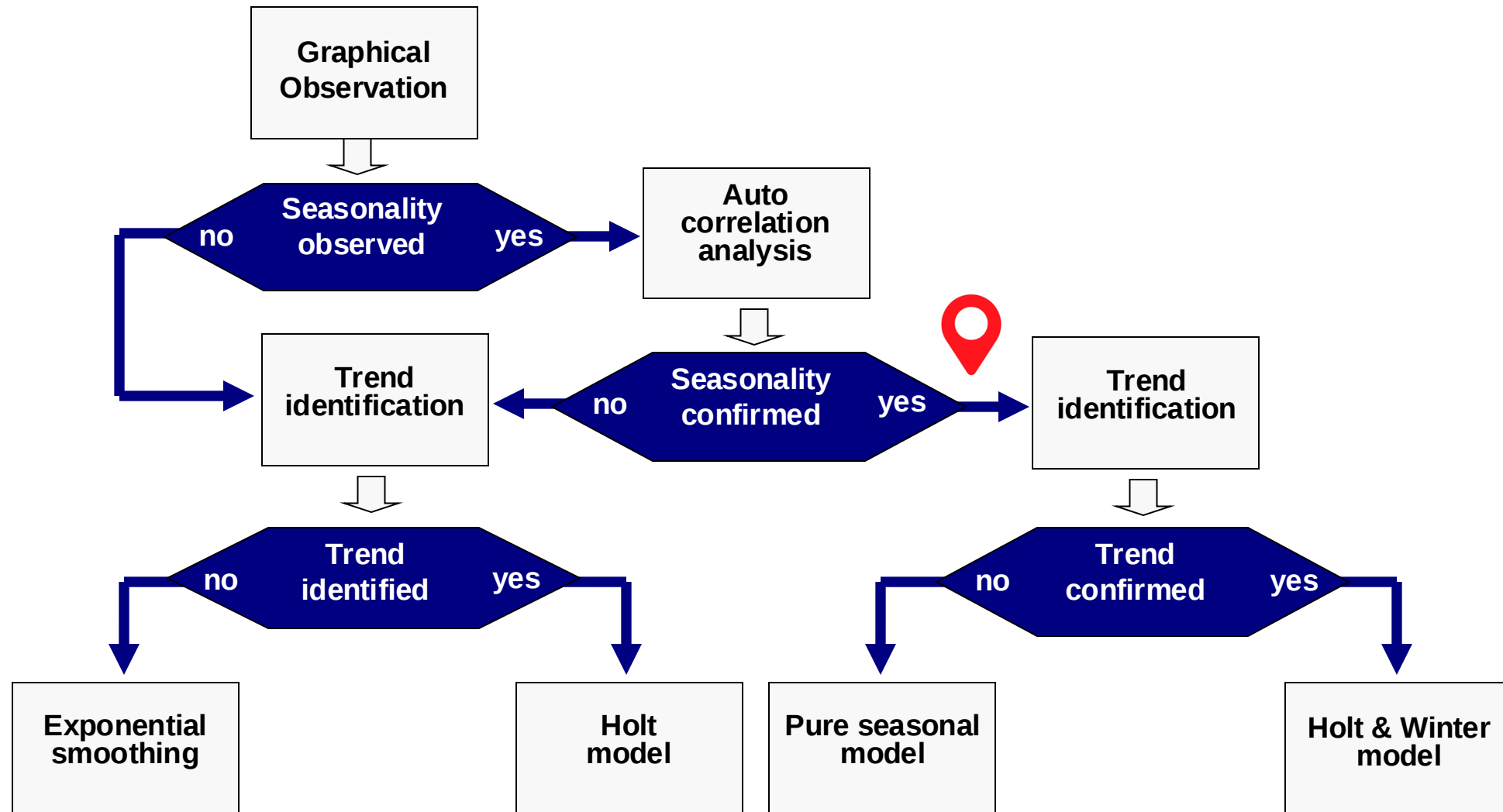
$$0 \leq \gamma \leq 1$$

Smoothing constant for seasonal

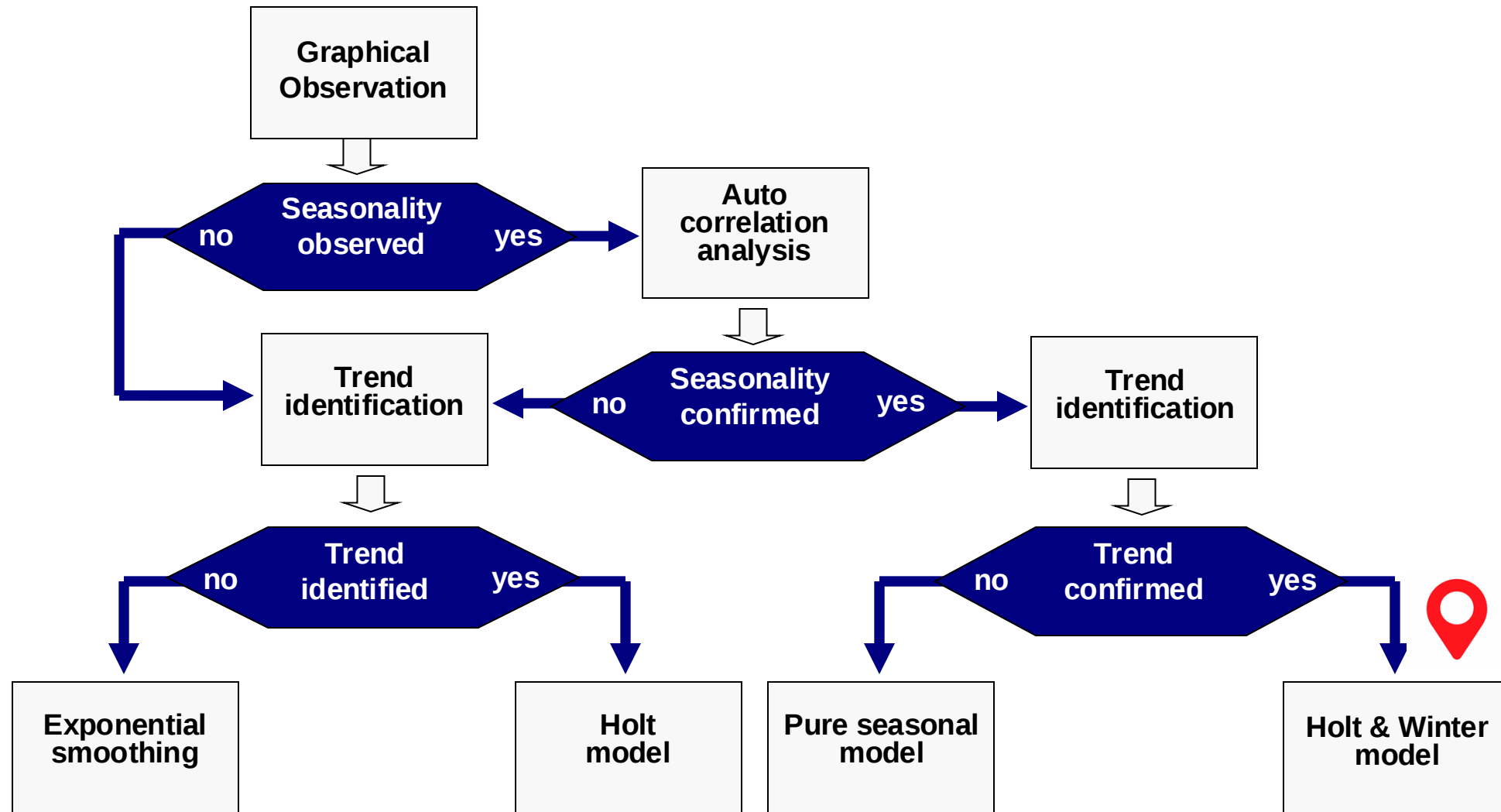
Forecast Method Selection Roadmap – Step 3: Method



Forecast Method Selection Roadmap – Step 3: Method



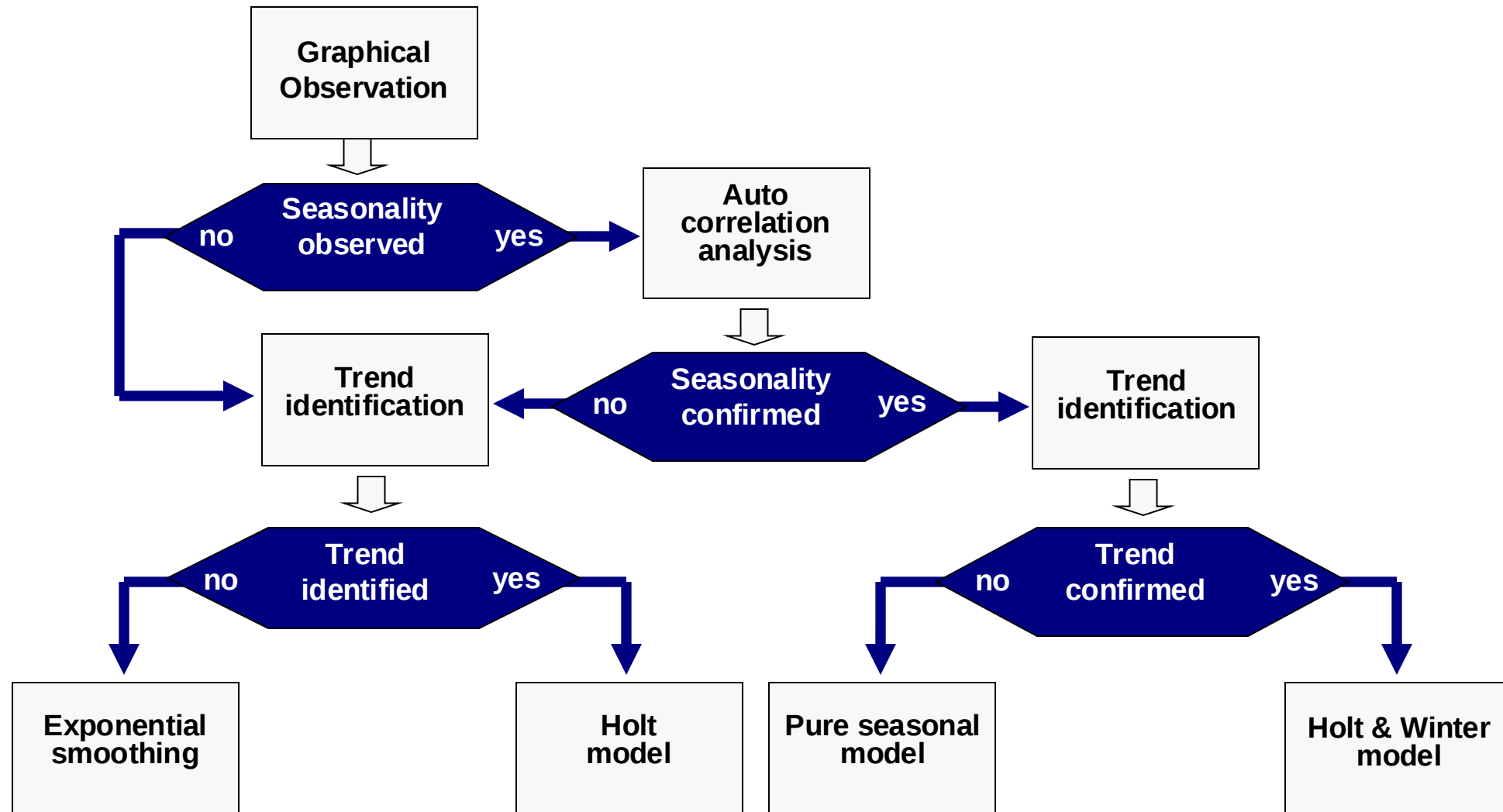
Forecast Method Selection Roadmap – Step 3: Method



Define Your Forecasting Method on the Roadmap



5 min



Time Series – Trend & Seasonality (Holt-Winter Model)

An exponential smoothing model (with three smoothing equations) for data with trend + seasonality:

Step 1) Forecast equation

$$F_{t+h} = (B_t + hT_t) \times S_{t+h-c}$$

c: periodicity of the seasonal effect

Step 2) Level equation

$$B_t = \alpha \frac{Y_t}{S_{t-c}} + (1 - \alpha)(B_{t-1} + T_{t-1})$$

$$0 \leq \alpha \leq 1$$

Smoothing constant for the based level

Step 3) Trend equation

$$T_t = \beta (B_t - B_{t-1}) + (1 - \beta)T_{t-1}$$

$$0 \leq \beta \leq 1$$

Smoothing constant for trend

Step 4) Seasonality equation

$$S_t = \gamma \frac{Y_t}{B_t} + (1 - \gamma)S_{t-c}$$

$$0 \leq \gamma \leq 1$$

Smoothing constant for seasonal

Seasonal Factors – Additive & Multiplicative

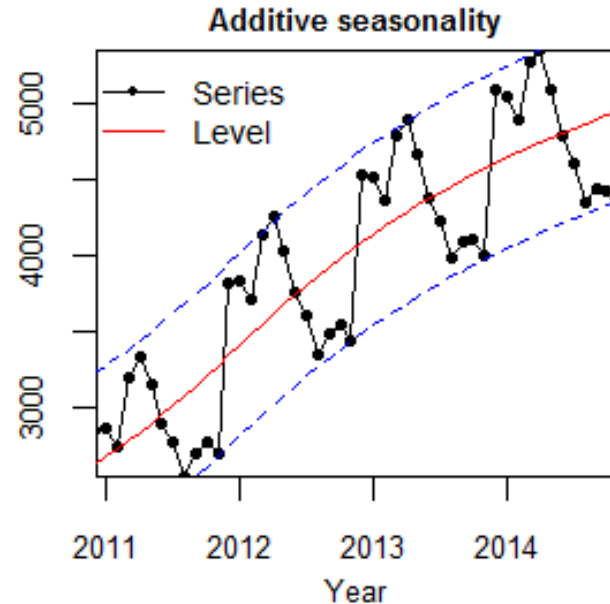
- Accordingly, the time series model used to described data ($\mathcal{Y}$) can be:

Additive

Modification by addition of a fixed quantity

$$Y_{t+1} = Y_t + 100$$

$$\mathcal{Y} = \mathcal{B} + \mathcal{T} + \mathcal{S} + \mathcal{R}$$

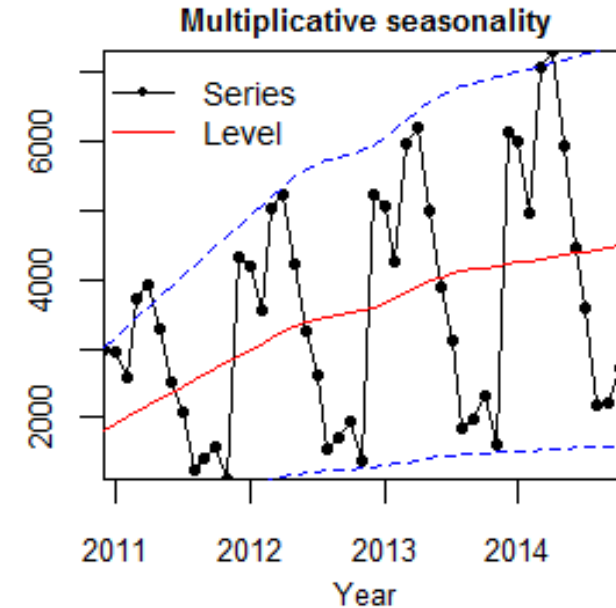


Multiplicative

Modification by multiplication by a coefficient

$$Y_{t+1} = 1.05 Y_t$$

$$\mathcal{Y} = \mathcal{B} \times \mathcal{T} \times \mathcal{S} \times \mathcal{R}$$



Time Series – Additive & Multiplicative Components

- Trend and Seasonal components can be additive or multiplicative;

$$\mathcal{Y} = \mathcal{F}(\mathcal{B}, \mathcal{T}, \mathcal{S}) + \mathcal{R} \quad [\mathcal{T}; \mathcal{S}] \quad \rightarrow \quad \begin{array}{l} 0 = \text{no component} \\ a = \text{Additive components} \\ m = \text{Multiplicative components} \end{array}$$

Examples:

- $[a; 0] =$
- Additive trend
 - No seasonal components

$$\mathcal{Y} = \mathcal{B} + \mathcal{T} + \mathcal{R}$$

- $[0; m] =$
- No trend
 - Multiplicative seasonal components

$$\mathcal{Y} = \mathcal{B} \times \mathcal{S} + \mathcal{R}$$

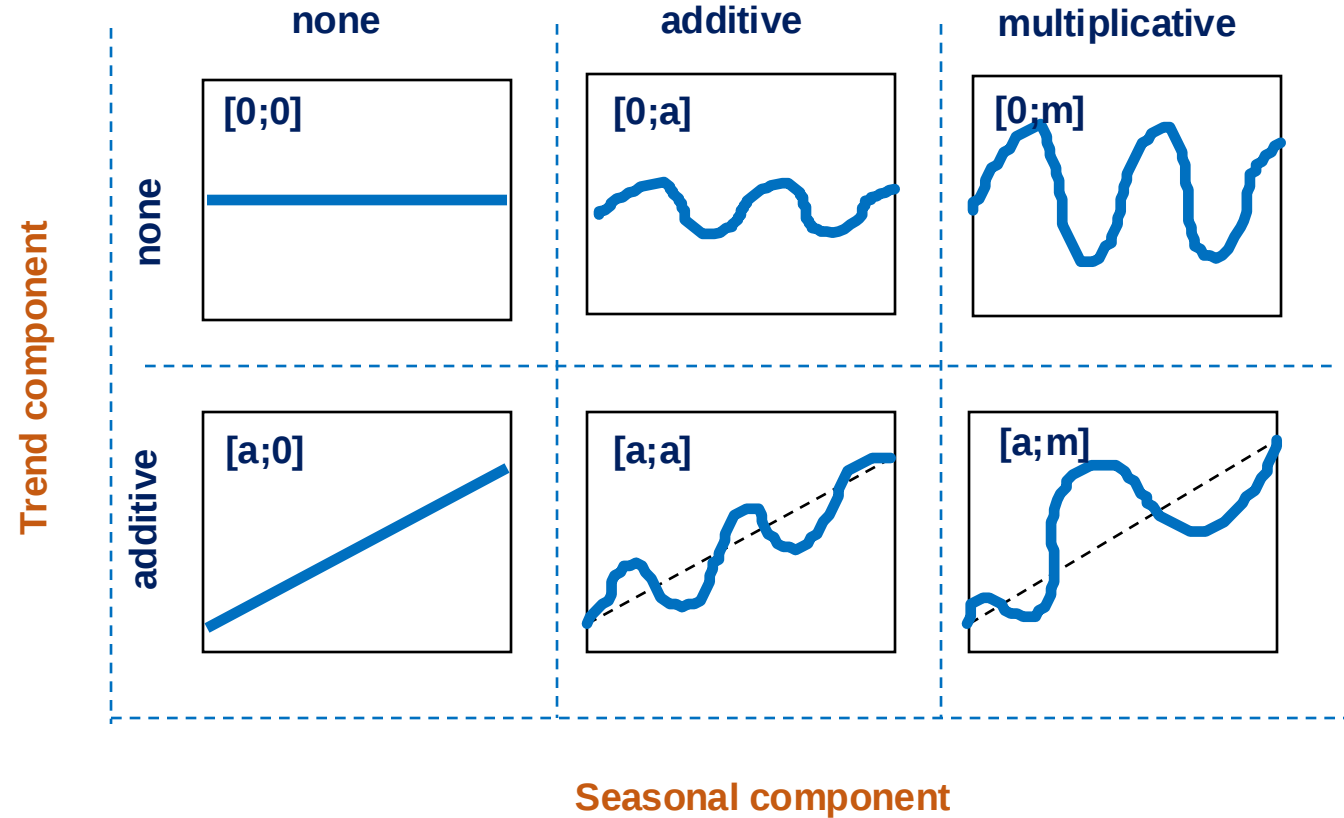
- $[a; m] =$
- Additive trend
 - Multiplicative seasonal component

$$\mathcal{Y} = (\mathcal{B} + \mathcal{T}) \mathcal{S} + \mathcal{R}$$

Time series – Additive & Multiplicative Components

0 = no component
 a = Additive components
 m = Multiplicative components

$[\mathcal{T}; \mathcal{S}]$ 



Time series – $[0;0]$

$[0;0]$ • No trend, No seasonal component

$$\mathcal{Y} = \mathcal{F}(\mathcal{B}) + \mathcal{R}$$

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

$$F_{t+h} = F_t + \alpha(Y_t - F_t) = \alpha Y_t + (1 - \alpha)F_t$$

$$\mathcal{Y} = \mathcal{B} + \mathcal{R}$$



$[0;0]$

Time series – $[0;m]$

$[0;m]$ • No trend, Multiplicative seasonal component

$$\mathcal{Y} = \mathcal{F}(\mathcal{B}, \mathcal{S}) + \mathcal{R}$$

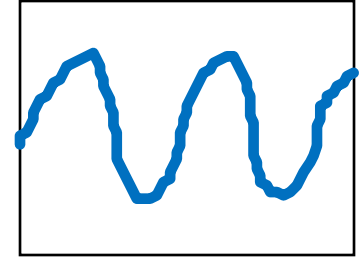
$$B_t = \alpha \frac{Y_t}{S_{t-c}} + (1 - \alpha) B_{t-1}$$

c: periodicity of the seasonal effect

$$S_t = \gamma \frac{Y_t}{B_t} + (1 - \gamma) S_{t-c}$$

$$F_{t+h} = B_t \times S_{t+h-c}$$

$$\mathcal{Y} = \mathcal{B} \times \mathcal{S} + \mathcal{R}$$



$[0;m]$

Time series – $[a;0]$

$[a;0]$ • Additive trend, No seasonal component

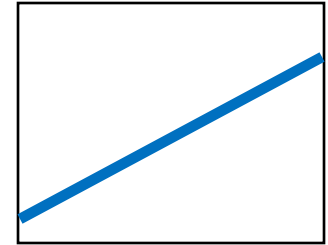
$$\mathcal{Y} = \mathcal{F}(\mathcal{B}, \mathcal{T}) + \mathcal{R}$$

$$B_t = aY_t + (1-a)(B_{t-1} + T_{t-1})$$

$$T_t = b(B_t - B_{t-1}) + (1-b)T_{t-1}$$

$$F_{t+h} = B_t + hT_t$$

$$\mathcal{Y} = \mathcal{B} + h\mathcal{T} + \mathcal{R}$$



$[a;0]$

Time series – $[a;a]$

$[a;a]$ • Additive trend and seasonal component

$$\mathcal{Y} = \mathcal{F}(\mathcal{B}, \mathcal{T}, \mathcal{S}) + \mathcal{R}$$

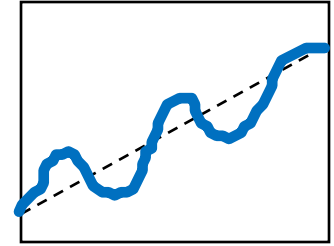
$$B_t = \alpha(Y_t - S_{t-c}) + (1 - \alpha)(B_{t-1} + T_{t-1})$$

$$T_t = \beta(B_t - B_{t-1}) + (1 - \beta)T_{t-1}$$

$$S_t = \gamma(Y_t - B_t) + (1 - \gamma)S_{t-c}$$

$$F_{t+h} = (B_t + hT_t) + S_{t+h-c}$$

$$\mathcal{Y} = \mathcal{B} + h\mathcal{T} + \mathcal{S} + \mathcal{R}$$



$[a;a]$

Time series – $[a;m]$

$[a;m]$ • Additive trend, Multiplicative seasonal component

$$\mathcal{Y} = \mathcal{F}(\mathcal{B}, \mathcal{T}, \mathcal{S}) + \mathcal{R}$$

$$B_t = \alpha \frac{Y_t}{S_{t-c}} + (1 - \alpha)(B_{t-1} + T_{t-1})$$

c : periodicity of the seasonal effect

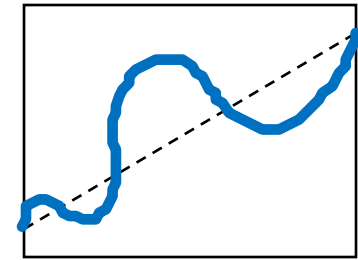
$$T_t = \beta(B_t - B_{t-1}) + (1 - \beta)T_{t-1}$$

$$S_t = \gamma \frac{Y_t}{B_t} + (1 - \gamma)S_{t-c}$$

$$F_{t+h} = (B_t + hT_t) \times S_{t+h-c}$$

h : forecasting horizon (1, 2, ..., 12)

$$\mathcal{Y} = (\mathcal{B} + \mathcal{T})\mathcal{S} + \mathcal{R}$$



$[a;m]$

Assignment 5 – Tasks



5 min

- 1) Identify the demand typology for each product family (constant, cyclic, seasonal, with trend).
- 2) Test whether there is seasonality in your dataset or not (use auto-correlation)
- 3) Select a preliminary forecast model (align with task 1 and 2)
- 4) Compute possible initial trend components
- 5) Compute possible initial seasonal components
- 6) Validate the proposed initial model
- 7) Comment the results of the validation process
- 8) Set a logic for smoothing coefficients (alpha, beta, Gamma) for running your forecasting model.
- 9) Forecast the demand of your product (product family level) for the next 18 months.
- 10) Measure performance of your forecasting model (Use MAPE).

Production Management (ME-419)

Module 2 – Demand Management

Holt-Winter Model

Amin Kaboli

Week 5 – Session 2 – Oct 11th, 2024

Time Series – Trend (Holt Model)

An exponential smoothing model (with two smoothing equations) for data with trend:

Step 1) Forecast equation

$$F_{t+h} = B_t + hT_t \quad h = 1, 2, 3, \dots$$

Step 2) Level equation

$$B_t = \alpha Y_t + (1 - \alpha)(B_{t-1} + T_{t-1}) \quad 0 \leq \alpha \leq 1$$

Step 3) Trend equation

$$T_t = b(B_t - B_{t-1}) + (1 - b)T_{t-1} \quad 0 \leq \beta \leq 1$$

Time Series – Trend & Seasonality (Holt-Winter Model)

An exponential smoothing model (with three smoothing equations) for data with trend + seasonality:

Step 1) Forecast equation

$$F_{t+h} = (B_t + hT_t) \times S_{t+h-c}$$

c: periodicity of the seasonal effect

Step 2) Level equation

$$B_t = \alpha \frac{Y_t}{S_{t-c}} + (1 - \alpha)(B_{t-1} + T_{t-1})$$

$$0 \leq \alpha \leq 1$$

Smoothing constant for the based level

Step 3) Trend equation

$$T_t = \beta (B_t - B_{t-1}) + (1 - \beta)T_{t-1}$$

$$0 \leq \beta \leq 1$$

Smoothing constant for trend

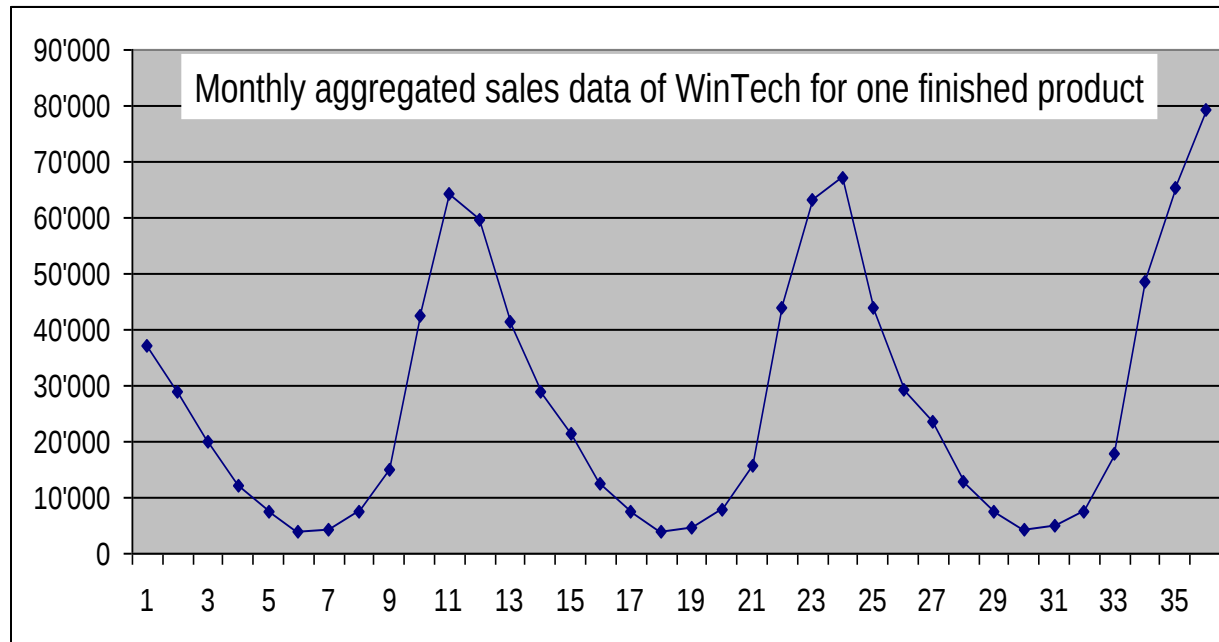
Step 4) Seasonality equation

$$S_t = \gamma \frac{Y_t}{B_t} + (1 - \gamma)S_{t-c}$$

$$0 \leq \gamma \leq 1$$

Smoothing constant for seasonal

Model Initiation – Holt & Winter



Holt & Winter Model

$$F_{t+h} = (B_t + hT_t) \times S_{t+h-c}$$

$$B_t = \alpha \frac{Y_t}{S_{t-c}} + (1 - \alpha)(B_{t-1} + T_{t-1})$$

$$T_t = \beta(B_t - B_{t-1}) + (1 - \beta)T_{t-1}$$

$$S_t = \gamma \frac{Y_t}{B_t} + (1 - \gamma)S_{t-c}$$

There is no unique process, however, its recommended to identify the most obvious components

Model Initiation – Use of Our Dataset

cycle 1	cycle 2	cycle 3
used to initiate trend and seasonal components		
	used to initiate the base	
		used to validate the model

Holt & Winter Model

$$F_{t+h} = (B_t + hT_t) \times S_{t+h-c}$$

$$B_t = \alpha \frac{Y_t}{S_{t-c}} + (1 - \alpha)(B_{t-1} + T_{t-1})$$

$$T_t = \beta(B_t - B_{t-1}) + (1 - \beta)T_{t-1}$$

$$S_t = \gamma \frac{Y_t}{B_t} + (1 - \gamma)S_{t-c}$$

Initial trend component (T'): Cycle 1, 2, 3

Initial Seasonal component (S'): Cycle 1, 2, 3

Initial base (B'): Cycle 2

Model validation: Cycle 3

Model Initiation – Steps

- Step 1.** Identify the initial trend (T')
- Step 2.** Identify the initial seasonal components (S')
- Step 3.** Identify the initial base (B')
- Step 4.** Identify the initial forecasting model (F')
- Step 5.** Validate the forecasting model ($MAPE'$)

Holt & Winter Model

$$F_{t+h} = (B_t + hT_t) \times S_{t+h-c}$$

$$B_t = \alpha \frac{Y_t}{S_{t-c}} + (1 - \alpha)(B_{t-1} + T_{t-1})$$

$$T_t = \beta(B_t - B_{t-1}) + (1 - \beta)T_{t-1}$$

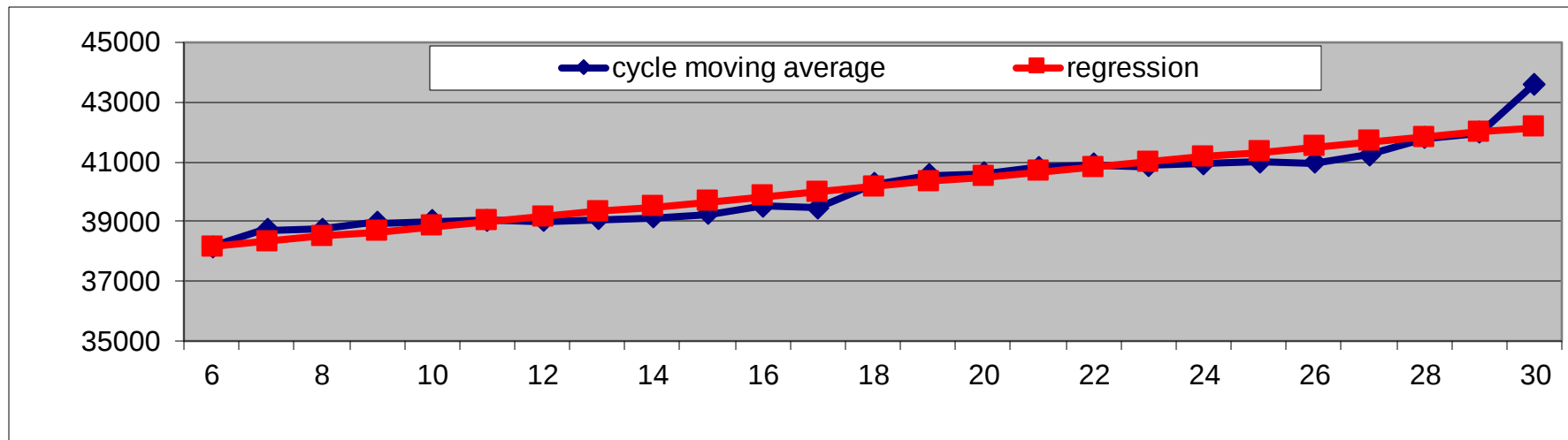
$$S_t = \gamma \frac{Y_t}{B_t} + (1 - \gamma)S_{t-c}$$

Model Initiation – Step 1



Step 1. Identify the initial trend (T')

1. Calculate the cycle moving average $\bar{Y}_t = \frac{1}{c} \left[\sum_{i=t-(c-2)/2}^{i=t+(c-2)/2} Y_i + \frac{1}{2} \left(Y_{t-c/2} + Y_{t+c/2} \right) \right]$ $c=12$ (even)
2. Determine the additive trend component by linear regression of $\bar{Y}_t$
3. Define initial trend



Model Initiation – Step 1.1



1. Calculate the cycle moving average $\bar{Y}_t$

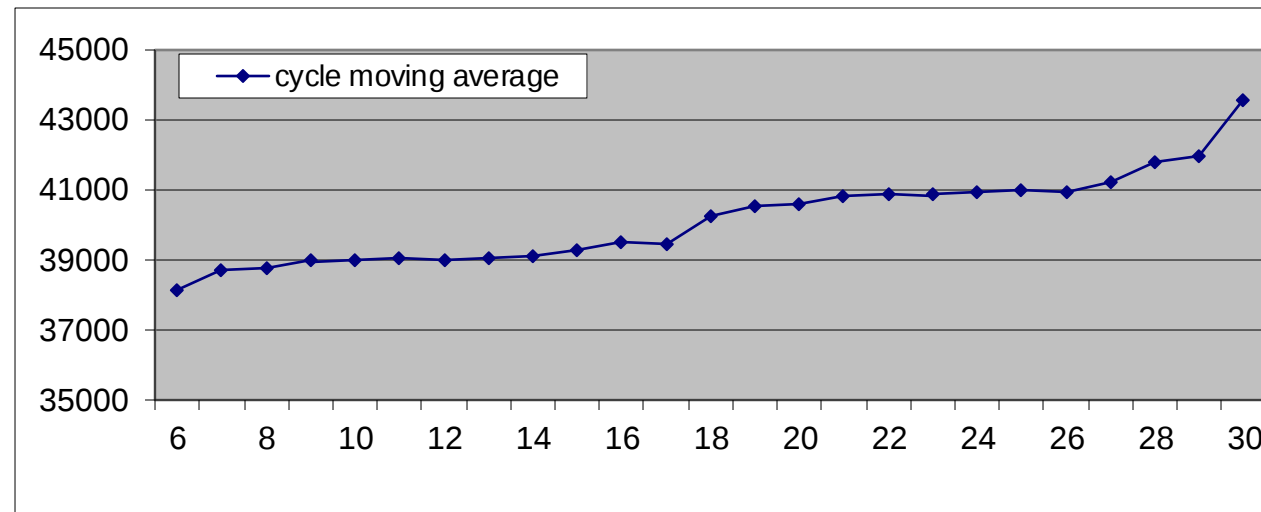
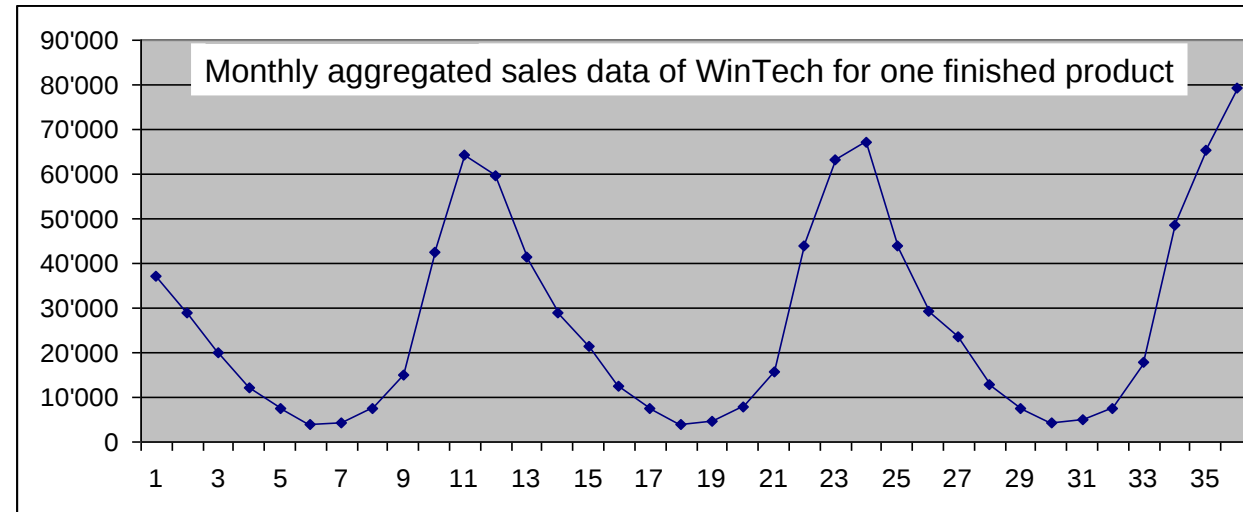
If c (periodicity of the seasonal effect) is odd

$$\bar{Y}_t = \frac{1}{C} \sum_{i=t-(c-1)/2}^{i=t+(c-1)/2} Y_i$$

If c (periodicity of the seasonal effect) is even

$$\bar{Y}_t = \frac{1}{C} \left[\sum_{i=t-(c-2)/2}^{i=t+(c-2)/2} Y_i + \frac{1}{2} \left(Y_{t-c/2} + Y_{t+c/2} \right) \right]$$

Model Initiation – Step 1.1



Model Initiation – Step 1.2 & Step 1.3

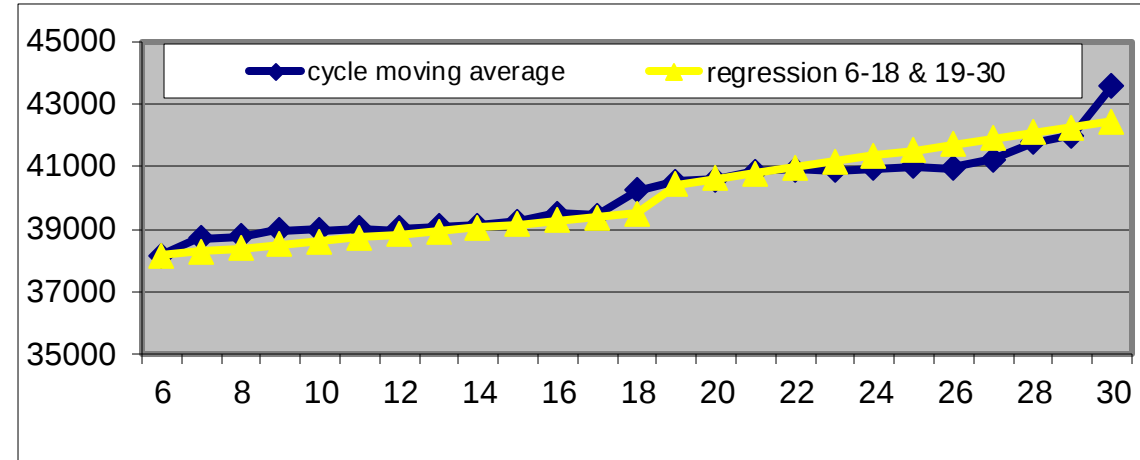


1.2. Determine the additive trend component by linear regression of $\bar{Y}_t$

For smaller range of data (per year)

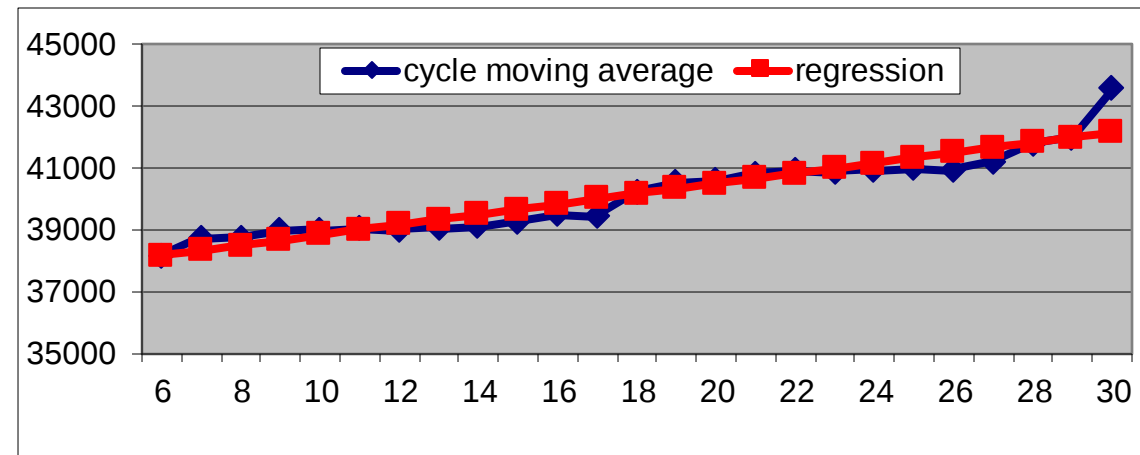
$T'(6-18) = 110 \text{ part / period}$

$T'(19-31) = 183 \text{ part / period}$



For the entire data

$T'(6-30) = 166 \text{ part / period}$



Model Initiation – Steps

Step 1. Identify the initial trend (T')

Step 2. Identify the initial seasonal components (S')

Step 3. Identify the initial base (B')

Step 4. Identify the initial forecasting model (F')

Step 5. Validate the forecasting model ($MAPE'$)

Holt & Winter Model

$$F_{t+h} = (B_t + hT_t) \times S_{t+h-c}$$

$$B_t = \alpha \frac{Y_t}{S_{t-c}} + (1 - \alpha)(B_{t-1} + T_{t-1})$$

$$T_t = \beta(B_t - B_{t-1}) + (1 - \beta)T_{t-1}$$

$$S_t = \gamma \frac{Y_t}{B_t} + (1 - \gamma)S_{t-c}$$



Model Initiation – Step 2

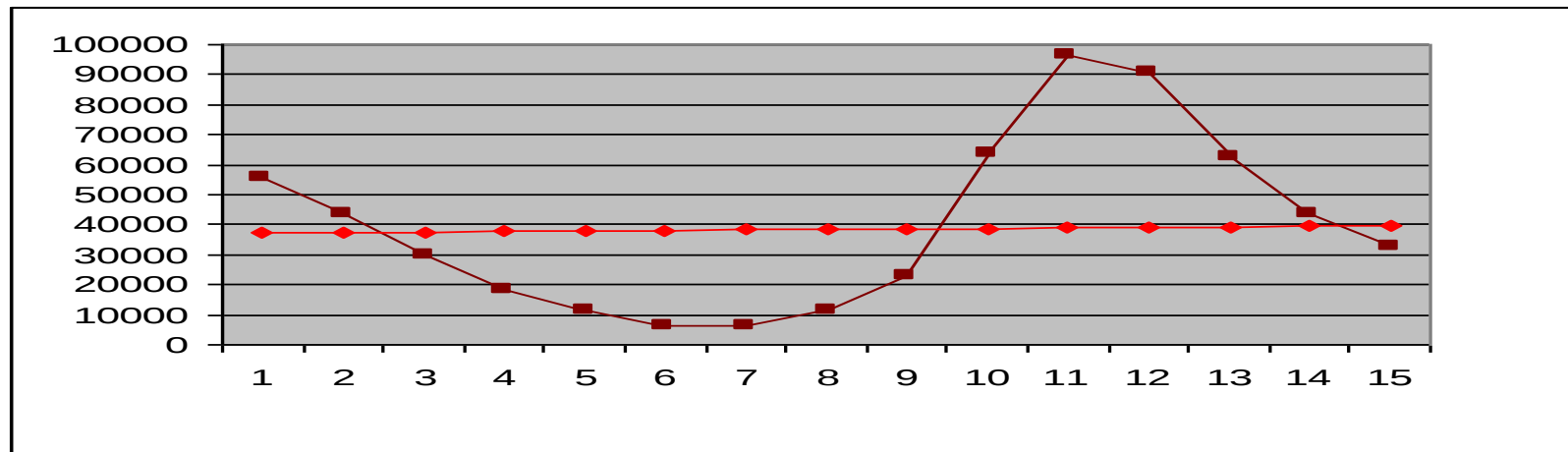
Step 2. Identify the initial seasonal components (S')

1. Define the given cycle $[t^o; t^o + (c - 1)]$

2. Define the cycle average $\bar{Y}_c = \frac{1}{c} \sum_{t=t^o}^{t^o+(c-1)} Y_t$

3. Define deseasonalized time series $\tilde{Y}_t = \bar{Y}_c + T' \left[t - t^o - \frac{c-1}{2} \right]$

4. Define initial seasonal coefficient $S'_t = \frac{Y_t}{\tilde{Y}_t}$



Model Initiation – Step 2.3



2.3. Determine the values of the seasonal components

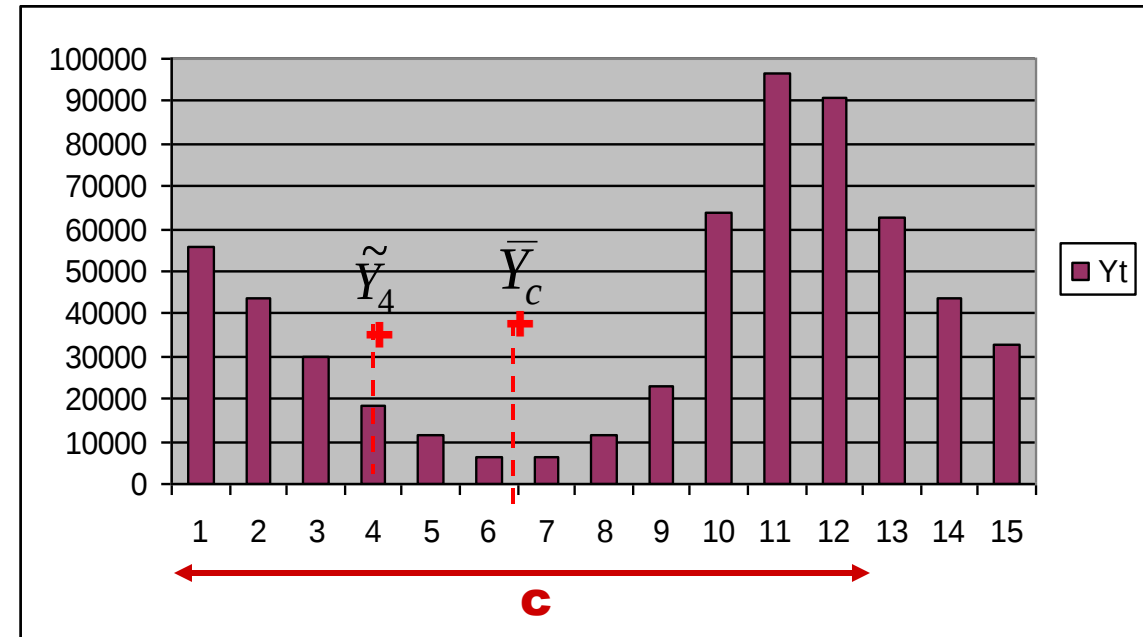
Eliminate the seasonal effect and create deseasonalized time series

$$\tilde{Y}_t = \bar{Y}_c + T' \left[t - t^\circ - \frac{c-1}{2} \right]$$

With cycle of: $[t^\circ; t^\circ + (c-1)]$ *and cycle average of:* $\bar{Y}_c = \frac{1}{c} \sum_{t=t^\circ}^{t^\circ+(c-1)} Y_t$

$$\tilde{Y}_t = \bar{Y}_c + T' \left[t - t^\circ - \frac{c-1}{2} \right]$$

$$\tilde{Y}_4 = \bar{Y}_c + T' \left[4 - 1 - \frac{12-1}{2} \right] = \bar{Y}_c - 2.5T'$$

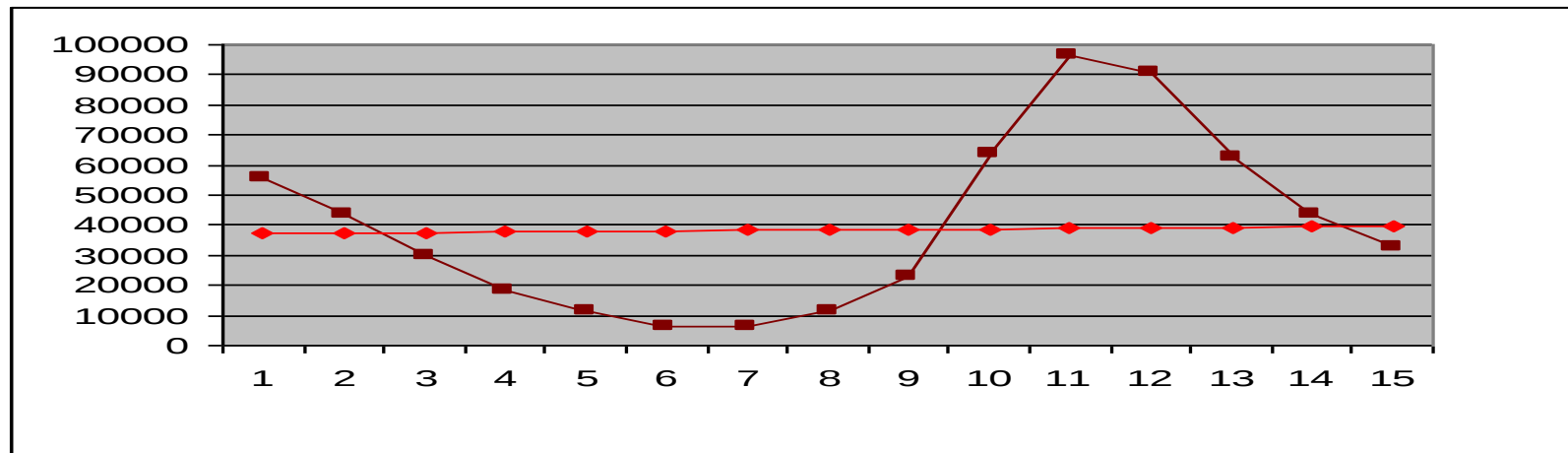


Model Initiation – Step 2



Step 2. Identify the initial seasonal components (S')

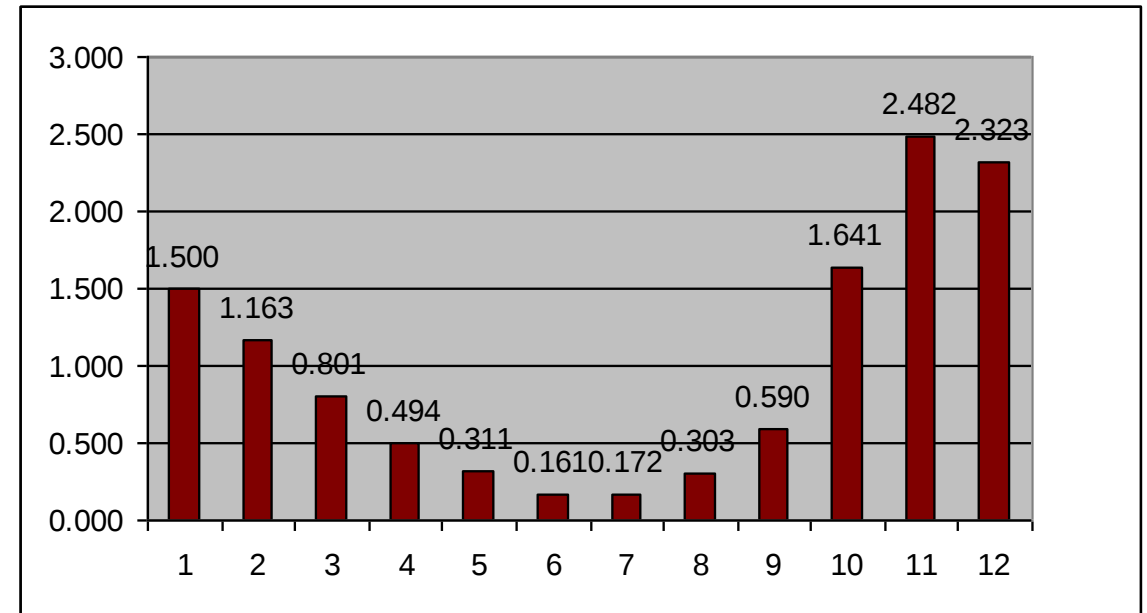
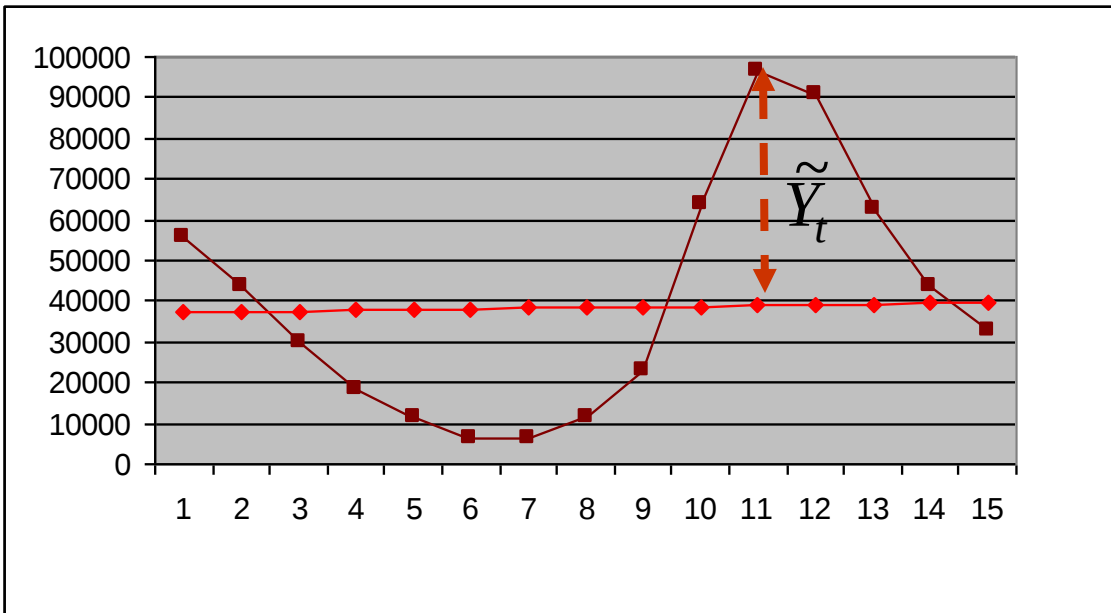
1. Define the given cycle $[t^o; t^o + (c - 1)]$
2. Define the cycle average $\bar{Y}_c = \frac{1}{c} \sum_{t=t^o}^{t^o+(c-1)} Y_t$
3. Define deseasonalized time series $\tilde{Y}_t = \bar{Y}_c + T' \left[t - t^o - \frac{c-1}{2} \right]$
4. Define initial seasonal coefficient $S'_t = \frac{Y_t}{\tilde{Y}_t}$



Model Initiation – Step 2.4



2.4. Define initial seasonal coefficient $S'_t = \frac{Y_t}{\tilde{Y}_t}$



Model Initiation – Steps

Step 1. Identify the initial trend (T')

Step 2. Identify the initial seasonal components (S')

Step 3. Identify the initial base (B')

Step 4. Identify the initial forecasting model (F')

Step 5. Validate the forecasting model ($MAPE'$)

Holt & Winter Model

$$F_{t+h} = (B_t + hT_t) \times S_{t+h-c}$$

$$B_t = \alpha \frac{Y_t}{S_{t-c}} + (1 - \alpha)(B_{t-1} + T_{t-1})$$

$$T_t = \beta(B_t - B_{t-1}) + (1 - \beta)T_{t-1}$$

$$S_t = \gamma \frac{Y_t}{B_t} + (1 - \gamma)S_{t-c}$$

Model Initiation – Step 3



Step 3. Identify the initial base (**B'**)

1. Calculate the average value of cycle 2 $\bar{Y}_c = \frac{1}{c} \sum_{t=t^0}^{t^0+(c-1)} Y_t$
2. Define initial base $B' = \bar{Y}_2 + \frac{c-1}{2} T' ; c=12$

Example: Initial base (**B'**) = 40243 + 5.5 * 166

Model Initiation – Steps

Step 1. Identify the initial trend (T')

Step 2. Identify the initial seasonal components (S')

Step 3. Identify the initial base (B')

Step 4. Identify the initial forecasting model (F')

Step 5. Validate the forecasting model ($MAPE'$)

Holt & Winter Model

$$F_{t+h} = (B_t + hT_t) \times S_{t+h-c}$$

$$B_t = \alpha \frac{Y_t}{S_{t-c}} + (1 - \alpha)(B_{t-1} + T_{t-1})$$

$$T_t = \beta(B_t - B_{t-1}) + (1 - \beta)T_{t-1}$$

$$S_t = \gamma \frac{Y_t}{B_t} + (1 - \gamma)S_{t-c}$$

Model Initiation – Step 4

4.1. Define the validation cycle (Year 3)

4.2. Define the initial model $F'_{t+h} = (B' + hT') \times S'_{t+h}$

$$\text{Initial model } (F'_{t+h}) = (40243 + h * 166) * S'_{t+h}$$

$h = 1, 2, \dots, 12$

Examples:

$$h=1 ; F'_{24+1} = (40243 + (1) * 166) * S'_{24+1}$$

$$h=5 ; F'_{24+5} = (40243 + (5) * 166) * S'_{25+5}$$

$$h=11 ; F'_{24+11} = (40243 + (11) * 166) * S'_{25+11}$$

Note: I used the third cycle of my data for initial forecast and validation of my model

Model Initiation – Steps

Step 1. Identify the initial trend (T')

Step 2. Identify the initial seasonal components (S')

Step 3. Identify the initial base (B')

Step 4. Identify the initial forecasting model (F')

Step 5. Validate the forecasting model ($MAPE'$)

Holt & Winter Model

$$F_{t+h} = (B_t + hT_t) \times S_{t+h-c}$$

$$B_t = \alpha \frac{Y_t}{S_{t-c}} + (1 - \alpha)(B_{t-1} + T_{t-1})$$

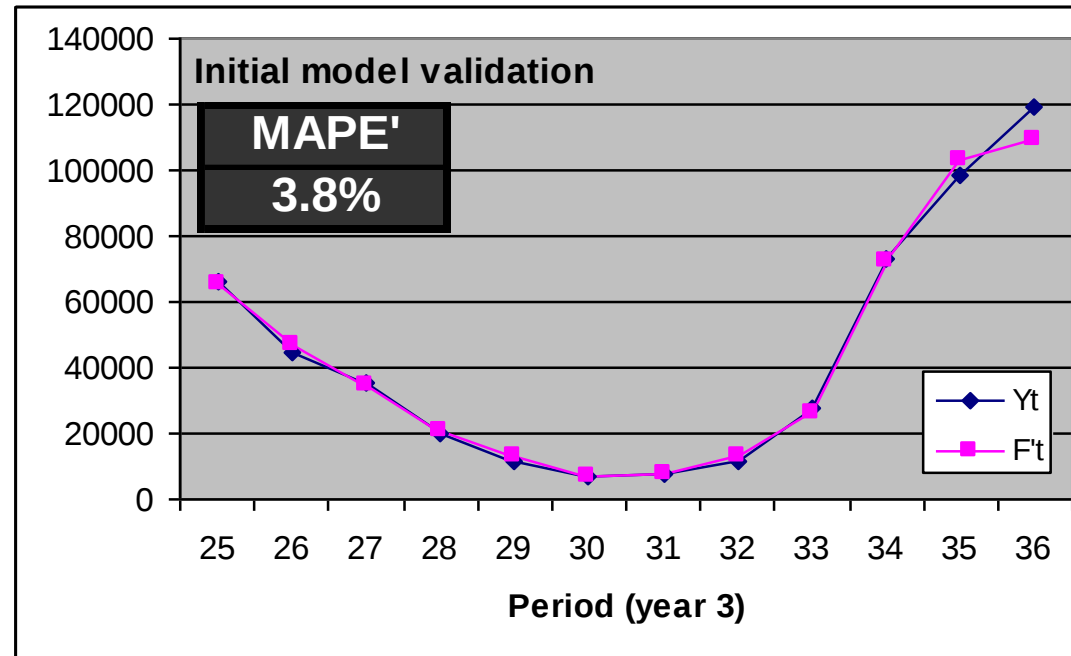
$$T_t = \beta(B_t - B_{t-1}) + (1 - \beta)T_{t-1}$$

$$S_t = \gamma \frac{Y_t}{B_t} + (1 - \gamma)S_{t-c}$$

Model Initiation – Model Validation

5. Determine the reliability measure $MAPE' = \frac{1}{C} \sum_{h=1}^c \left| \frac{Y_{t^{\circ}+h} - F'_{t^{\circ}+h}}{Y_{t^{\circ}+h}} \right|$

where $c = 12$, and $h = 1, 2, \dots, 12$



Initial model validation

Model Initiation – Steps

Step 1. Identify the initial trend (T')

Step 2. Identify the initial seasonal components (S')

Step 3. Identify the initial base (B')

Step 4. Identify the initial forecasting model (F')

Step 5. Validate the forecasting model ($MAPE'$)

Holt & Winter Model

$$F_{t+h} = (B_t + hT_t) \times S_{t+h-c}$$

$$B_t = \alpha \frac{Y_t}{S_{t-c}} + (1 - \alpha)(B_{t-1} + T_{t-1})$$

$$T_t = \beta(B_t - B_{t-1}) + (1 - \beta)T_{t-1}$$

$$S_t = \gamma \frac{Y_t}{B_t} + (1 - \gamma)S_{t-c}$$

Assignment 5 – Tasks



15 min

- 1) Identify the demand typology for each product family (constant, cyclic, seasonal, with trend).
- 2) Test whether there is seasonality in your dataset or not (use auto-correlation)
- 3) Select a preliminary forecast model (align with task 1 and 2)
- 4) Compute possible initial trend components
- 5) Compute possible initial seasonal components
- 6) Validate the proposed initial model
- 7) Comment the results of the validation process
- 8) Set a logic for smoothing coefficients (alpha, beta, Gamma) for running your forecasting model.
- 9) Forecast the demand of your product (product family level) for the next 18 months.
- 10) Measure performance of your forecasting model (Use MAPE).

Production Management (ME-419)

Module 2 – Demand Management

Forecasting Model Performance

Amin Kaboli

Week 5 – Session 3 – Oct 11th, 2024

Demand Management – Forecasting Steps



Demand forecast
at the item and
aggregate levels



Goal: What is the purpose of the forecast (Type of products, Granularity, Horizon)



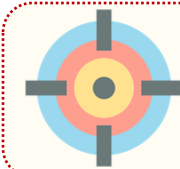
Data: Obtain, clean, and analyze appropriate data



Method: Select a forecasting method (Qualitative vs Quantitative)

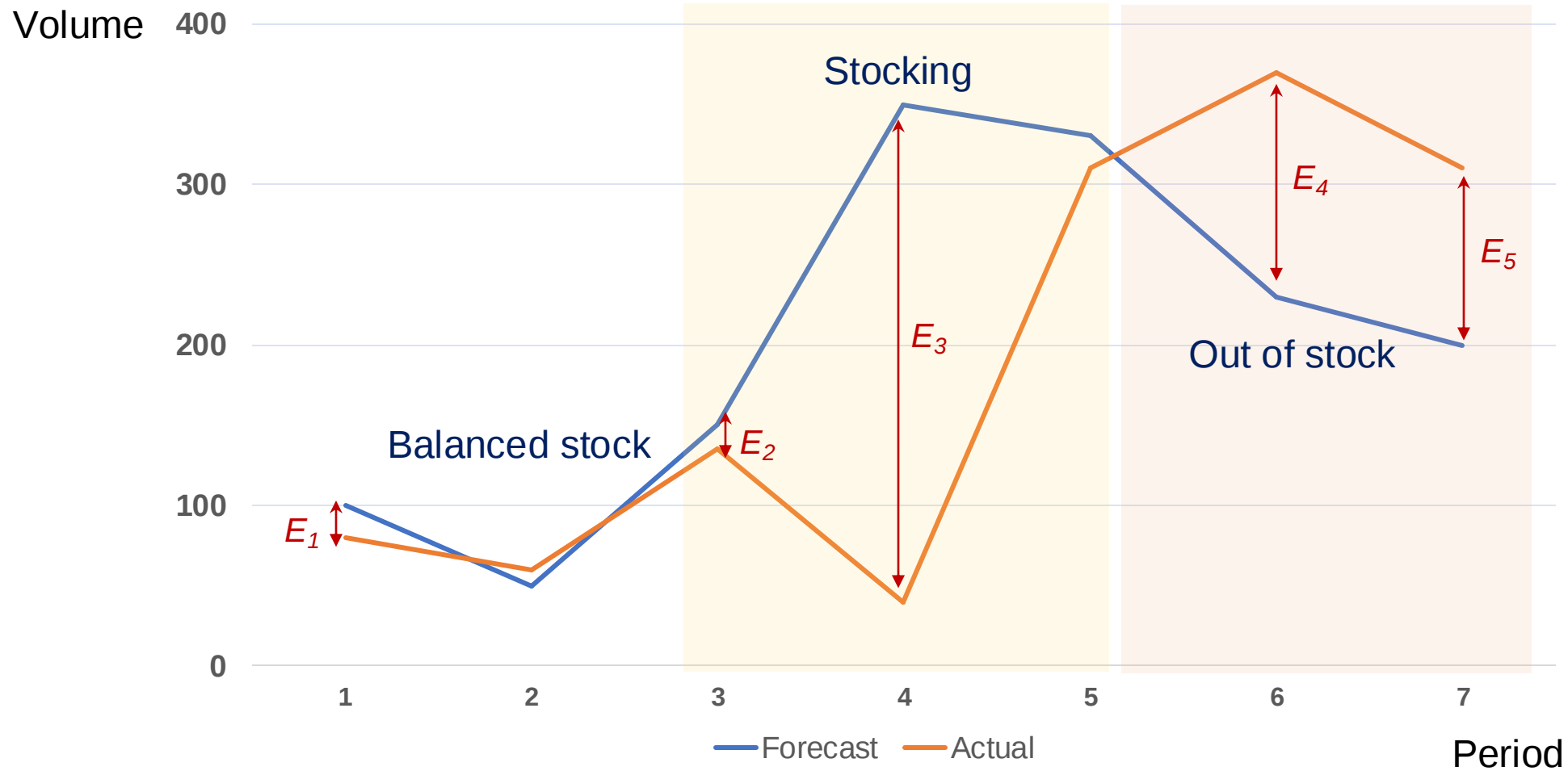


Forecast: Make the forecast



Performance: Monitor the forecast errors

Step 5: Performance – Monitor the Forecasting Error



Step 5: Performance – Monitor the Forecasting Error

E_t : forecast error calculated at the end of period t when the actual value Y_t is known;

Y_t : actual demand for period t

F_t : forecasting for period t

$$\text{error: } E_t = Y_t - F_t$$

PE_t : percentage error calculated at the end of period t when actual value Y_t is known

$$\text{percentage error: } PE_t = \frac{Y_t - F_t}{Y_t} = \frac{E_t}{Y_t}$$

Monitoring Forecasting Error – ME & MAE

E_t : forecast error calculated at the end of period t when the actual value Y_t is known;

F_t : forecasting for period t

$$\text{error: } E_t = Y_t - F_t$$

Mean Error (ME)

$$ME_t = \frac{1}{n} \sum_{i=t-n+1}^t [E_i]$$

Mean Absolute Error (MAE)

$$MAE_t = \frac{1}{n} \sum_{i=t-n+1}^t |E_i|$$

Monitoring Forecasting Error – MPE & MAPE

E_t : forecast error calculated at the end of period t when the actual value Y_t is known;

F_t : forecasting for period t

$$\text{error: } E_t = Y_t - F_t$$

$$\text{percentage error: } PE_t = \frac{Y_t - F_t}{Y_t} = \frac{E_t}{Y_t}$$

Mean Percentage Error (MPE)

$$MPE_t = \frac{1}{n} \sum_{i=t-n+1}^t PE_i$$

Mean Absolute Percentage Error (MAPE)

$$MAPE_t = \frac{1}{n} \sum_{i=t-n+1}^t |PE_i|$$



2 min

Exercise 1: Monitoring Forecasting Error

		$\alpha = 0.6$			$n = 3$	
Period t	1	2	3	4	5	6
Actual value Y	850	880	950	1300	1350	1000
Forecasted value F	920	878	879	922	1149	1269
Error E	-70	2	71	378	201	
Percentage error PE	-8%	0%	7%	29%	15%	
Mean error ME			1	150	217	
Mean percentage error MPE			0%	12%	17%	
Mean absolute error MAE			48	150	217	
Mean absolute percentage error MAPE			5%	12%	17%	
Smoothed mean error SME			36	241	217	
Smoothed mean error SMAE			50	247	220	

$$ME_t = \frac{1}{n} \sum_{i=t-n+1}^t [E_i] \quad MAE_t = \frac{1}{n} \sum_{i=t-n+1}^t |E_i| \quad MPE_t = \frac{1}{n} \sum_{i=t-n+1}^t PE_i \quad MAPE_t = \frac{1}{n} \sum_{i=t-n+1}^t |PE_i|$$

Monitoring Forecasting Error – With Smoothing

E_t : forecast error calculated at the end of period t when the actual value Y_t is known;

F_t : forecasting for period t

$$\text{error: } E_t = Y_t - F_t$$

Smoothed Mean Error (SME)

$$SME_t = \alpha E_t + (1 - \alpha) SME_{t-1}$$

Smoothed Mean Absolute Error (SMAE)

$$SMAE_t = \alpha |E_t| + (1 - \alpha) SMAE_{t-1}$$

Smoothed Mean Absolute Percentage Error (SMAPE)

$$SMAPE_t = \alpha |PE_t| + (1 - \alpha) SMAPE_{t-1}$$

Exercise 2: Monitoring Forecasting Error – With Smoothing



2 min

		$\alpha = 0.6$			$n = 3$	
Period t	1	2	3	4	5	6
Actual value Y	850	880	950	1300	1350	1000
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Smoothed mean error SME			36	241	217	
Smoothed mean error SMAE			50	247	220	

$$SME_t = \alpha E_t + (1 - \alpha)SME_{t-1}$$

$$SMAE_t = \alpha |E_t| + (1 - \alpha)SMAE_{t-1}$$

Step 5: Performance – Monitoring Forecasting Errors

Forecasting Error (E)

$$E_t = Y_t - F_t$$

Forecasting Percentage Error (PE)

$$PE_t = \frac{Y_t - F_t}{Y_t} = \frac{E_t}{Y_t}$$

Mean Error (ME)

$$ME_t = \frac{1}{n} \sum_{i=t-n+1}^t [E_i]$$

Mean Absolute Error (MAE)

$$MAE_t = \frac{1}{n} \sum_{i=t-n+1}^t |E_i|$$

Mean Percentage Error (MPE) Mean Absolute Percentage Error (MAPE)

$$MPE_t = \frac{1}{n} \sum_{i=t-n+1}^t PE_i$$

$$MAPE_t = \frac{1}{n} \sum_{i=t-n+1}^t |PE_i|$$

Smoothed Mean Error (ME)

$$SME_t = \alpha E_t + (1 - \alpha) SME_{t-1}$$

Smoothed Mean Absolute Error (MAE)

$$SMAE_t = \alpha |E_t| + (1 - \alpha) SMAE_{t-1}$$

Smoothed Mean Absolute Percentage Error (MAPE)

$$SMAPE_t = \alpha |PE_t| + (1 - \alpha) SMAPE_{t-1}$$

Demand Management – Forecasting Steps



Demand forecast
at the item and
aggregate levels



Goal: What is the purpose of the forecast (Type of products, Granularity, Horizon)



Data: Obtain, clean, and analyze appropriate data



Method: Select a forecasting method (Qualitative vs Quantitative)



Forecast: Make the forecast



Performance: Monitor the forecast errors

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15 min

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Learning Points – Summary

- Time series: stationary models, trend, seasonality
- Making a demand (or sales) forecast
- Monitoring the forecast errors and measuring forecast accuracy

Production Management (ME-419)

Coaching Rooms

Amin Kaboli

Week 5 – Session 4 – Oct 11th, 2024

Please Follow Your coaches to Your Designated Rooms

Coaches



Saria
GCA 330



Joao
GCA 331



Xavier
GRA 332

The Art of Giving and Receiving Effective Feedback



Feedback is a gift



Feedback/comments are
always welcome

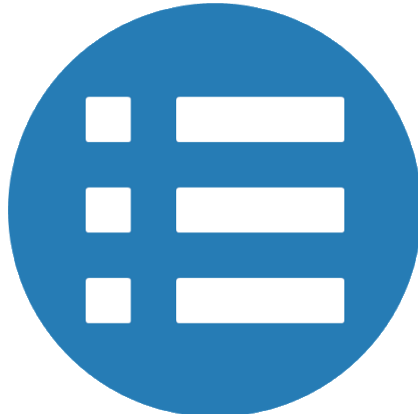
Giving Effective Feedback



Respectful

Ask for permission

May I share my observation



Fact-based

Share facts/ your feelings

What I observed/felt is that ...



Constructive

Stay focused on growth

What I suggest is that ...



Concise

Be to-the-point and short

Max three key points



Open

Be open to any reaction

I respect your feeling ...

Receiving Effective Feedback



Receive the gift

Be open and receptive

I appreciate your feedback



Listen

Listen to listen!

The goal is to listen not to answer, no interruption
(zip it)



Understand

Focus on THE message

The goal is to understand,
ask questions, clarify,
repeat key points, ...



Decide

You always have a choice

*Thank you, I have never
seen it this way*
OR
*Thank you, let me reflect
and get back to you?*



Follow up

Reach a common understanding

There are many ways to
follow up: revise the work,
set up a meeting, ...