LIUC
Università Cattaneo

Demand Forecasting (Part A)

Prof. Tommaso Rossi
School of Industrial Engineering

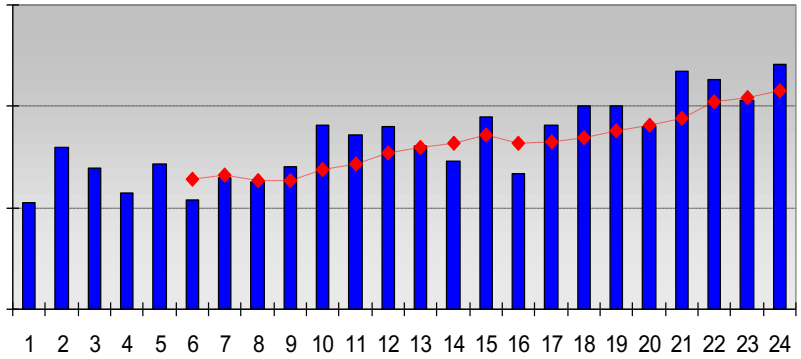
Agenda

LIUC
Università Cattaneo

1. Demand planning process

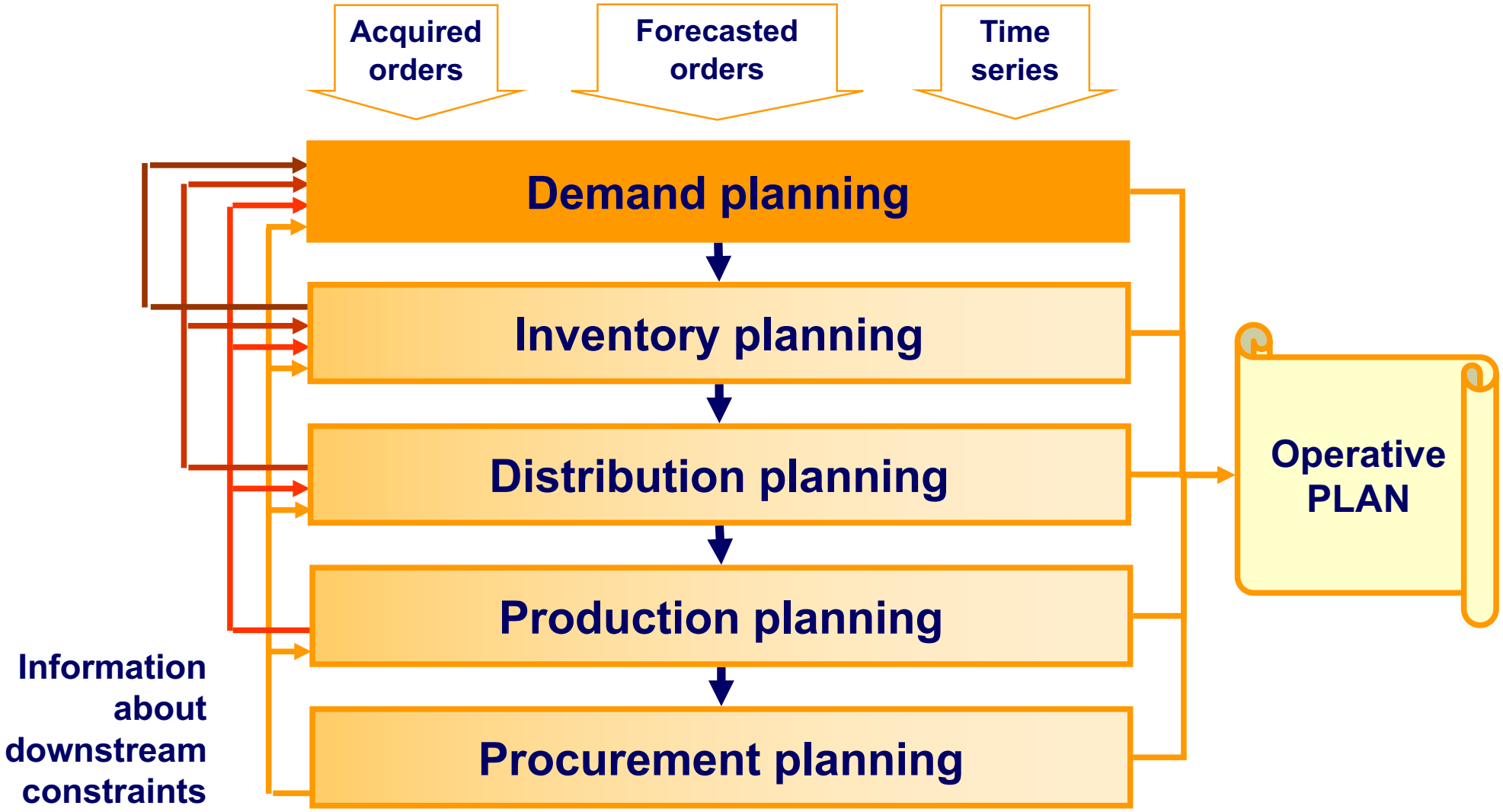
2. Demand forecasting system and methodologies

3. Forecasting process



Main Objective

LIUC
Università Cattaneo



Objectives

- Interpret & Explain the past demand
- Forecast the future demand by using all the available information
- Manage the demand:
  - Influence the future demand with specific actions (e. g. promotional campaigns, price policies, ...) in order to make it higher or more steady
  - Manage possible production/distribution capacity shortage, etc.

Input and Output

- Input: received orders, time series of the past demand, negotiations, market experience, general and industry trends, actions of the competitors, causal factors, ...

- Output: demand plan (with a definite detail level and planning horizon depending on the use of the forecast) + measure of the plan accuracy, ...

Process settings choices

- **Some settings:**
  - objectives: who needs the forecast and for which reason
  - who owns/collects the input data and with which frequency
  - who owns/maintains the database with all the data
  - centralization: one primary forecast generating secondary forecasts VS different forecasts and then sharing and consolidation
  - frequency of the forecasting process
  - indicators to measure the effectiveness of the process
  - …

Nature of the forecasting problem

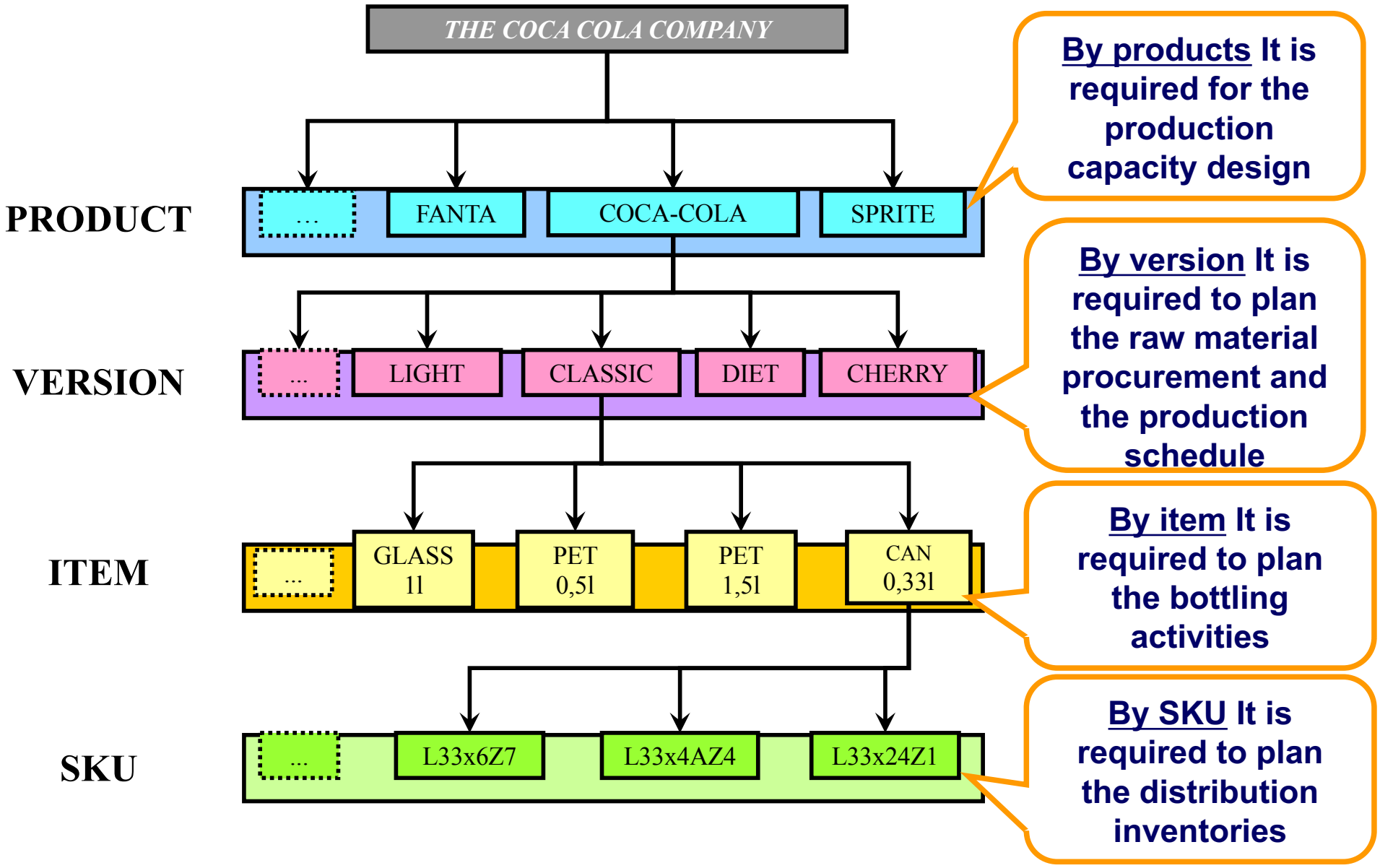
- **Axes to define the forecasting problem:**
  - object of the forecasting
  - product level
  - planning horizon
  - geographical aggregation
  - influencing variables
  - required accuracy

Object of the forecasting

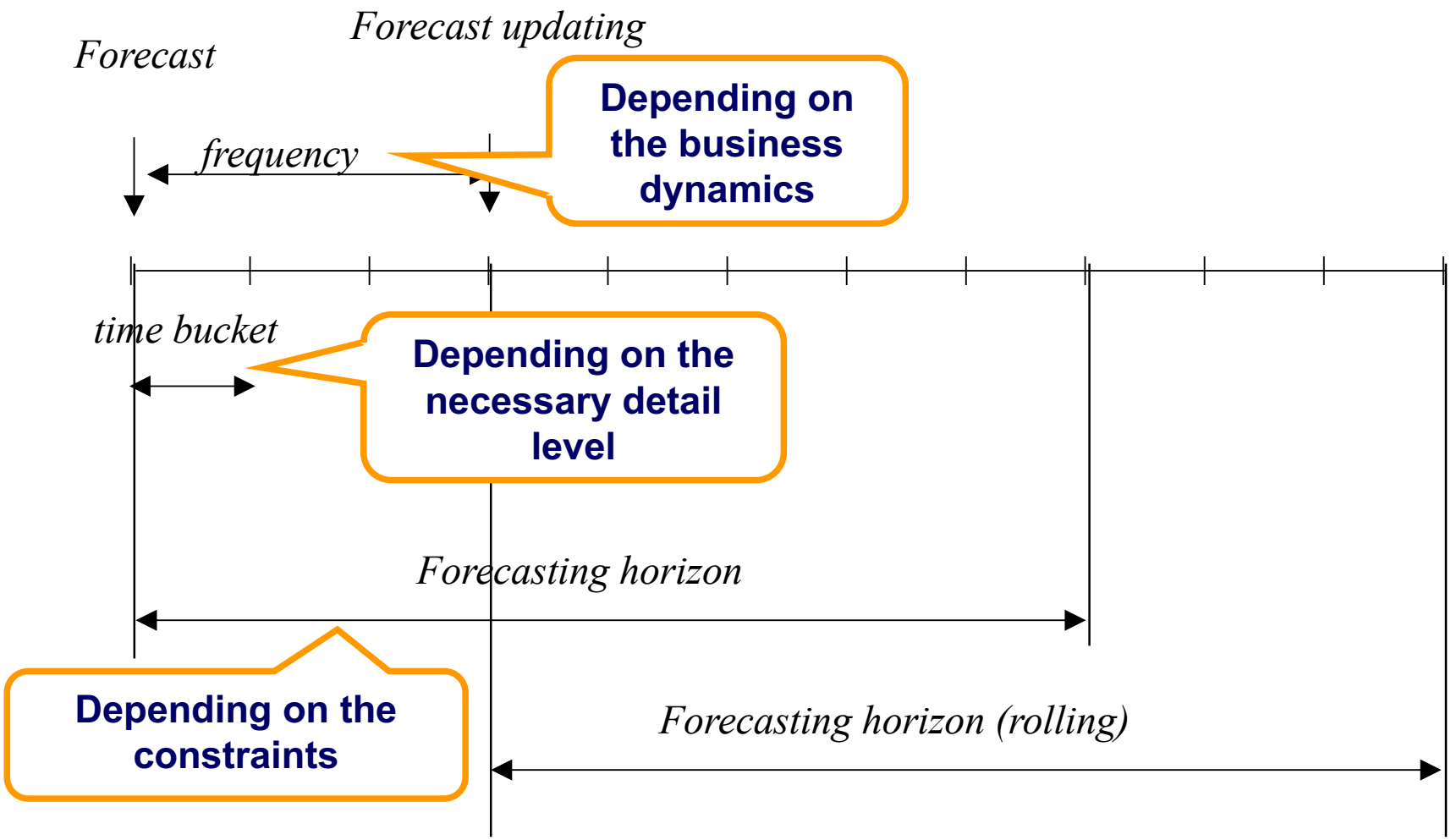
- **What is forecasted:**
  - number of orders, order lines
  - the volume of sales
  - sales in terms of money

- **Which unit of measure**
  - SKU, cases, pallets
  - €, $, ¥…
  - m^3, tons…

Product level



Planning horizon



The accuracy of forecasting…

INCREASING THE GROUPING LEVEL OF PRODUCT

(*ex. product family forecast have better accuracy than sum of forecasts of single products of family)*

INCREASING THE GROUPING LEVEL OF TIME

(*ex. monthly forecast have better accuracy than sum of forecasts of single weeks of month)*

INCREASING THE GROUPING LEVEL OF PLACE

(*ex. forecast of total sales of Italy have better accuracy than sum of forecasts of single regions of Italy)*

INCREASING THE FORECAST HORIZON

(ex. as forecast horizon is longer as random events are frequent and the forecast accuracy is worse*)*

Accuracy

- **The accuracy of the forecasting process depends on:**
  - the aggregation level in terms of time, product, geographical areas (because of error compensation)
  - the anticipation, how much time before the forecast is made (the closer, the better accuracy)

Process objectives

- **The nature of the forecasting process (object, time horizon, etc) depends on the use of the forecast**

- **Example of objectives:**
  - support the distribution planning
  - define the parameters to manage the materials
  - size the production capacity
  - …

Example:
Fast moving consumer goods

Objective	Process
Sizing production capacity and storage capacity of the central warehouse	➢ Aggregation: trade family ➢ Time bucket: monthly demand ➢ Horizon: 1-3 years
Production and material planning	➢ Aggregation: production family ➢ Time bucket: weekly demand ➢ Horizon: 3 - 6 months
Distribution planning	➢ Aggregation: SKU ➢ Distinction per regional warehouse or customer ➢ Time bucket: daily demand ➢ Horizon: 1-2 weeks

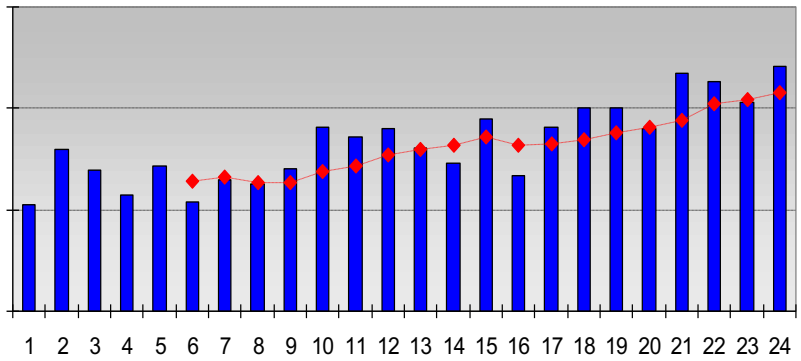
Agenda

LIUC
Università Cattaneo

1. Demand planning process

2. Demand forecasting system and methodologies

3. Forecasting process accuracy



Main principles of the forecasting system

- **The forecasting system should:**
  - adapt to the nature of the forecasting problem and not vice versa
  - use a set of forecasting techniques, quantitative e qualitative, not only one
  - be used as means of communication between who generates and who uses the forecast
  - communicate to the users not only the forecast but also the estimated error
  - include mechanisms to manage the exceptions (e.g.: promos, …)
  - help the user in choosing the most appropriate techniques

The main forecasting methodologies

LIUC
Università Cattaneo

"TIME SERIES" APPROACHES	- MOVING AVERAGE *(simple, weighted,..)* - EXPONENTIAL SMOOTHING *(Winters...)* - DECOMPOSITION - ARIMA (*Box Jenkins)*
RELATIONAL/CAUSAL APPROACHES	- REGRESSION *(linear, squared,...)* - ECONOMETRICS / INPUT-OUTPUT
QUALITATIVE APPROACHES	- SALES FORCE - EXPERT PANELS / DELPHI METHOD - FUTURE SCENARIOS / ANALOGIES - MARKET SEARCH, SURVEYS, TEST - MARKETING

Causal approaches (1)

LIUC
Università Cattaneo

The forecast for the future demand (F_{t+1}) is based on the identification of a functional relationship between the demand and other variables influencing the demand and on the forecast or measure of these variables

$$F_{t+1} = f\ (X1_{t+1}, X2_{t-N}, \ldots)$$

The link can be "contemporaneous" (and in this case it is necessary to be able to forecast the variable) or consider a time delay between cause and effect (and in this case it can be sufficient to use the historical data of the independent variable)

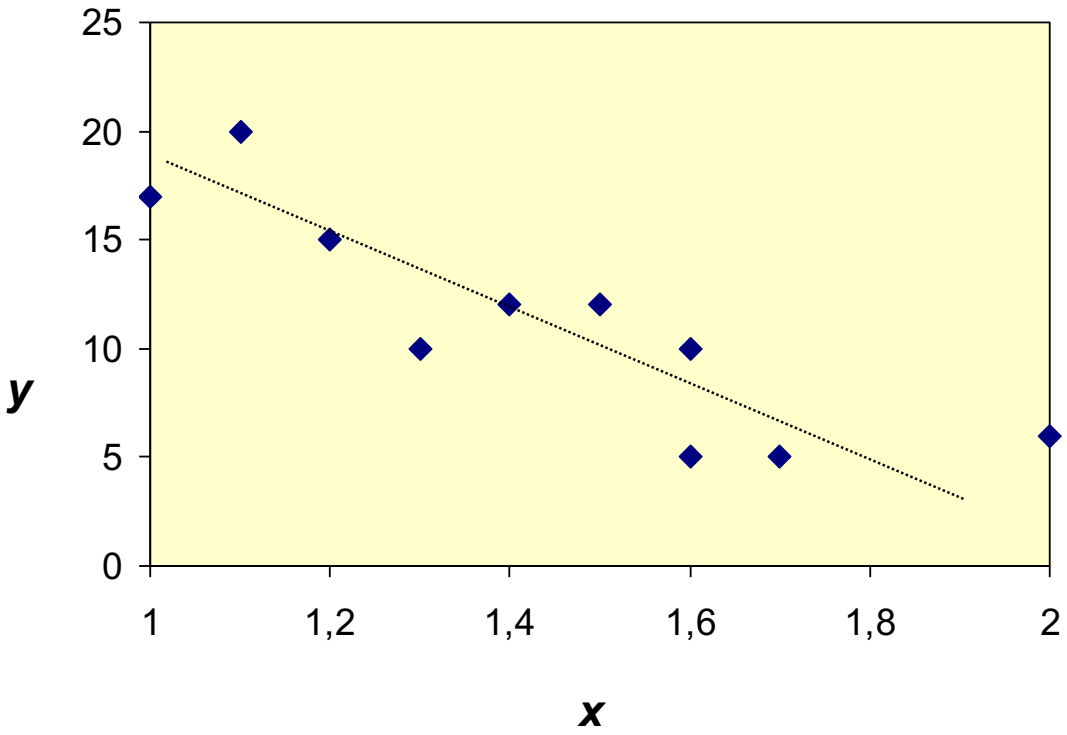
Causal approaches (2)

A causal link between a group of independent variables and the demand, formalized through a functional relationship "f":

- Identification of the independent variables (price, investments on advertising, promotions, temperature, humidity, traffic, weather, …)
- Identification of the links between the variables (equation linear, squared, exponential, ...)
- Assess the equation parameters
- Forecast the dependent variable (demand) is obtained thanks to future forecasts (or historical data) for the independent variables

Example: linear regression

$$y = A + B \cdot x + \varepsilon$$



Is there a function able to explain the link between the dependent and the independent variable ?

$$\hat{y} = a + b \cdot x$$

What is the value of the coefficients *a* and *b*?

Example: linear regression

LIUC
Università Cattaneo

Coefficients a and b

$$b = \frac{\sum_{i=1}^{n} (x_i - \bar{x}) * (y_i - \bar{y})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

$$a = \bar{y} - b\,\bar{x}$$

Example: linear regression

LIUC
Università Cattaneo

- The coefficient assesses the quality of the linear regression model
- -1 =< r =< 1
- If r is close to 1 a significant linear correlation exits (usually “acceptable” if > 0,6)

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x}) * (y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 * \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Causal approaches (3)

LIUC
Università Cattaneo

PROs

- They take into account the external factors that influence or explain the demand (price, weather conditions, etc.)
- Higher "intelligence" on the factors explaining the demand
- Possibility to integrate/correct the forecasts based on time series

CONs

- They require cumbersome data analysis
- A functional relationship has to be built and validated
- It's necessary to be able to forecast the casual factors better than the demand (dependent variable)

Qualitative approaches (1)

LIUC
Università Cattaneo

- **Sales force**

Marketing prepares and modifies the demand forecast on the basis of the knowledge of customer initiatives, planned promotions, macroeconomic patterns, etc. the information on the sales are gathered and elaborated on the basis of a bottom-up approach (salesmen, area manager, Marketing director)

- **Delphi method**

Interaction of a group of experts through a questionnaire that interactively reports the answers step by step given (anonymously), till a consensus – the most possible unanimous – is reached.

Qualitative approaches (2)

LIUC
Università Cattaneo

- **Expert panel**

A group of people belonging to different functions (marketing, design, production, finance, …) is in charge of making the forecasts

- **Market surveys**

Mail or interviews to a sample of customers to understand their behavior in the purchasing

- **Analogy with other products**

Identification of products with characteristics similar to the new product that will be launched

Qualitative approaches (3)

PROs

- They can take into account all the factors that have never happened and can influence the demand
- Able to create “consensus”, involvement and “ownership” on the output of the forecasting process

CONs

- Limited capability of analysis both quantitative and formal and difficulty in managing “lots of numbers”
- High costs in terms of “manual” analysis of data and facts + meetings, or external costs (surveys, etc.)
- Risk of fallacious correlations to support the thesis, excess of confidence regarding the conclusion, excess of conformity among the group members

“Time series” approaches (1)

LIUC
Università Cattaneo

The forecast for future demand (F_{t+1}) is based on the analysis (possible) and extrapolation of the time series of the past demand

$$F_{t+1} = f(D_t, .., D_{t-N})$$

The function linking the forecast and the past demand depends on the specific model. There are two basic alternatives:

- models of time series extrapolation
- models of analysis and extrapolation from time series (two steps: 1. Analysis 2. Extrapolation)

“Time series” approaches (3)

PROs

- Relatively simple
- Based on historical data normally available
- Easy to automate
- If preceded by the analysis of the time series give a good level of understanding of the demand behavior (trend, seasonality, …)
- Easy to update the models

CONs

- Limited consideration of the external factors
- Not suitable for products with no pattern or with few/no data on past demand (new products)
- Long set up periods might be required to select and set the models

“Time series” approaches (2)

- Before making the sales forecast it is necessary to analyze the past behavior of the time series to identify possible components (trend, seasonality, …)

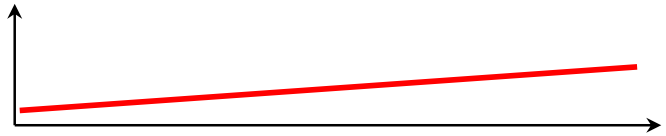
seasonality

erratic component

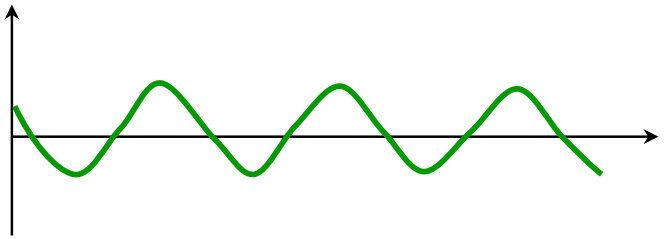
$$F_{t+1} = f(T_t, S_t, C_t, \varepsilon_t)$$

trend

ciclicity

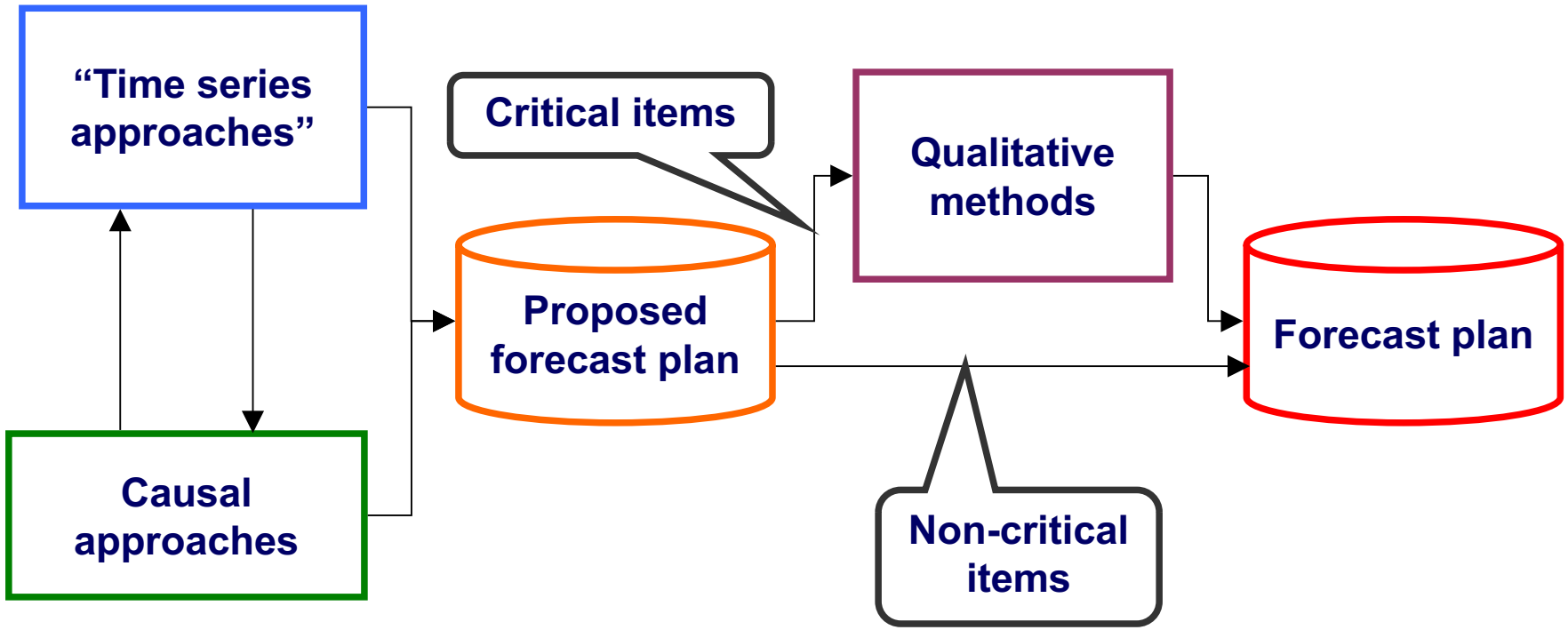


Tt : Trend component



St : Seasonality component

Joint use of the different methodologies



- Critical items:
  - Already known (item value, lifecycle stage, replenishment lead time, etc.)
  - Identified through alarm systems (*management by exception*)

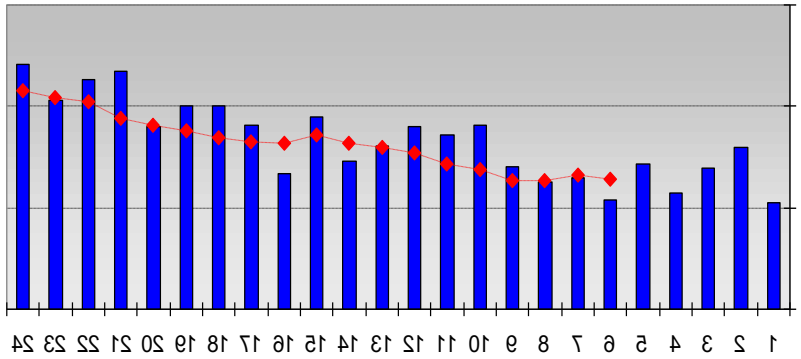
Agenda

LIUC
Università Cattaneo

1. Demand planning process

2. Demand forecasting system and methodologies

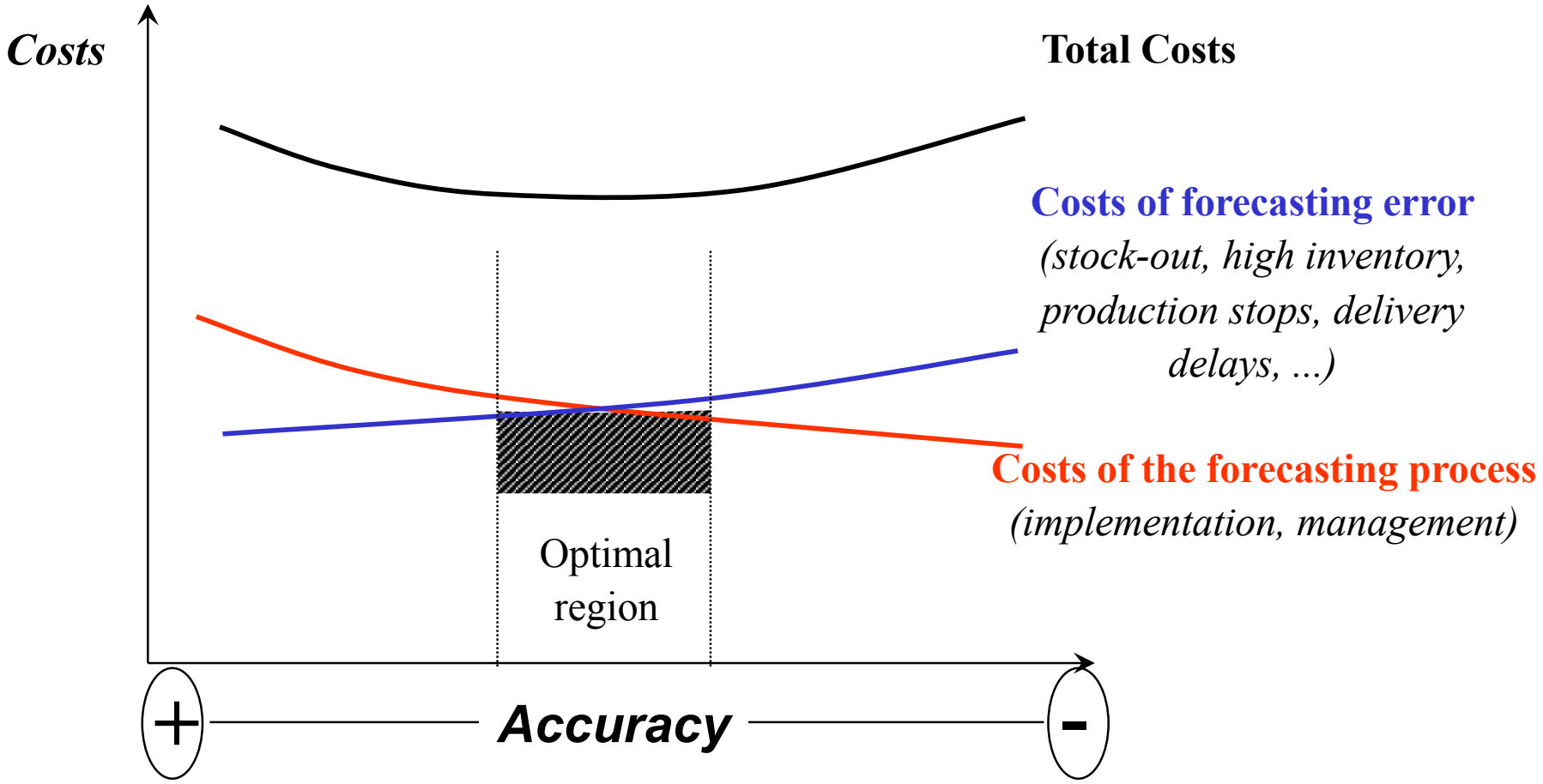
3. Forecasting process accuracy



Forecasting process performances

LIUC
Università Cattaneo

Costs vs. Benefits trade-off



Accuracy of the forecasting process

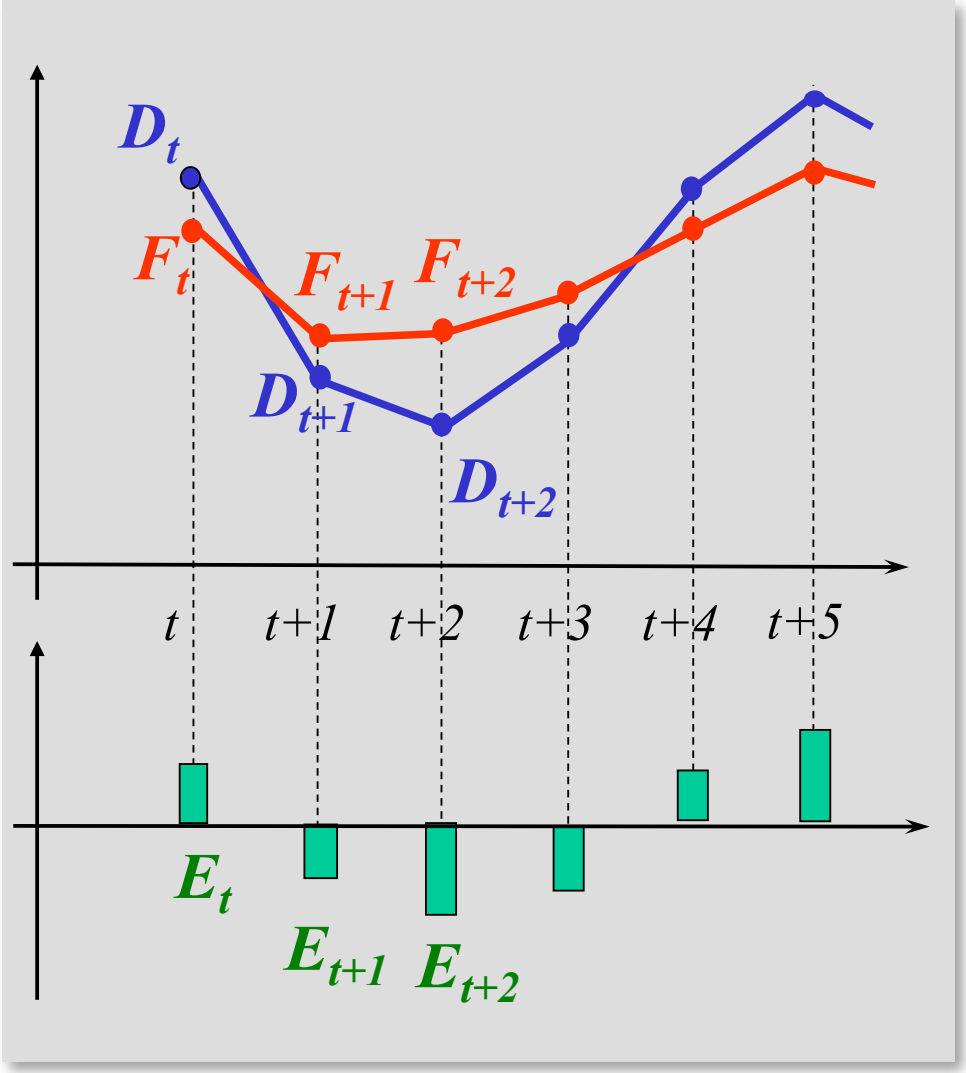
- **Monitoring the forecasting process accuracy has the following objectives:**
  - choice of the best fitting forecasting technique
  - setting of the parameters of the selected forecasting technique(s)
  - review of the technique or the parameters
    - new explicative variables
    - change of some parts of the model
    - particular or anomalous

Forecasting process performance measures: forecasting error (1)

LIUC
Università Cattaneo

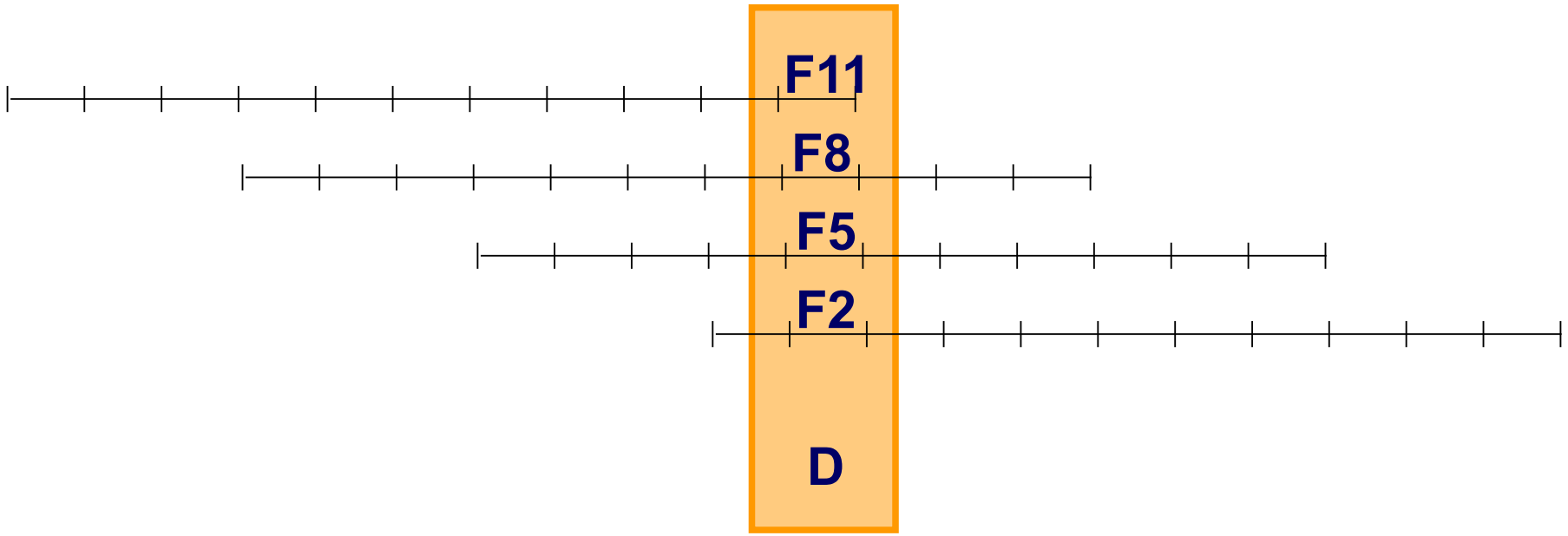
The forecasting error at time t has been defined as the difference between the real value of the demand and the forecasted value at time t

$$E_t = D_t - F_t$$



Forecasting process performance measures: forecasting error (2)

- There are n (horizon/frequency) forecasting values (not only one) with the respect to a specific value of the demand (item, area, period)
- As a consequence there are also n errors… which is the right one for the accuracy measurement?



Forecasting error measures

LIUC
Università Cattaneo

ERROR STATISTICS

Type	Name	Symbol	Formula	Comment
DISTORSION	**Mean error**	**ME**	$ME = \frac{\sum_{t=1}^{n} E_t}{n}$	**Measure of the BIAS**
CONSISTENCY	**Mean absolute deviation**	**MAD**	$MAD = \frac{\sum_{t=1}^{n} \lvert E_t \rvert}{n}$	**Positive and negative errors don't cancel out**
	Medium absolute percentage deviation	**MAPE**	$MAPE = \frac{\sum_{t=1}^{n} \frac{\lvert E_t \rvert}{D_t}}{n} \times 100$	**Percentage error**
	Mean squared error	**MSE**	$MSE = \frac{\sum_{t=1}^{n} (E_t)^2}{n}$	**Bigger errors weight more**
	Standard deviation error	**SDE**	$SDE = \sqrt{\frac{\sum_{t=1}^{n} (E_t)^2}{n-1}}$	**Same as MSE but with a better unit of measure**
TRACKING SIGNAL	**Tracking signal**	**TS**	$TS = \frac{\sum_{t=1}^{n} E_t}{MAD}$	**It shows if there are always positive or always negative errors**