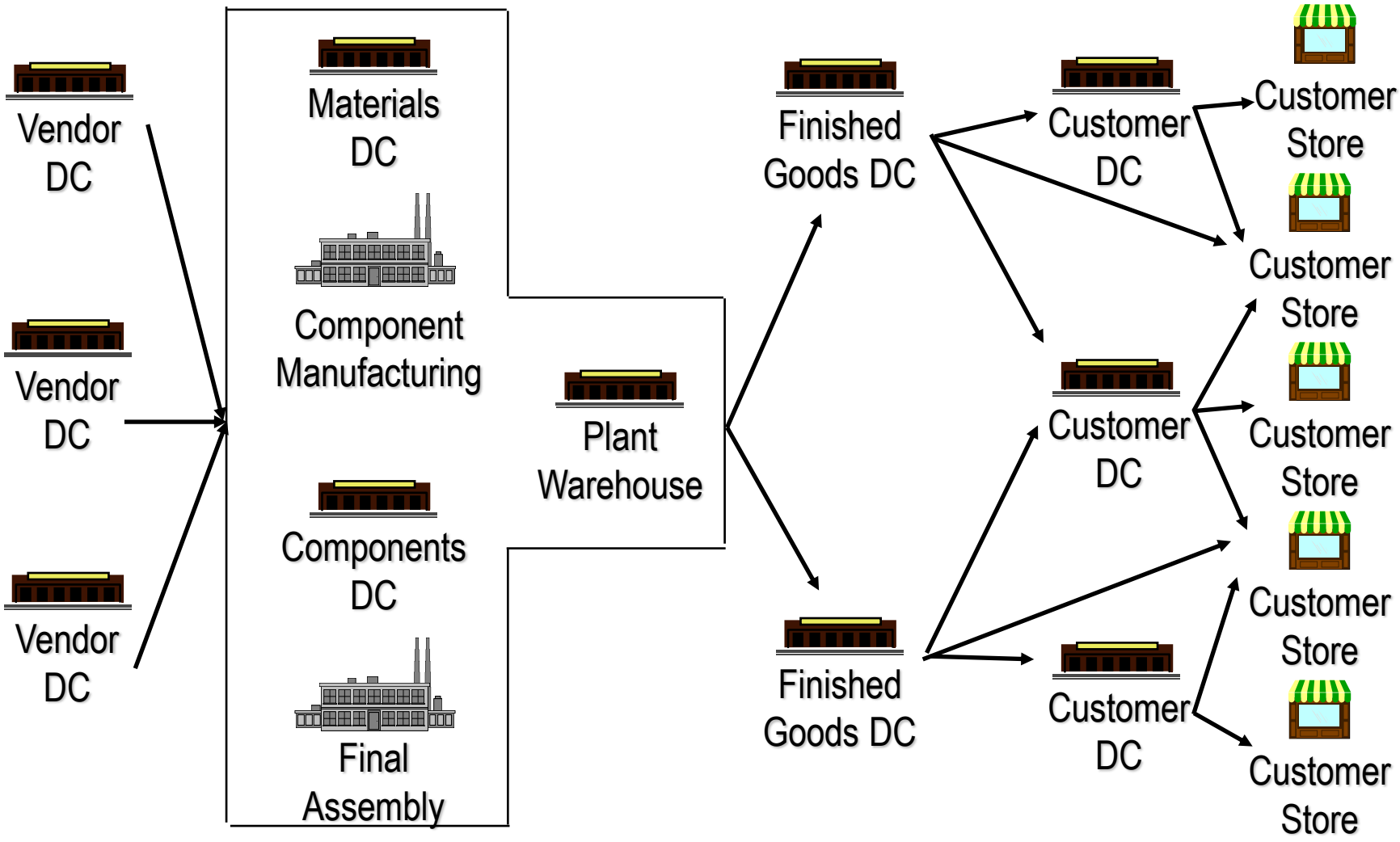
Demand Forecasting in the Supply Chain
The use of ForecastPro TRAC ®

Marco Arias Vargas
Global EMBA
INCAE

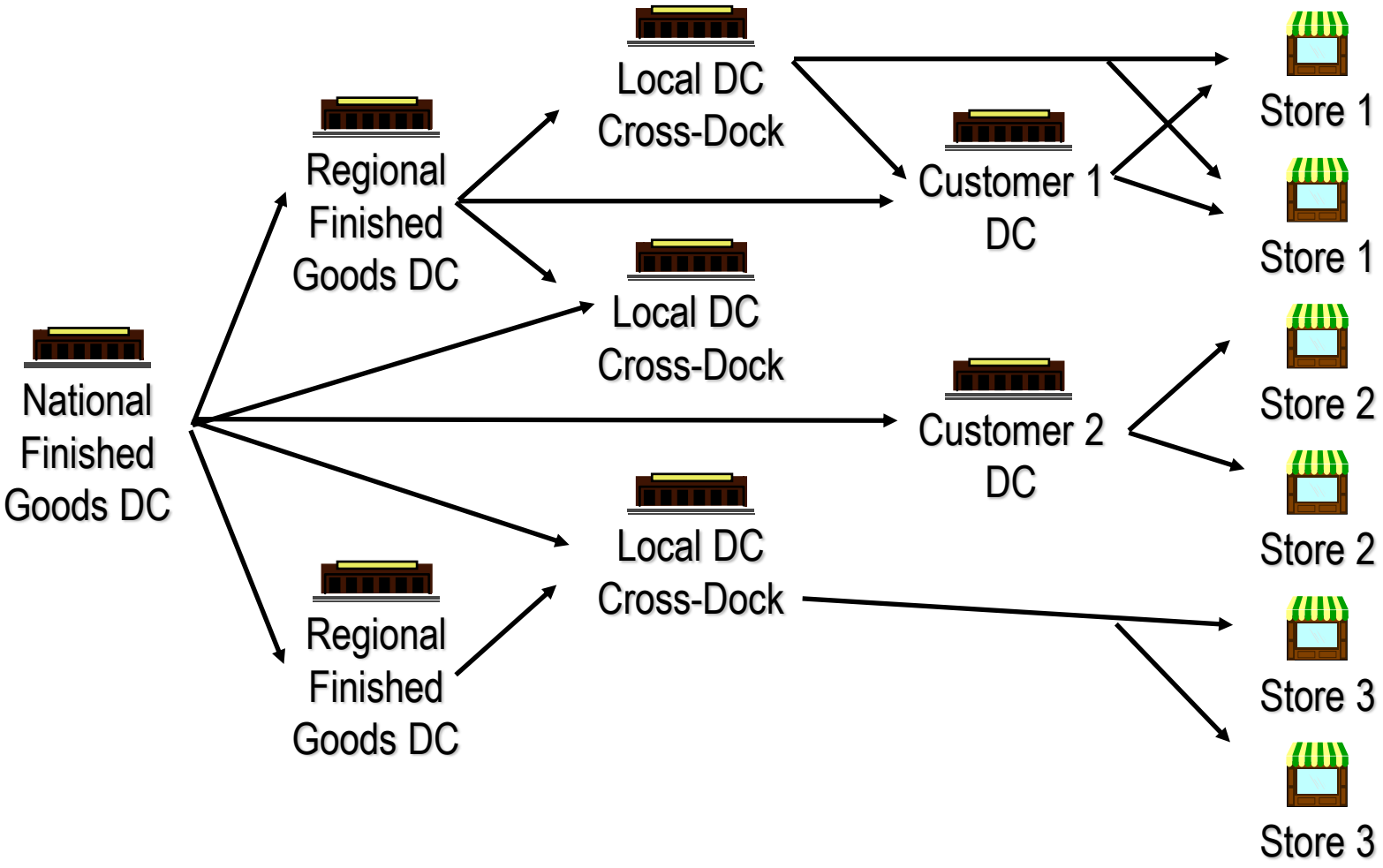
Value Creation in the Supply Chain: Logistics processes interrelations

- The Supply Chain is complex and can be configurated in several ways, depending on the business model.
- This “chain”, has become a network.
- This “network”, has become global.

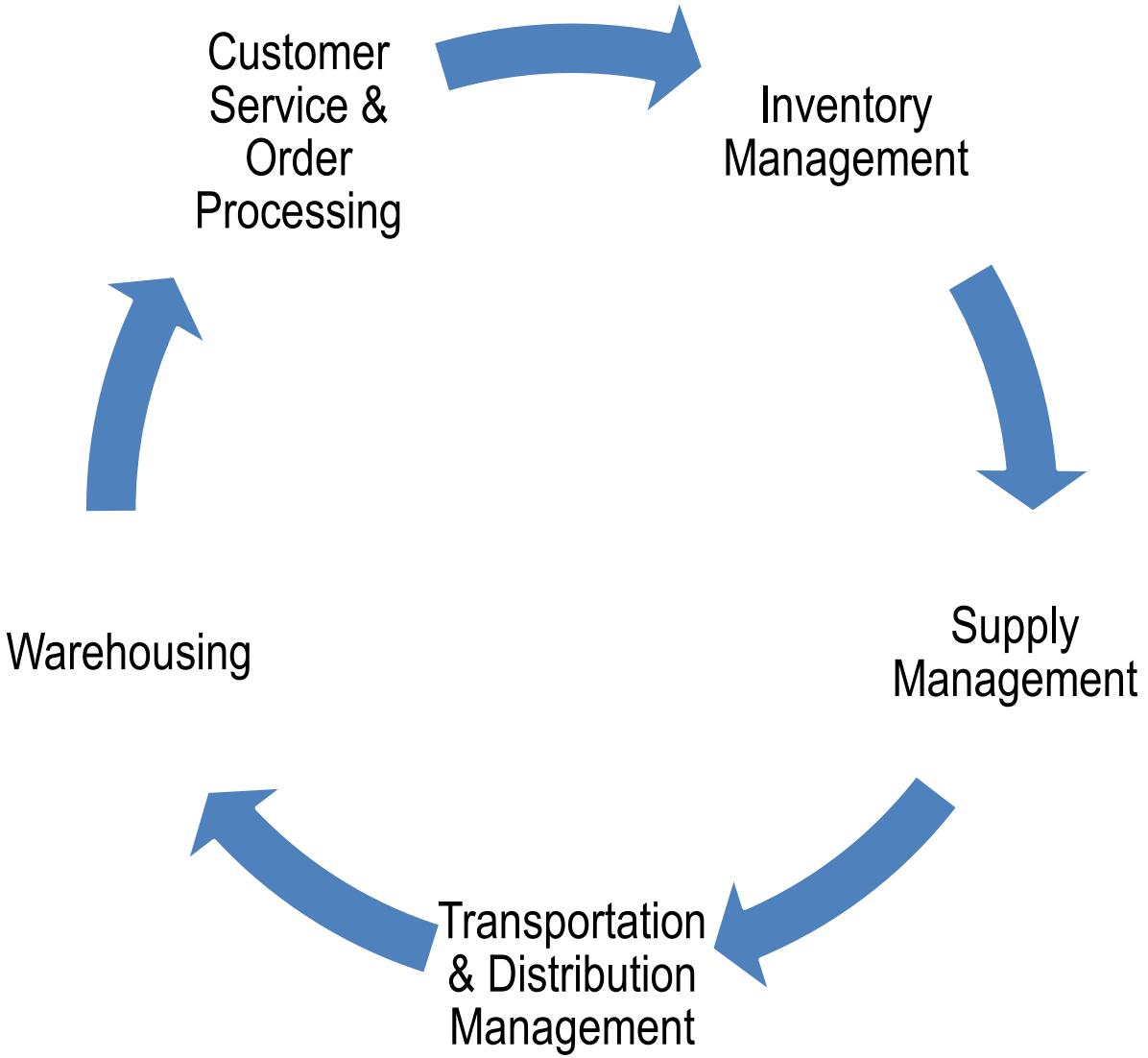
Complexity in the Supply Chain



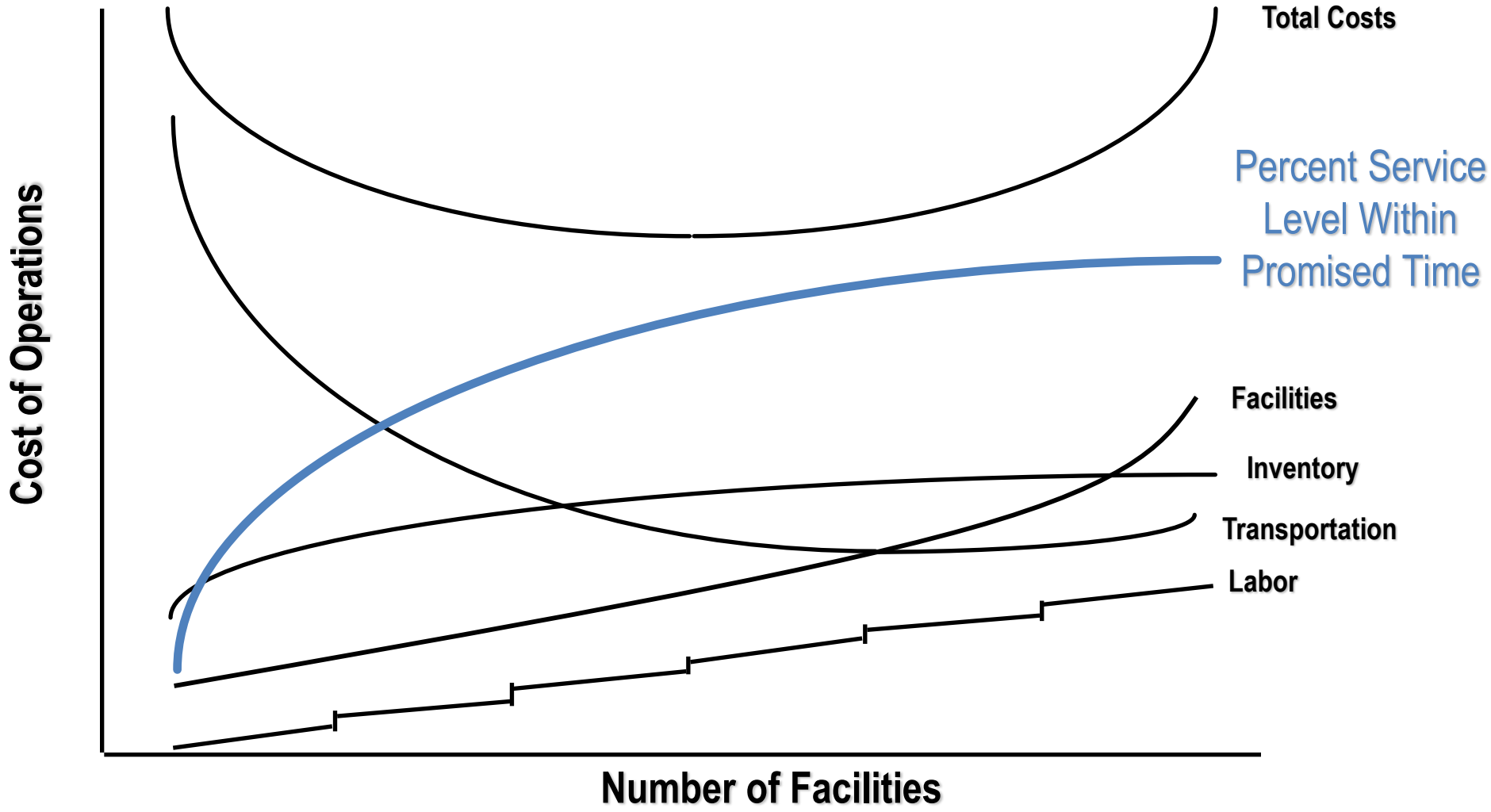
Different Supply Chain configurations based on the business model



Interrelated processes in the Supply Chain

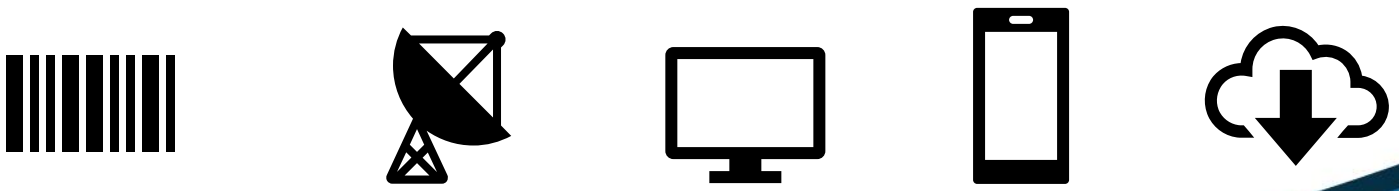


Typical relations in SCM

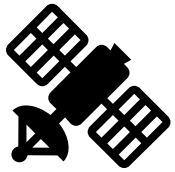


Trends and challenges in SCM

- Consumers are highly informed and they require higher service levels.
- Next day or same day deliveries.
- Increased number of sku´s due to the need for variety.
- Go from Silo Forecasting to Consensus, then to S&OP, CPFR and IBP (with scenario simulation).
- Minimize inventory levels, knowing that the Forecast errors are around 25% to 30%.
- Omni - channel distribution and order processing.
- Reverse Logistics.



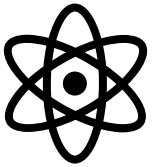
Trends and challenges in SCM



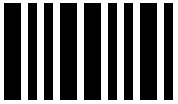
- Increasing use of 3PL´s and 4PL´s.
- Increasing use of technology specialized in SCM: WMS, TMS, CRM, RFID, among others.

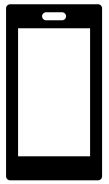
- Robotics.
- Blockchain for secure transaccions along the SC.

- Cloud Manufacturing.
- 3D printing.

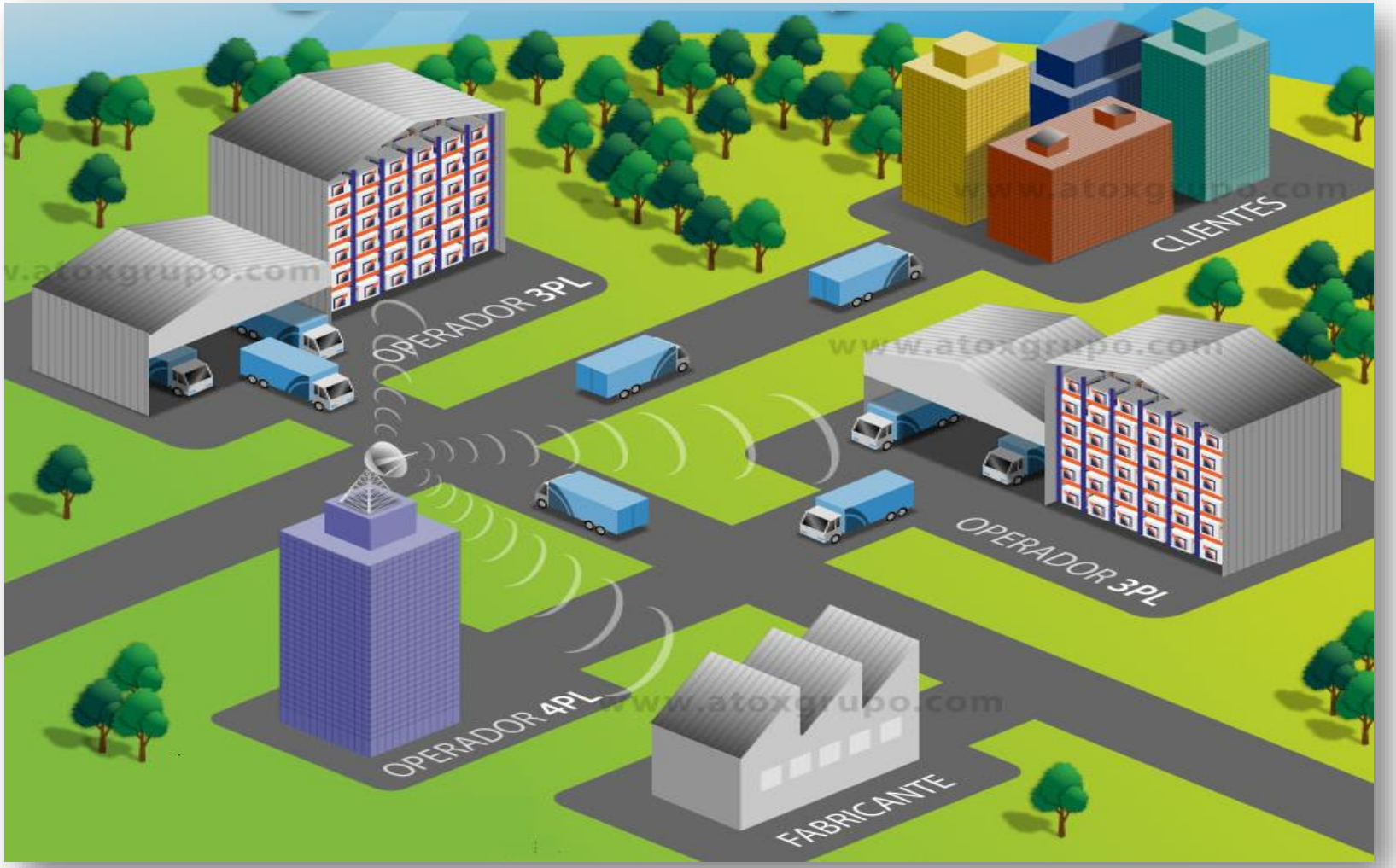


- Internet of Things, IoT.
- Big Data, driven by social networks.

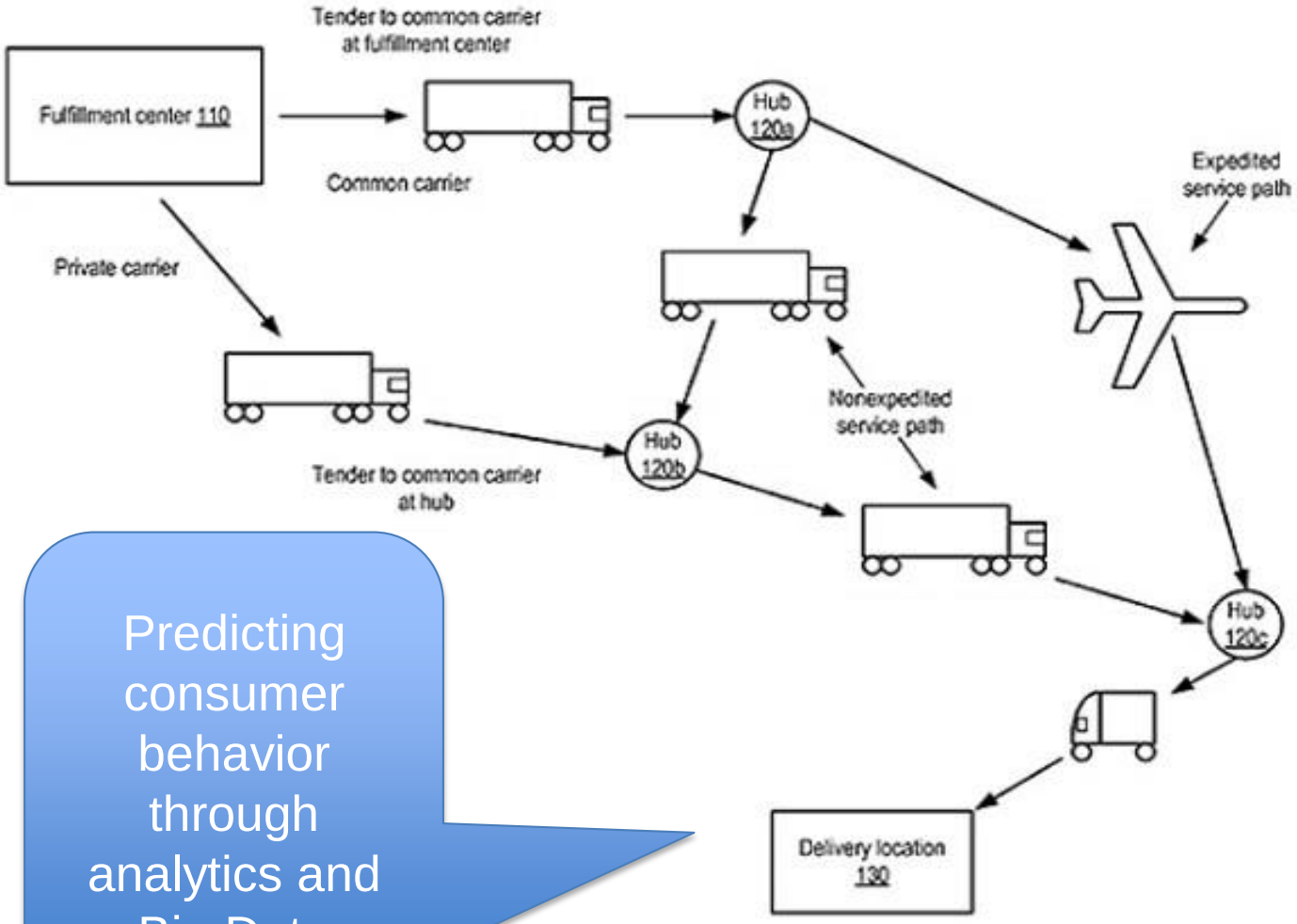




3PL and 4PL dynamics

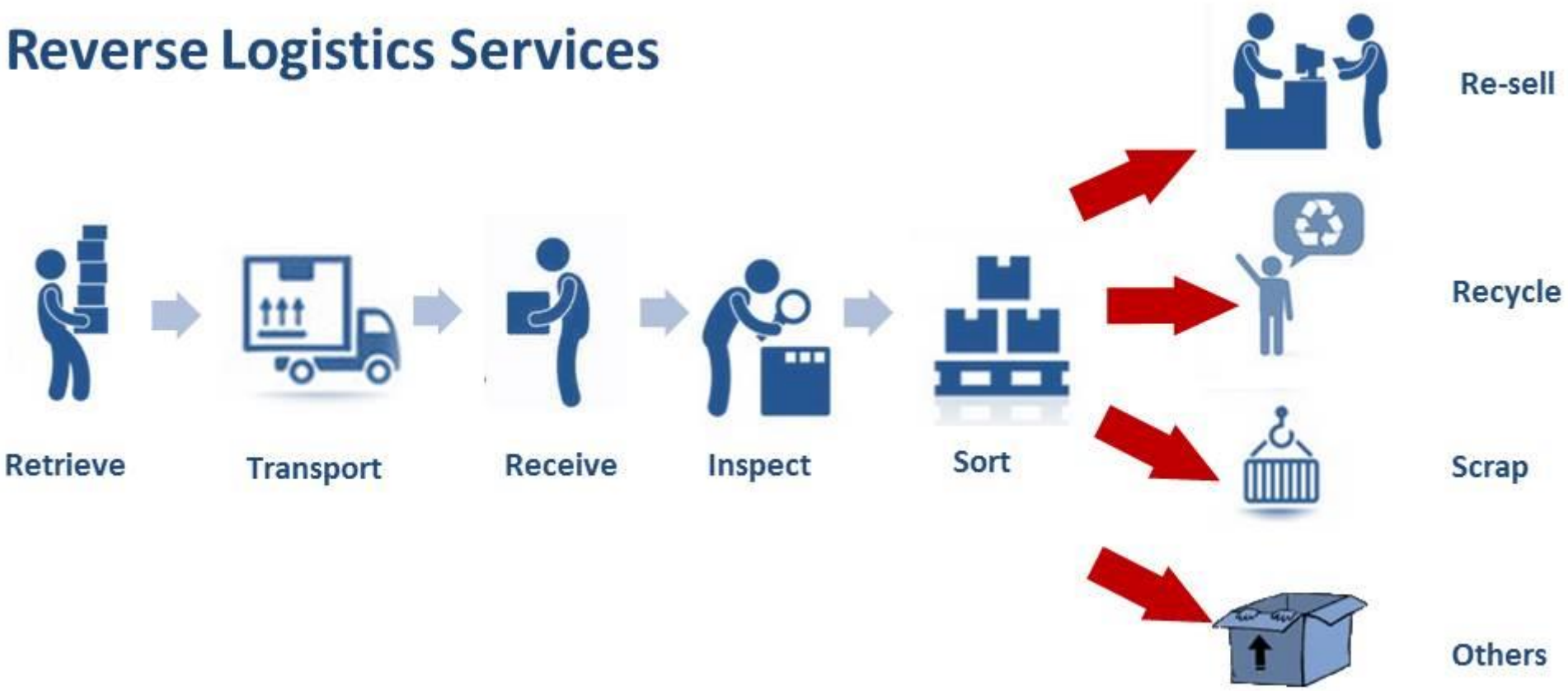


Big data:
Amazon Method and System for Anticipatory Package Shipping

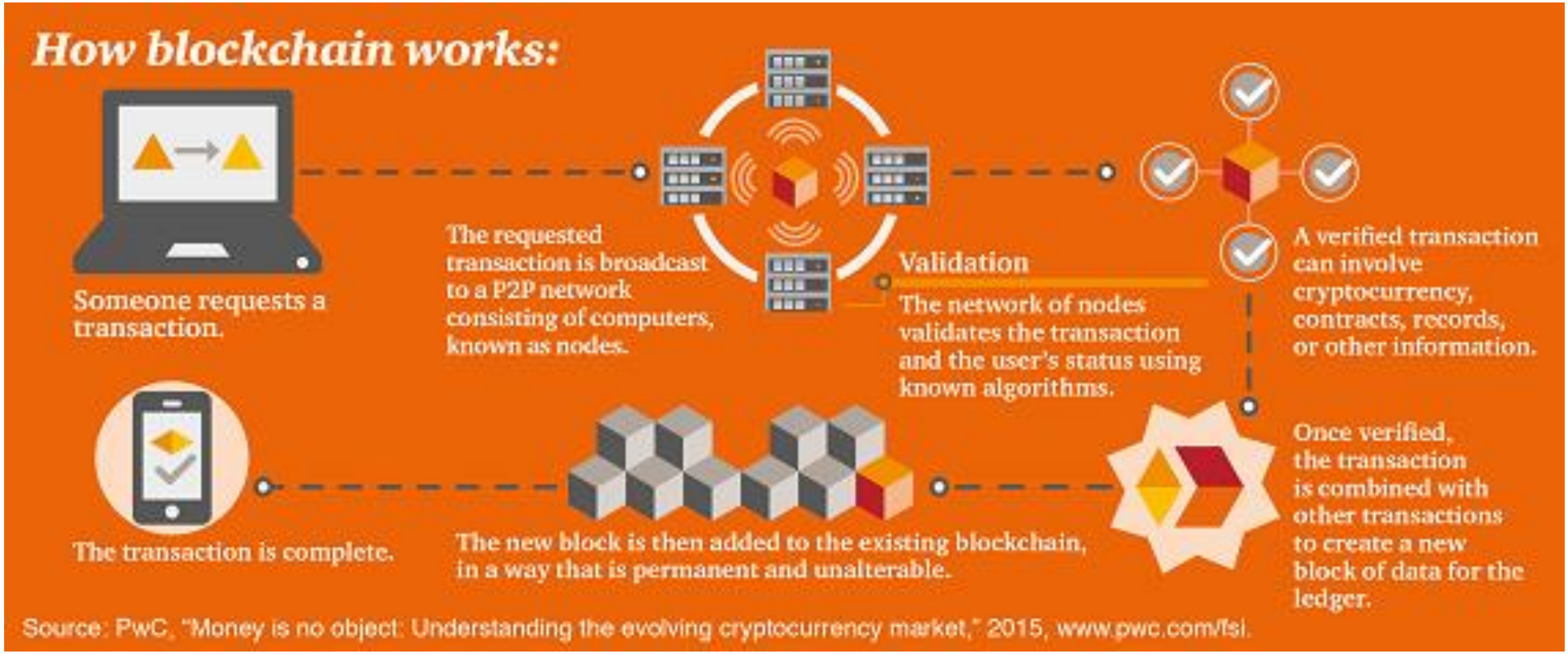


Predicting consumer behavior through analytics and Big Data

Reverse Logistics … Huge Opportunity



Blockchain


How blockchain works:
Someone requests a transaction.
The requested transaction is broadcast to a P2P network consisting of computers, known as nodes.
Validation
The network of nodes validates the transaction and the user's status using known algorithms.
A verified transaction can involve cryptocurrency, contracts, records, or other information.
Once verified, the transaction is combined with other transactions to create a new block of data for the ledger.
The new block is then added to the existing blockchain, in a way that is permanent and unalterable.
The transaction is complete.
Source: PwC, "Money is no object: Understanding the evolving cryptocurrency market," 2015, www.pwc.com/fsi.

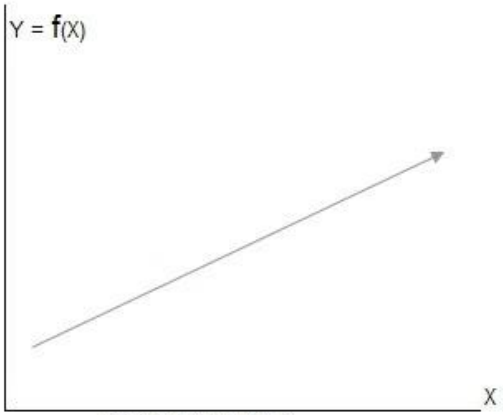
Impact of demand forecasting in the SC

- The forecasts look forward to project an estimate of future values based on past behavior.
- The Forecast accuracy is one of the most important variables in Inventory Management.
- The statistical forecasts are performed based on time series.
- The time series reflect the reality of the historical behavior of the demand.

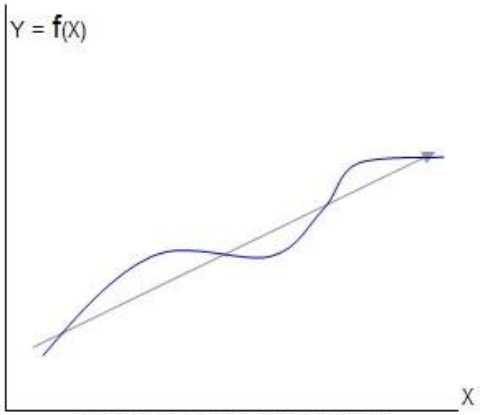
- An accurate Forecast has significant impact in the following business aspects:
  - Efficiency in the inventory level
  - Less warehousing requirements
  - Better customer service level
  - Increased cash flow

Components of the time series

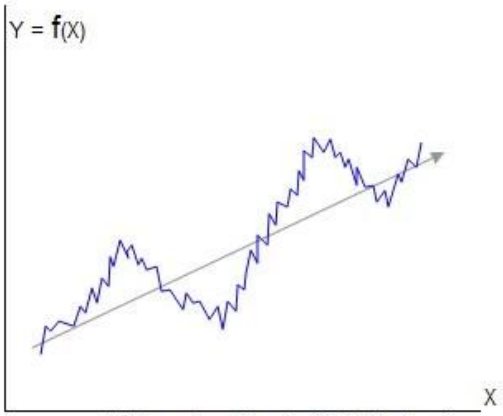
- Level, a
- Trend, b
- Seasonal Variations, F
- Special Events, E
- Random Fluctuations



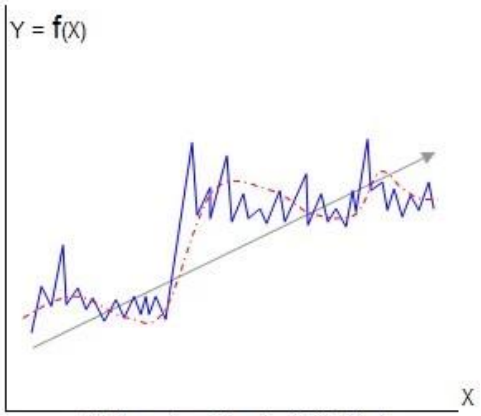
(1) Long-term Trend



(2) Long-term Trend with Cyclical Variations/Movements



(3) Long-term Trend with Cyclical and Seasonal Variations/Movements

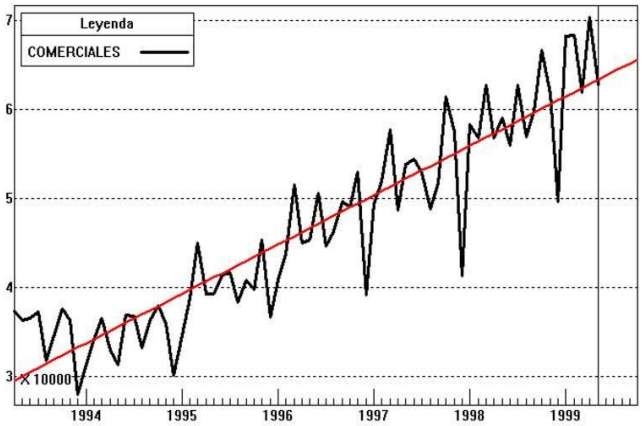


(4) Long-term Trend with Cyclical, Seasonal, and Random Variations/Movements

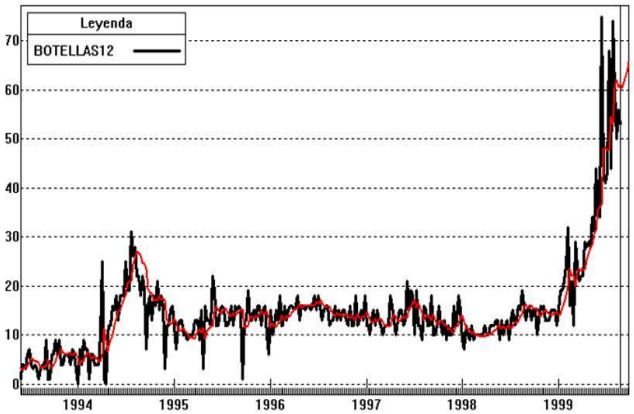
Trend types

- Linear
- Exponential growth or decline
- Damped
- Constant level (no trend)

Linear



Exponential



Damped

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Types of Seasonality

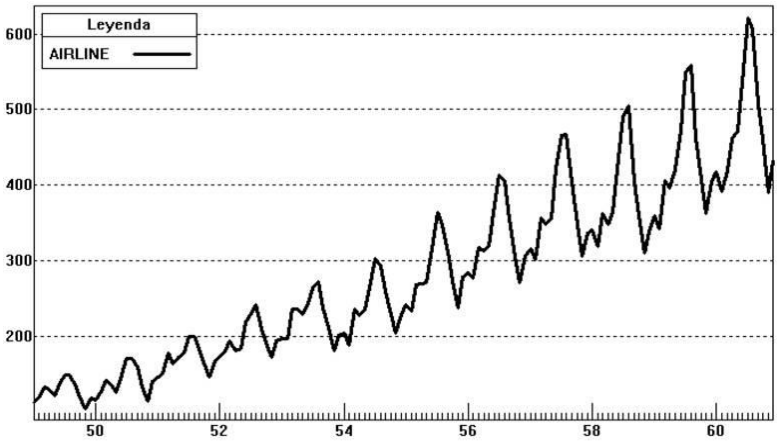
Causes of Seasonality:

- Climate
- Holidays
- School Calendar
- Accounting Purposes

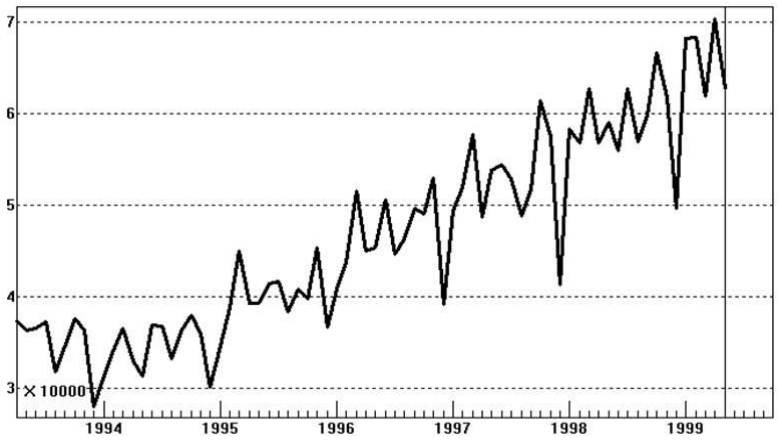
Types of Seasonality:

- Additive: constant unitary fluctuation
- Multiplicative: constant percentage fluctuation

Multiplicative



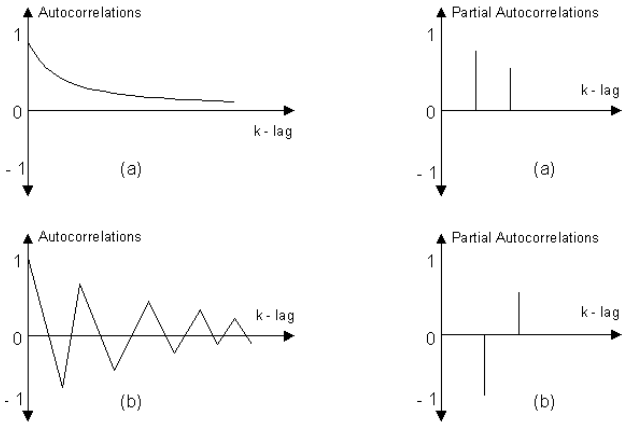
Additive



Other components of the time series

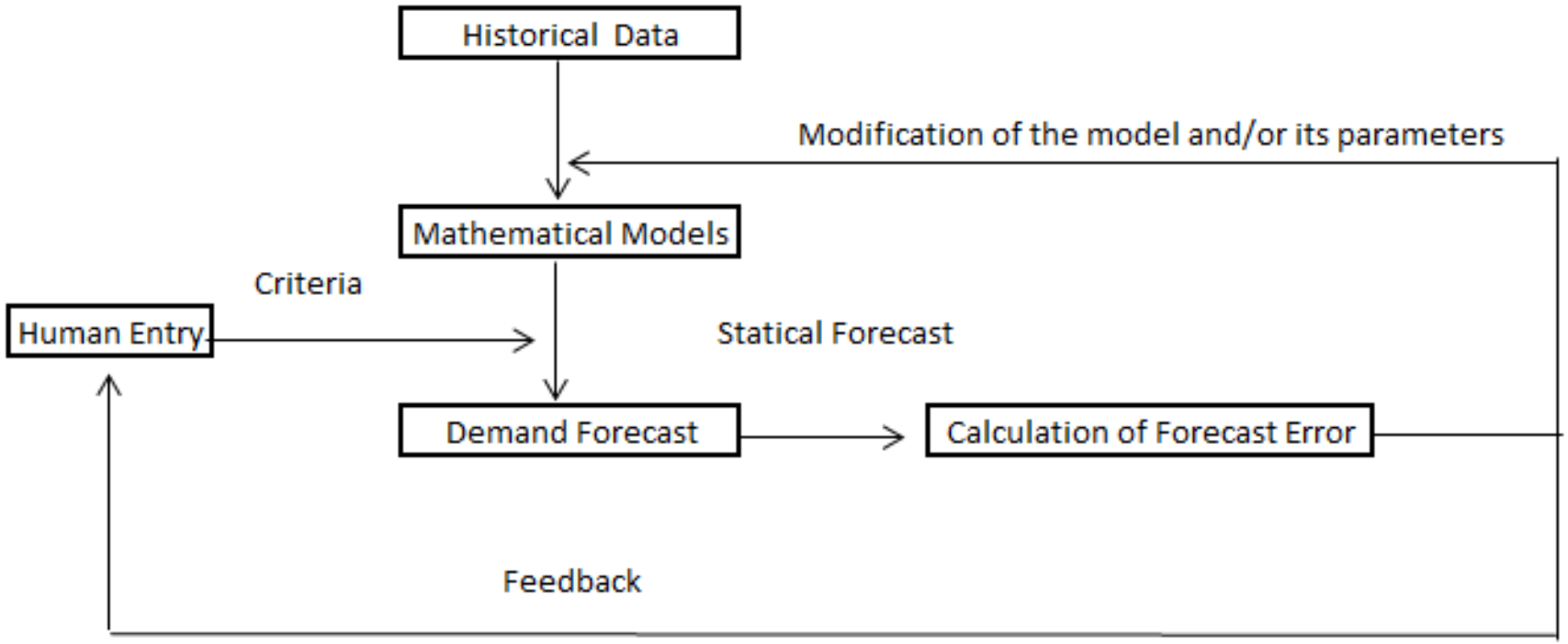
- **Special Events:**
- Natural Disasters
- Labor Strikes
- New laws and regulations
- Holidays that not every year occur in the same week each year
- Irregular product promotions

- **Random Fluctuations (Noise):**
- It is the inherent and unpredictable component of a variable.
- It is important to measure the noise in a time series to learn how predictable it is.
- Series with high noise can not be predicted accurately.



Behavior of the Autocorrelations and Partial Autocorrelations of AR(2)

Basic Steps to Develop Forecasts



Main Types of Forecasting Methods

- **Extrapolative Methods:** find a pattern and assume that the historical behavior will continue in the future.

- **Explanatory Methods:** Determine the factors that explain the past behavior of the variables to predict and measure the effects of these factors on the dependent variables. They assume that the relationships between variables do not change.

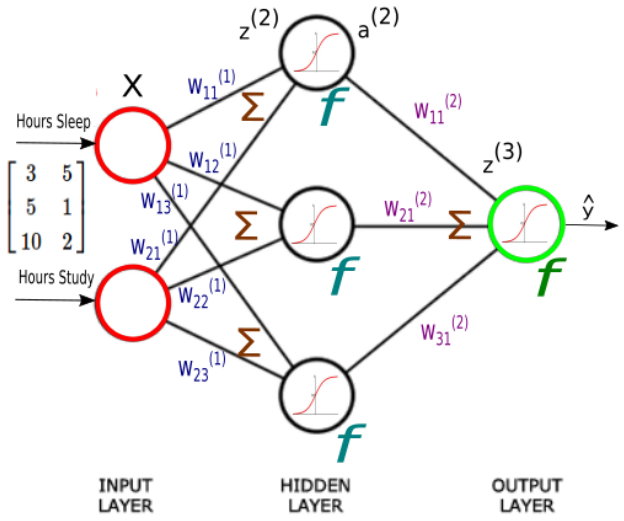
- **Methods based on judgement criteria:** experience and intuition of management, customer surveys and data vendors.

Extrapolative Methods

- **Random Walk:** Does not predict the future change. Used to measure how volatile a time series is.
- **Simple Moving Average:** For leveled demand. A sliding average of more recent data. Used for very short series.
- **Simple Exponential Smoothing:** For leveled demand, giving more importance to the most recent data.
- **Double Exponential Smoothing:** For demands with level and trend. This model can smooth special events.
- **Winters:** For demands with level, trend and seasonality. This model can smooth special events.
- **Box-Jenkins:** For demands with level, trend and seasonality. Data shows autocorrelation and this autocorrelation in the data is used to identify a time series model.
- **Methods for intermittent data:** Predicts time series of low volume with frequent zeros. Example: Croston Model and Discrete Data Models.

Methods with Explanatory Variables

- **Dynamic Regression:** Extension of the classical regression to incorporate delayed variables and delayed error terms.
- **ARIMAX:** Extension of Box-Jenkins to include explanatory variables.
- **Econometric Models:** A system of simultaneous equations to represent economic interrelations.
- **Neural Network:** similar to the neural architecture of the brain, these networks allow nonlinear connections between input and output variables.



Multilevel Forecasts

- Used to work with added series
  - For families (groups) of products.
  - For areas (groups) of distribution.
  - For routes (groups) of distribution.
  - For components (groups) of a final product.

- It can be done in two ways:
  - Statistically forecast lower levels and adding the results to each group.
  - Statistically predict the aggregate number of the group and segregate it into its component series (Up - Down)

Multilevel Forecast and its Use in Sales & Operation Plannig (S&OP)

- S&OP seeks to develop demand and supply plans based on the criteria of the different departments involved (Supply Chain, Marketing, Sales and Finance), through cross-functional teams that seek to generate and satisfy demand.

- S&OP starts from a baseline forecast that is the conductive base of the operational plans of all of the areas. The multilevel methods are vital to the accuracy of this starting point.

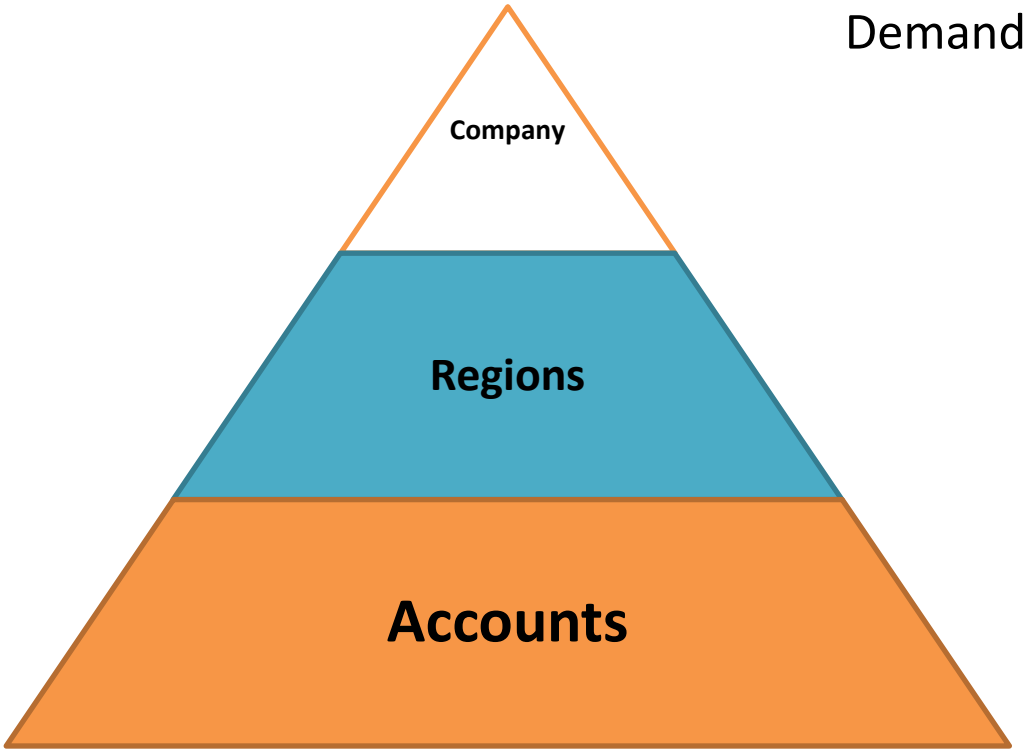
Multilevel Forecast and its Use in S&OP

- By working with multilevel models, forecasts can be expressed (aggregated or disaggregated) in the terms that each area needs to monitor it:

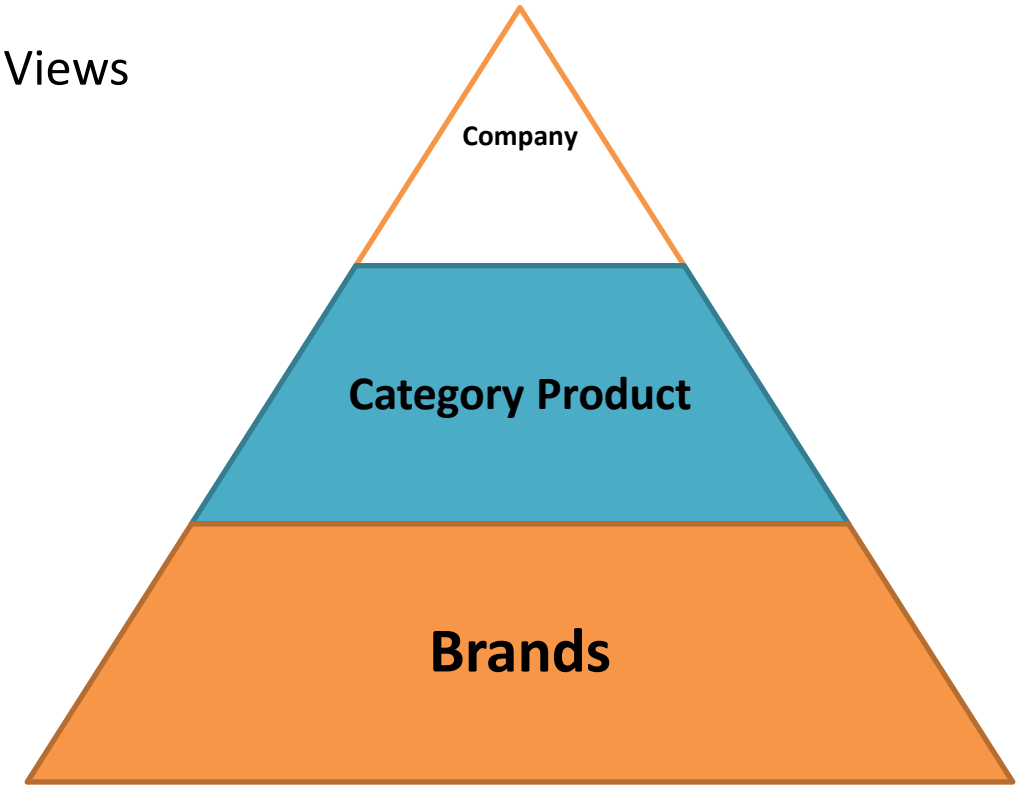
  - Marketing: Profit by Category
  - Sales: Sales by Customer
  - Supply Chain: Units – SKU´s, boxes
  - Finance: Budget Units

Importance of S&OP in Map Hierachy Multilevel Models

Demand Views



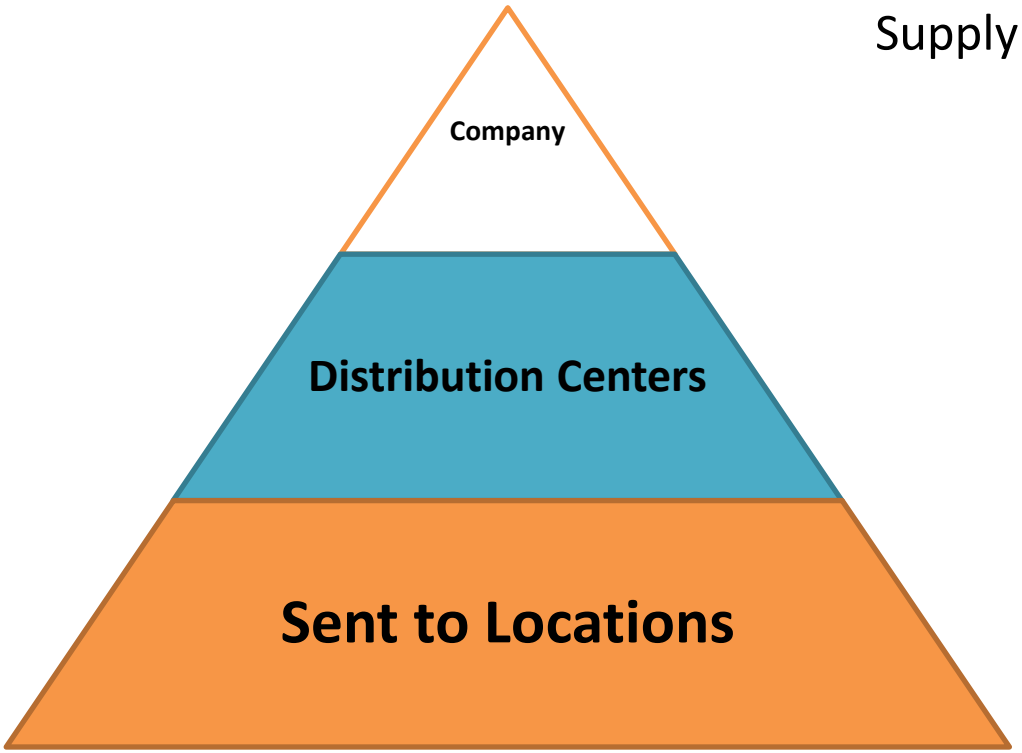
Sales View($)



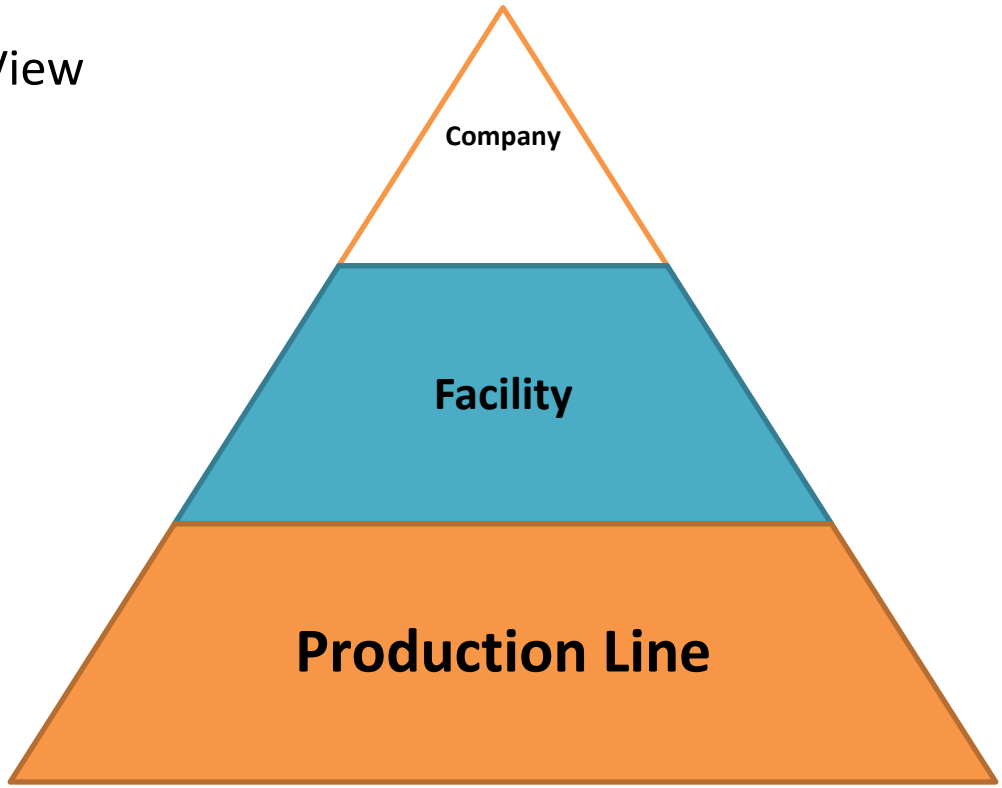
Market View ($, Uds)

Importance of S&OP in Map Hierachy Multilevel Models

Supply View



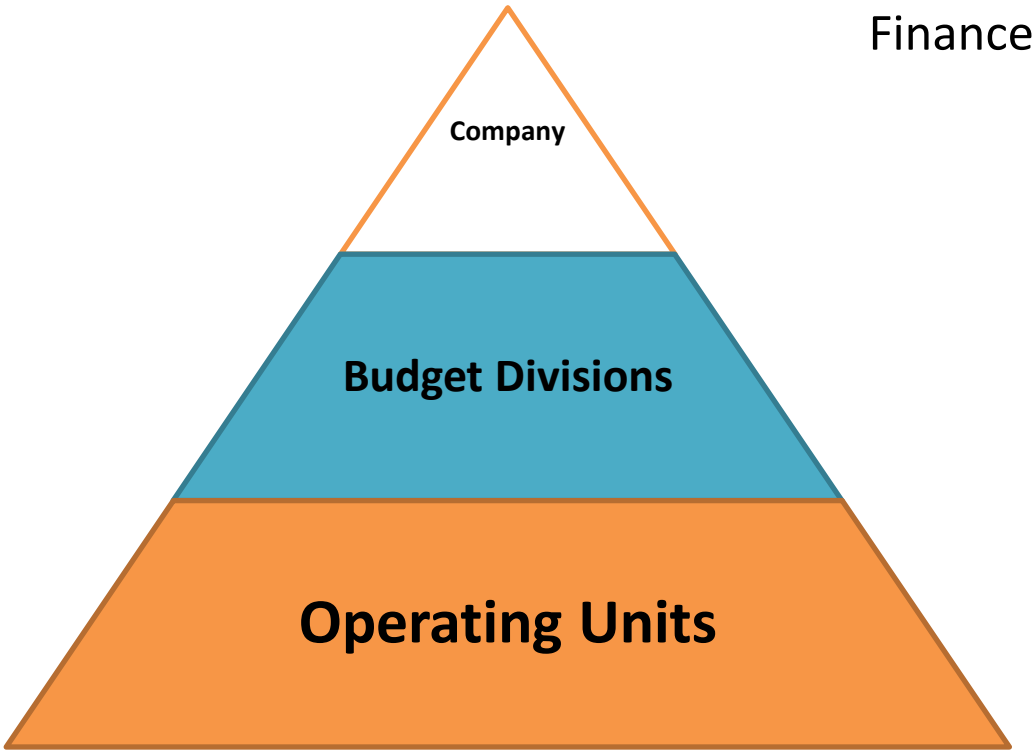
Logistic View (Units, Boxes)



Manufacturing View (Units)

Importance of S&OP in Map Hierachy Multilevel Models

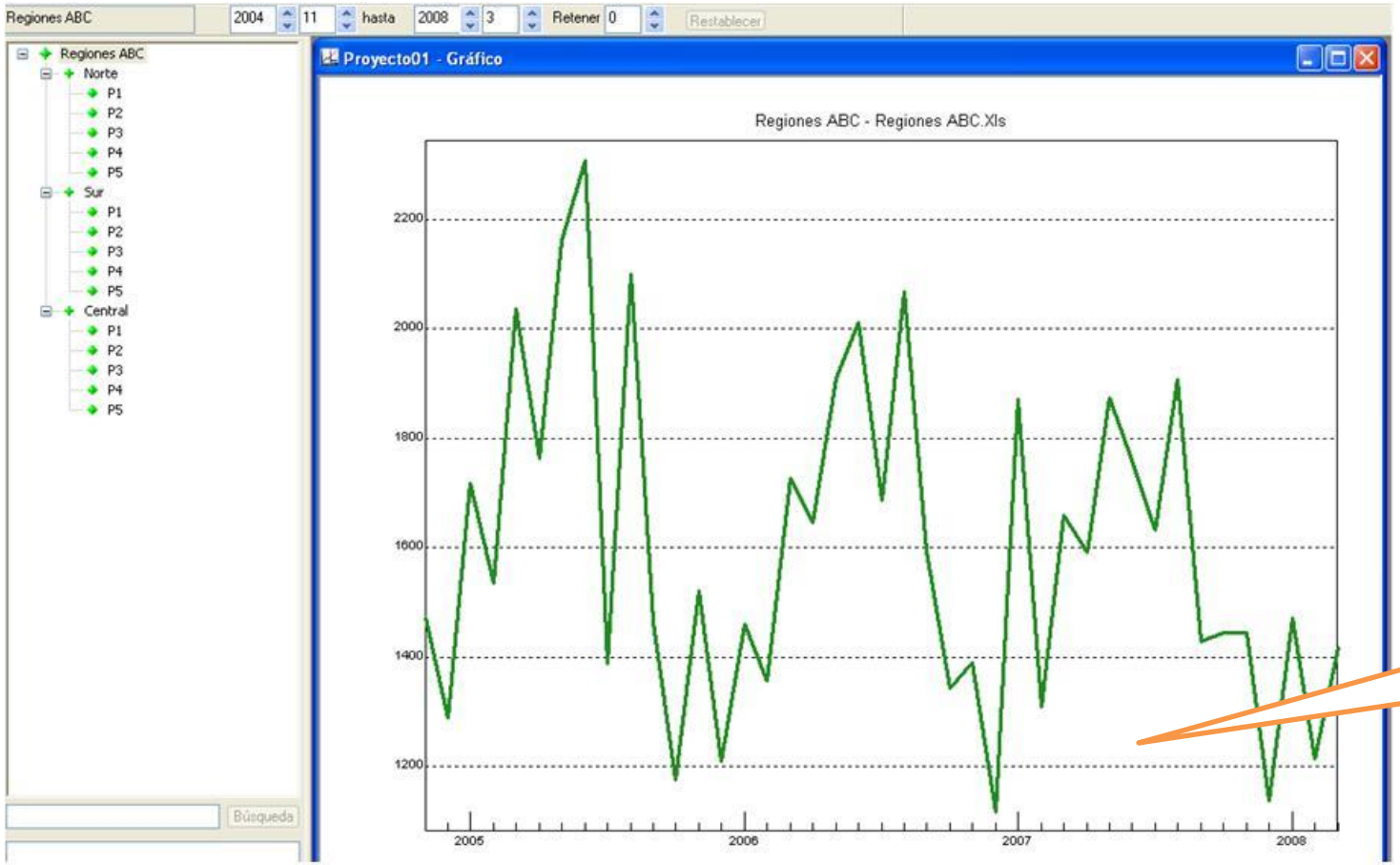
Finance View



Budget Units (Incomes, Margins)

Time (Incomes, Margins)

Example: ABC Company sells each of its 5 products in 3 different regions



Aggregate demand (added together)

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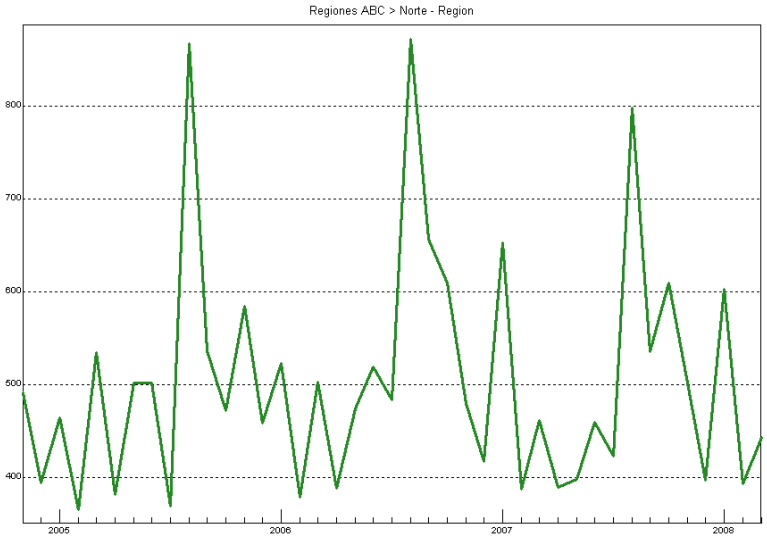
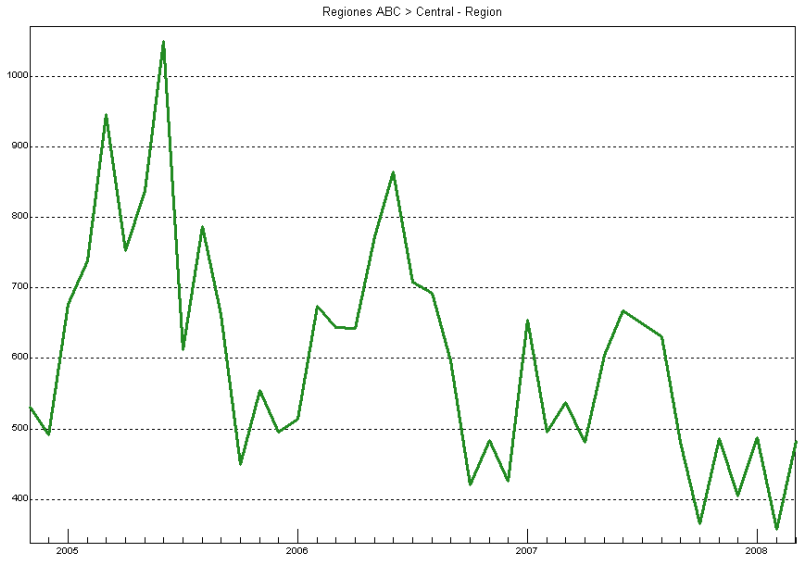
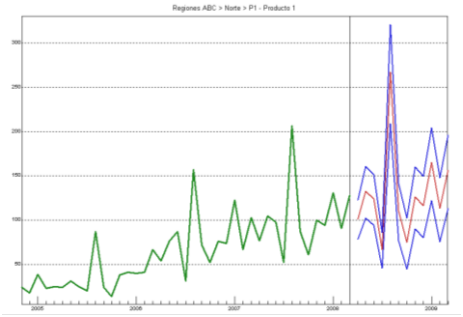
Example: Different behaviors in different regions



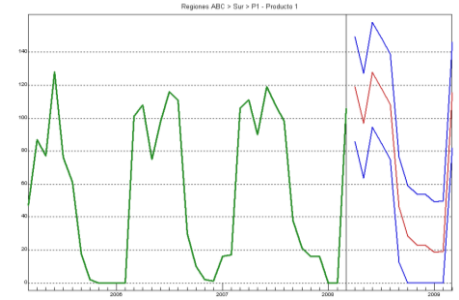
The behavior, in equivalent units, for the sum of the products differs by region



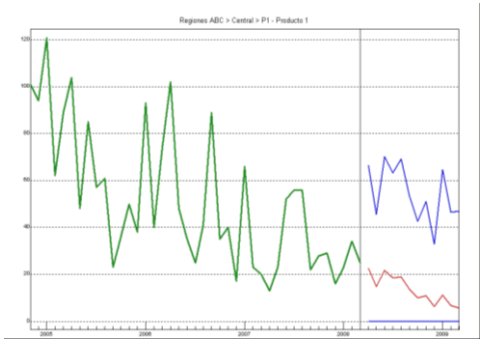
Example: Behavior of product 1



North



South



Central

The same product behaves differently depending on the region

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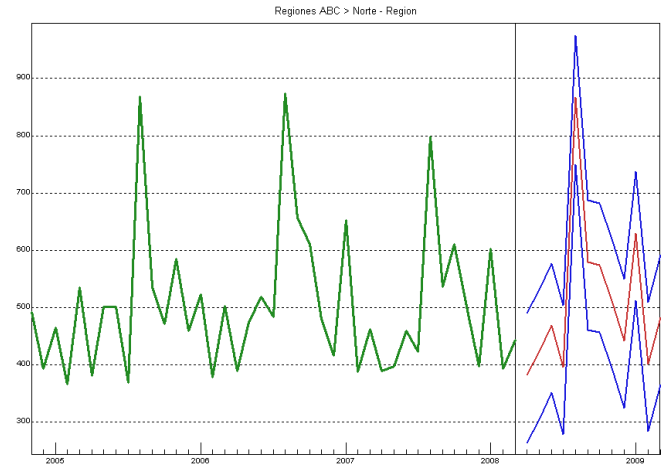
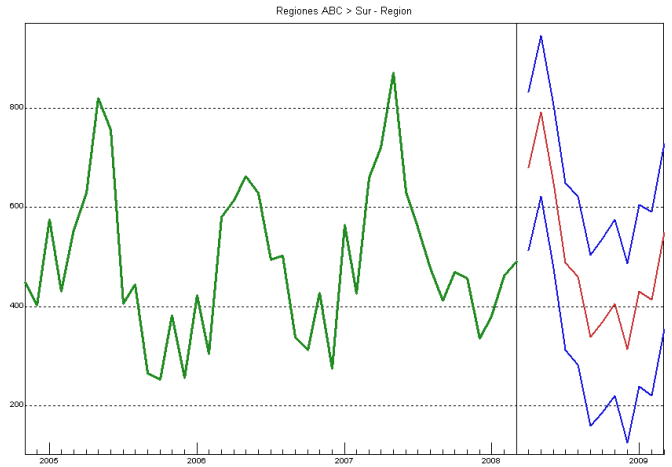
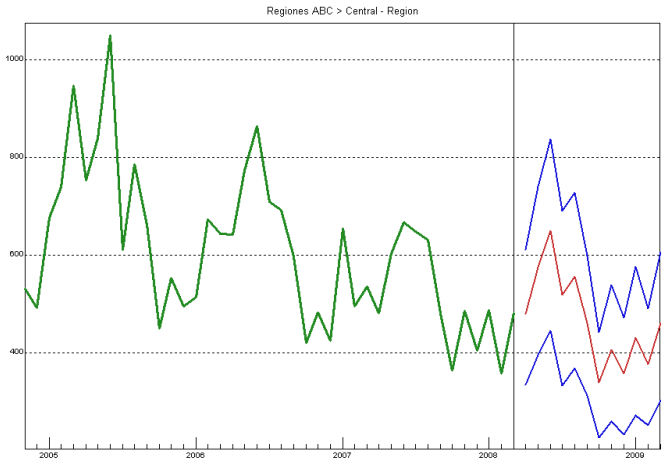
Example: Forecasting by region (aggregate forecasting)







Forecasts by Region

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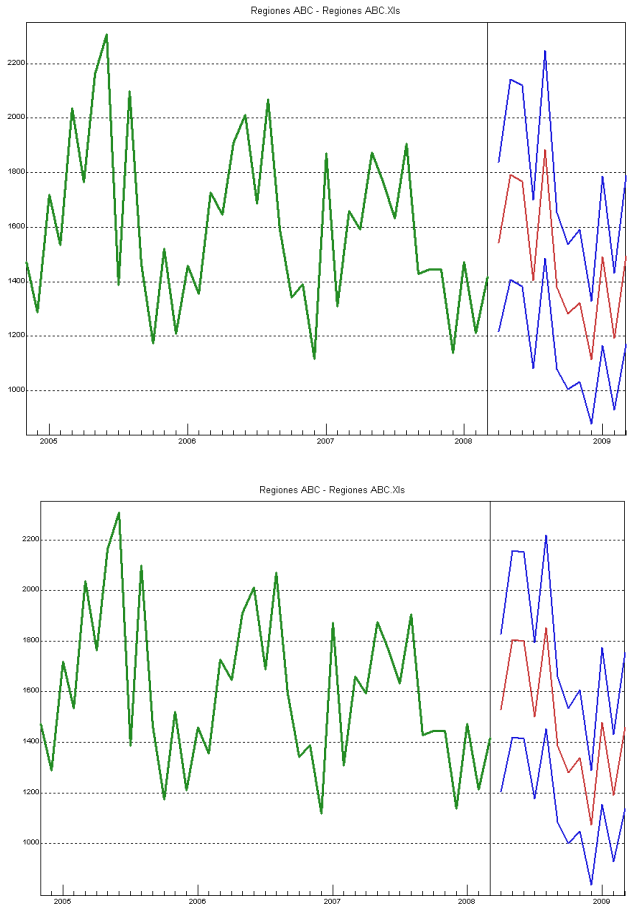
Example: Different multilevel forecasting Techniques



Bottom - Up

Top - Down

Forecasts differ according to the technique

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Collaborative Forecasting

Fundamentals

Silo against Consensus Forecasting

- Evolution during the last three decades:
  - Silo Forecasting (SF)
  - Consensus Forecasting (CF)
  - Sales and Operations Planning (S&OP)
  - Collaborative Planning and Forecast Replenishment (CPFR)

Silo Forecasting (SF)

- Multiple forecasts.
- Each business function (department) prepares it´s own forecasts, there is no official forecast for the company.
- No follow up for the results.
- It used to work in old environments dominated by the manufacturing function, where all that was produced, was sold. Now we have more demanding and less loyal customers, and they have a lot of options.
- This SF complicated the alignment between supply and demand.

Consensus Forecasting (CF)

- Generation of a unique set of forecasts for all the functional areas of the Company.
- All areas collaborate for the Forecast and expertise is introduced to complement the statistical Forecast.
- Each area knows different information that aggregates value to the consensus forecast, which is the one that at the end, all areas accept and use.

Generation of CF

- Get the data of what you need to forecast in the same “units”, so if you need to forecast shipments, get the data expressed in shipments or, if you need to forecast final customer´s sales, get the data from the point of sale (POS).
- Receive feedback from all the functional areas in order to get details like plans for customers (Sales), promotions (Marketing) and investments (Finance), among others.
- Start with an agreement of the assumptions to be used; things like prices, investments in promotions and the state of the economy, among others.
- Manage exemptions. Once the forecasts are generated, study the highest and the lowest points, in case you have to make an adjustment.
- Send the statistical forecasts to all the interested departments in order for them to check them, before the consensus meeting.
- Present the forecasts in a monthly meeting where the whole team can check the forecasts and the assumptions. If an adjustment needs to be made, the team must approve it. After the meeting, all the functional areas must work with the same set of data.

Requirements for a successful implementation of CF

- Collaboration between functional areas before introducing adjustments.
- Same weight and voice. Each area involved in the process should have the same “voice” in the final forecast.
- Sponsorship and support from the Managerial team.
- Knowledge of the mutual benefits for each functional area.
- Independent Forecasting department. This department must do the statistical forecast y coordinate the consensus meetings.
- Continuous monitoring of the forecast´s performance.
- Use of technology in order to gather and accommodate the data, select the statistical models and manage the special events.

Sales and Operations Planning (S&OP)

- Once the consensus forecast is ready, the S&OP process provides the way to anticipate problems and opportunities and to generate fast solutions.
- It´s an alignment process, not only between demand and supply, also guides all the functional areas in the same direction and shorten the planning process (monthly).
- S&OP objectives:
  - Align demand, supply and budget.
  - Integrate operational plans with strategic plans.
  - Integrate the product mix with the total volume.
  - Ability to act proactively.

Steps in an S&OP process

- Get data from sales, marketing and the other functional areas.
- Prepare the consensus forecasts. First, the Demand Planning team (Sales, Marketing and Finance) do their forecasts and then, they send it to the Supply Planning team (Manufacturing, Purchasing and Logistics). Both teams analyze the alternatives and possible scenarios.
- Do the pre – executive S&OP meeting. Operational forecast are analyzed to see if they are consistent with the strategic goals. Then, the feasibility of meeting the demand requirements balancing them with the supply is studied. Actions should be defined and a consensus plan should be the final product. This must be presented in the Executive S&OP meeting.
- Celebrate the Executive S&OP meeting. All the high – level managers participate and analyze the proposals to see if they are properly aligned with the strategic goals and the associated risks, then, they approve the action plans.

S&OP: Benefits

- Improvement in the forecast accuracy.
- Improvements in the inventory levels.
- Reduction of shortages.
- Higher customer service levels.
- Higher revenues.

Musts for a successful S&OP process

- Cross participation of the involved areas to ensure a robust consensus forecast.
- Involvement of key people in the process, specially people from the higher management team.
- Need of a “Champion”, a person with the power to ensure the effectiveness and continuity of the meetings.
- Respect for the calendars and the agendas in each meeting.
- Concentration in the global volume and in categories or families, not in sku´s.
- Clear definition of goal and KPI´s.

Musts for a successful S&OP process

- Post mortem audit of the results in order to understand the errors and to improve continuously.
- Guides for solving conflicts and courage to act in tough situations.
- Centralization of data and use of global standards for product identification.
- Use of technology to make the process simpler, from forecasting tools to demand / supply planning, MRP, DRP, APS, Scorecards and Dashboards to Scenario Simulation.
- Creation of incentive plans based on global performance, like total profit, total sales, total EVA, but not on specific activities.
- Always aim for continuous improvement.

Collaborative Planning and Forecasting Replenishment (CPFR)

- It´s an extension of the S&OP with the participation of suppliers and / or customers.
- Continuous work with the other participants of the value chain.
- It´s based on sharing information about sales, inventories, promotions, new product introductions and others.
- The data gathered from the POS are shared in order to maximize the service level and minimize supplier´s risks.
- CPFR is the most advanced way to manage inventory, where suppliers and customers work together to replenish inventory at the client´s locations.

CPFR: Benefits

- Suppliers have access to sales data and business plans of the customers.
- Improvements in forecast accuracy (even better than S&OP).
- Improvements in customer service levels.
- Better productivity and inventory levels.
- According to some studies, companies that have implemented CPFR along with S&OP, have improved their fill rate from 2% to 8% and, have reduced their inventory from 10% to 40% in their Supply Chains.

CPFR: Recommended steps

- Planning and Strategy: define rules for the collaborative relation and for the development of conjoint business plans.
- Demand and Supply management: Create sales forecasts, identify exemptions and solve them balancing demand and supply, to achieve the highest profit.
- Execution: Orders, shipments, receiving and storing products in retail stores, register sales transactions and payments.
- Analysis: monitoring plans and the execution of activities to fight exemptions caused by environmental issues, competition, flaws in the supply chain. Also to look for new opportunities. This requires the use of a score card and share it with customers and suppliers.

CPFR: keys for success

- Sponsorship from the higher management team.
- Selection of the right partner; experienced in collaboration processes, compromised with time and resources and also with an important business relation with the company.
- Trust and transparency between participants, for sharing all the necessary information.
- Crawl, walk and run. Start with a pilot plan at the category level.
- Keep together CPFR with S&OP to get to IBP (Integrated Business Planning).
- At the beginning, keep your expectative low.
- Continuous search for new ways to growth, as a whole.

ACCURACY AND EVALUATION

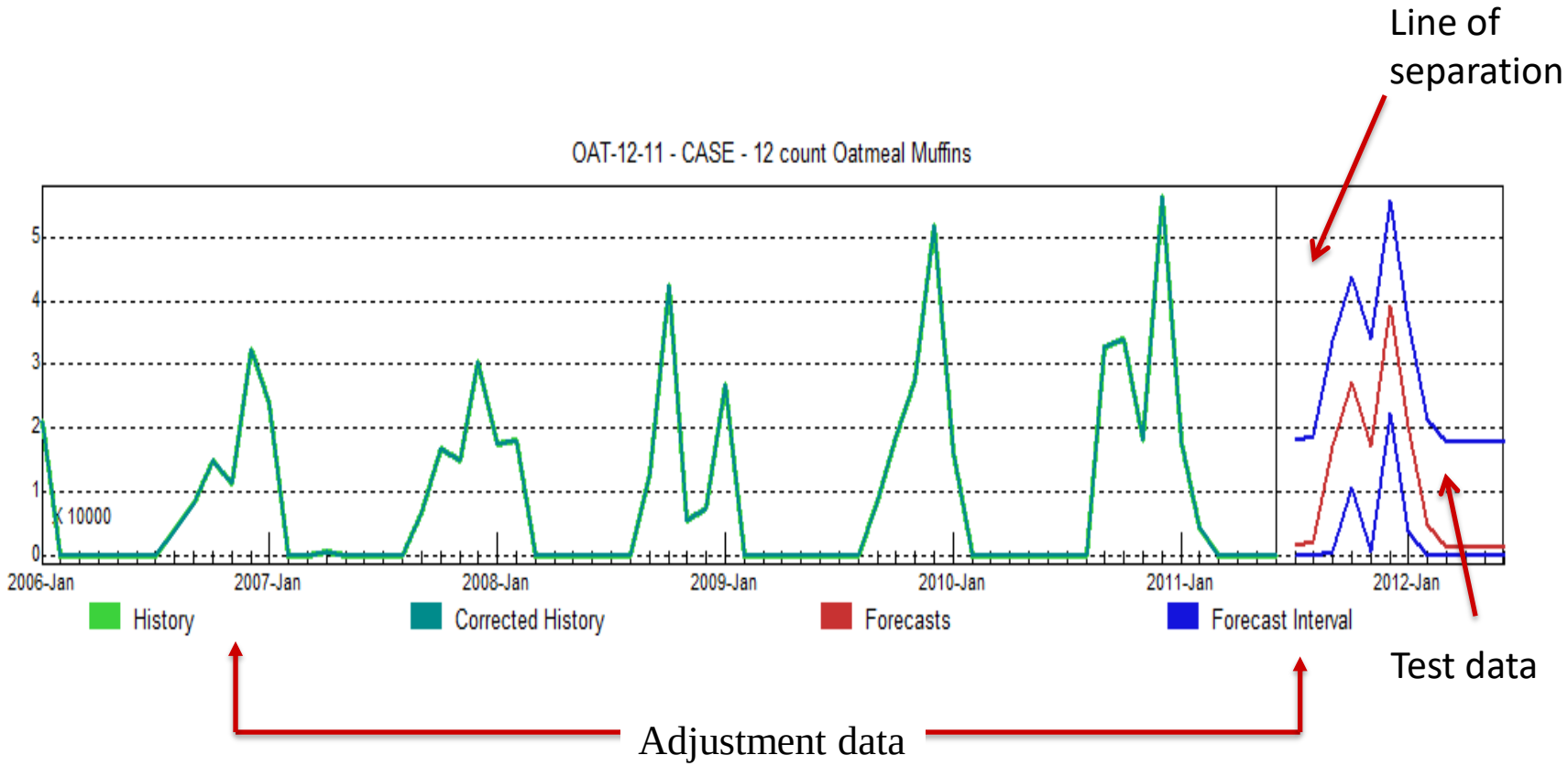
Metrics and Benchmarking

Accuracy and Evaluation of Forecasts

- **Issues to consider:**
  - How well the method adjusts the behavior of historical data? *(Internal Validity)*
  - How well the method will behave in future? *(External Validity, evaluations out of sample)*

Evaluations of out of sample Forecasts

- Split the historical series in adjustment data and test data.



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Mean Absolute Deviation (MAD)

MAD (Mean Absolute Deviation)

$$\sum_{t-1}^{n} \frac{|x_t - \tilde{x}_{t-1,t}|}{n}$$

Where the Forecast error is: $x_t - \tilde{x}_{t-1,t}$

Example:

Period	1	2	3	4	5	6
Actual Demand (X_t)	100	87	89	87	95	85
Forecast ($X_{t-1,t}$)	90	92	91	91	90	91
Deviation	10	-5	-2	-4	5	-6

- Absolute deviation: 32
- MAD: 5.33 units

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Several squared metrics

$$\sum_{t-1}^{n} (y_t - \hat{y}_t)^2$$ **Sum of Squared Errors**

$$\text{MSE} = \left(\frac{1}{n}\right) \text{SSE}$$ **Mean Square Error**

$$\text{RMSE} = \sqrt{\text{MSE}}$$ **Root Mean Square Error**

Mean Absolute Percentage Error (MAPE)

- **Absolute percentage errors**

$$\frac{100}{n}\sum_{t-1}^{n}\left|\frac{y_t - \hat{y}_t}{y_t}\right|$$

Month	Method 1	Method 2	Random Walk
September	2.26%	2.64%	4.40%
October	7.56%	5.59%	9.97%
November			
December	3.10%	6.32%	3.77%
MAPE	*4.19%*	*3.99%*	*5.13%*

WMAPE

- WMAPE assign weights according to sales volume:
  - **R:** Real data
  - **F:** Forecast data

$$\frac{\sum \frac{|R - F|}{R} * 100 * R}{\sum R}$$

Determination Coefficient

- **R-squared:**
  - Is the squared correlation between the variable and its estimated value.
  - R squared: (Explained Variance / Total Variance)
  - Explained Variance: Deviation between estimated and mean.
  - Unexplained Variance: Deviation between actaual and forecast data.
  - Adjusted R Squared: Consider the number of observations and explanatory variables.

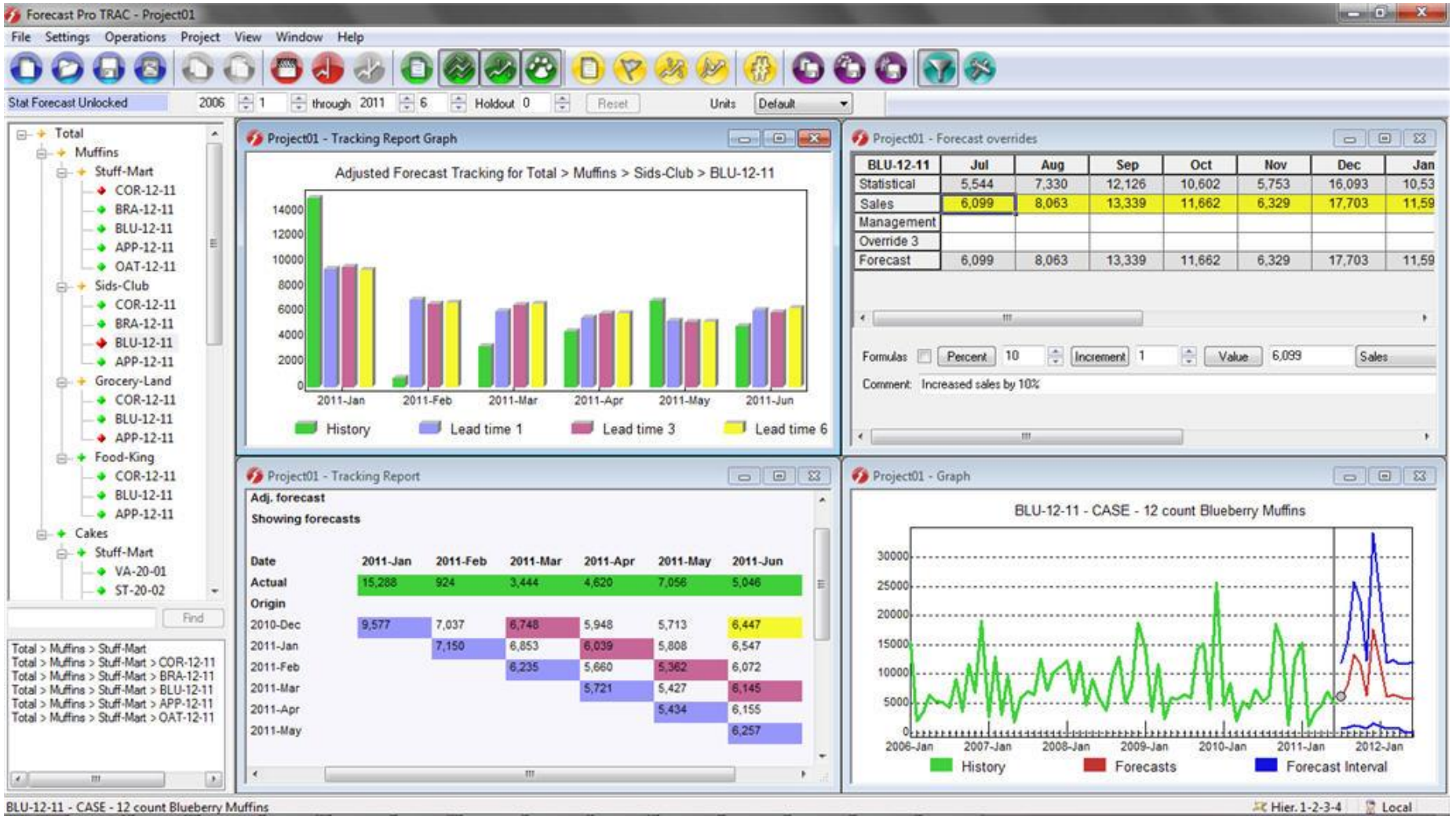
Bayesian Information Criterion (BIC)

- It is used to compare models.
- The smaller the BIC, the better the model.
- Balances the accuracy of the model with the complexity, measured by the number of parameters.
- Unexplained variations in the dependant variable and an increase in the number of explanatory variables, generate increases in the BIC.
- To minimize the BIC is needed a lesser amount of explanatory variables, or best fit of the model or both.
- The variance of the error, n: number of data and k: number of parameters and explanatory variables, the BIC can be expressed as:

$$\mathrm{BIC} = n \cdot \ln(\hat{\sigma_e^2}) + k \cdot \ln(n)$$

$$\hat{\sigma_e^2} = \frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})^2$$

Examples of Forecasting Using ForecastPRO®



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Benchmarking

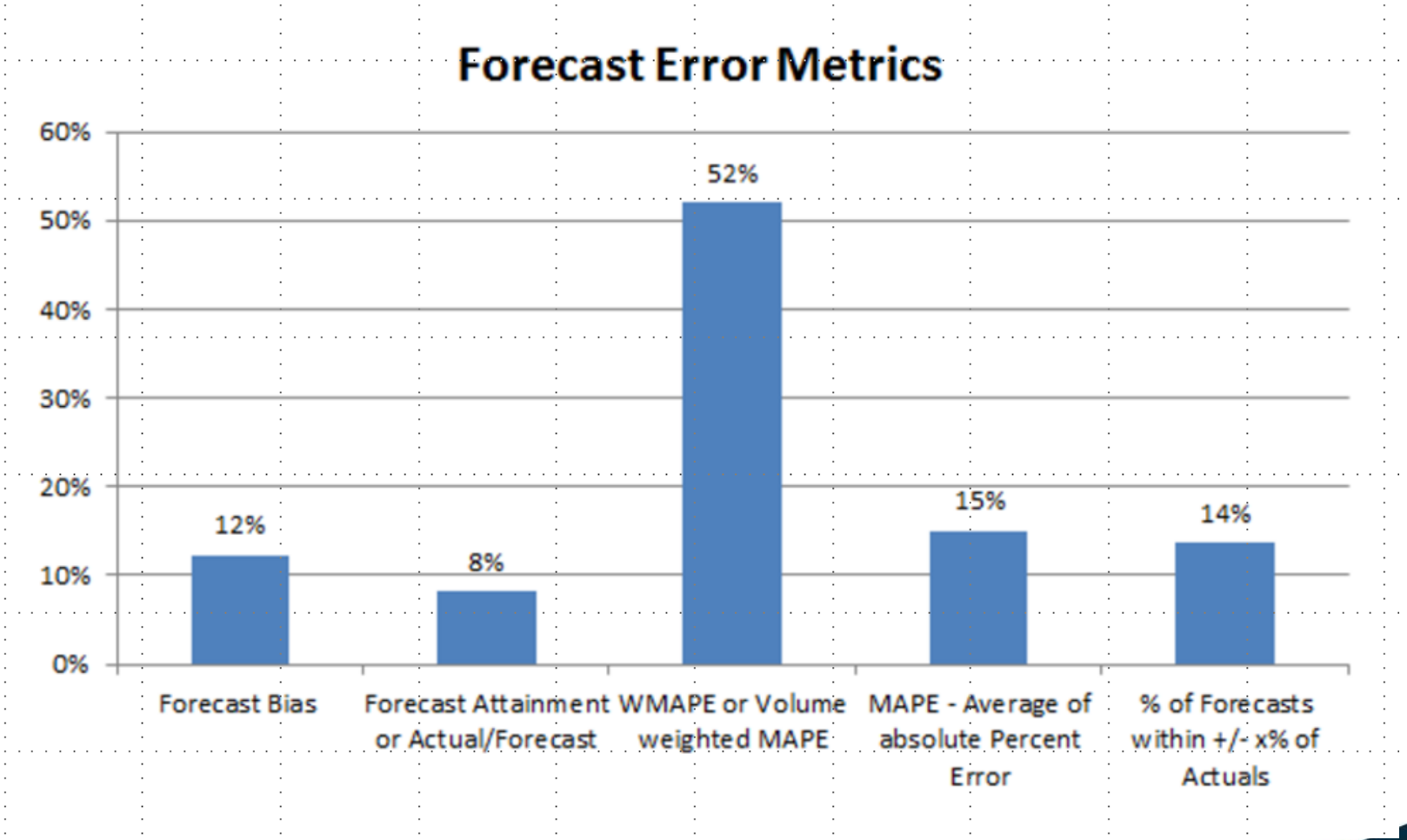
- According to the Institute of Business Forecasting:
  - Most popular forecasting models:
    - Time series: 67%
    - Cause and effect: 23%
    - Judgmental: 10%
  - Most popular time series models:
    - Simple and moving average: 58%
    - Exponential Smoothing: 28%
    - Box Jenkins: 28%
  - Most popular cause and effect models:
    - Regression: 77%
    - Econometrics: 20%

Benchmarking

- According to the Institute of Business Forecasting:
  - Forecast errors according to the horizon (sku level):
    - Annual: 29%
    - Monthly: 26%
  - Forecast errors according to the horizon (category level):
    - Annual: 21%
    - Monthly: 18%
  - Forecast errors according to the horizon (aggregated level):
    - Annual: 16%
    - Monthly: 13%

Benchmarking

- According to www.forecastingblog.com



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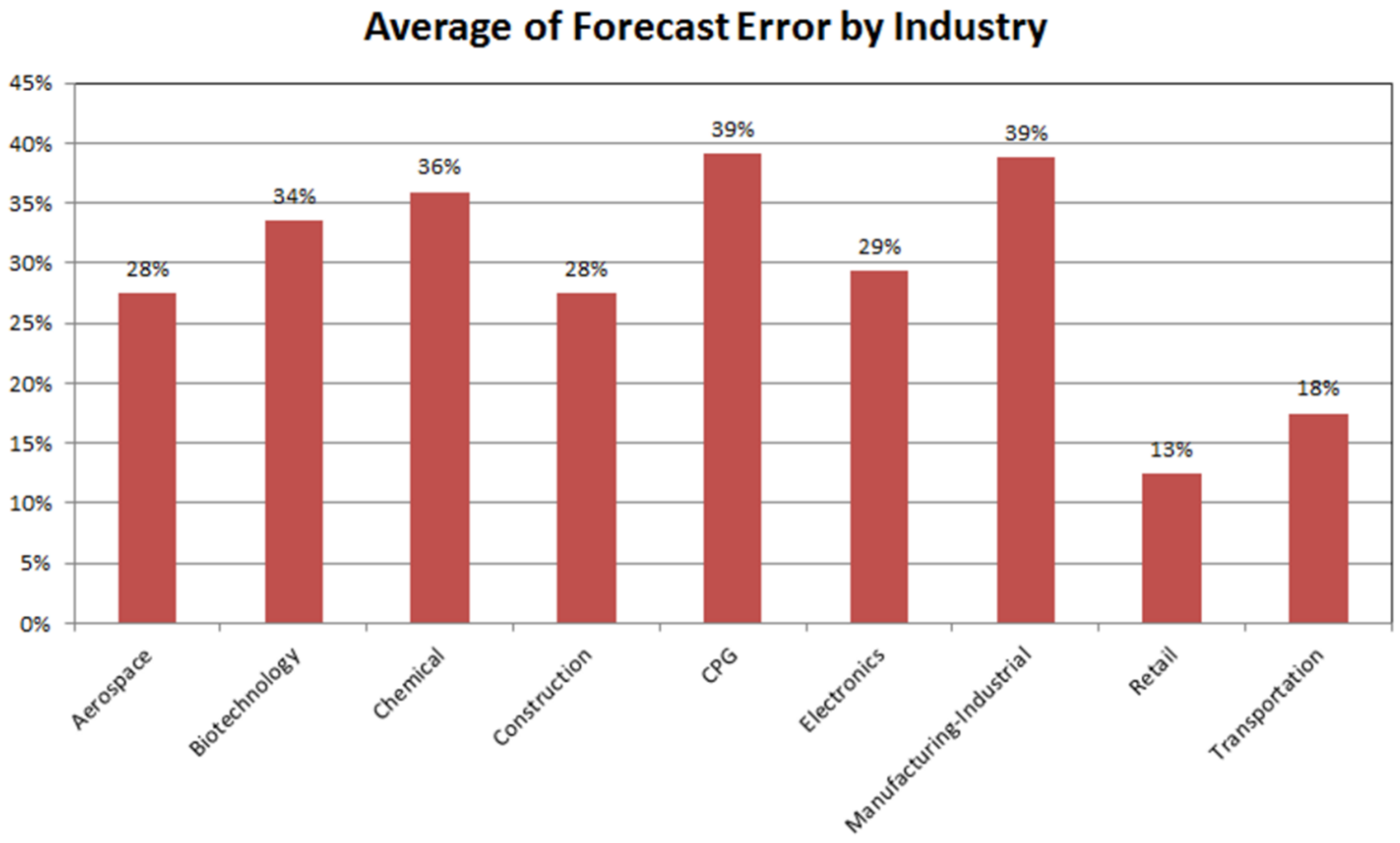
Benchmarking

- According to www.forecastingblog.com



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Inventory Management

- “Inventory Management plans, implements and controls the forecasts and the demand behaviors, the order quantities and the moments that the replenishments should be done, the average inventory and the service level to offer.”. Silver, Pyke y Peterson

- The goal is to achieve a service level, minimizing at the same time, the total relevant cost (CTR), which is composed by:
  - Annual ordering cost
  - Annual inventory carrying cost
  - Annual acquisition cost
  - Annual cost of stock outs (probabilstic)

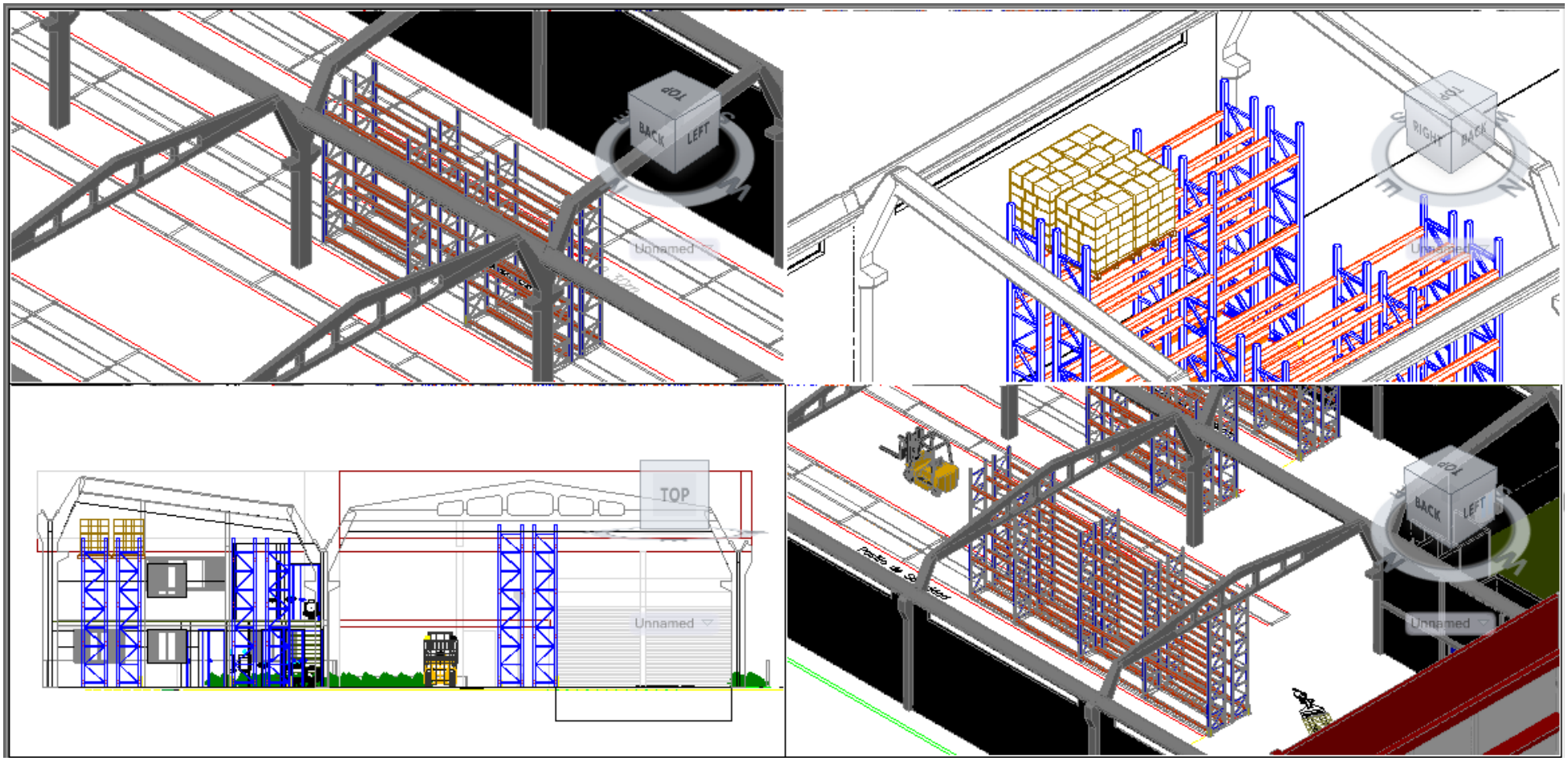
Inventory Management and it's processes

- Demand forecasting
- Definition of order quantities:
  - EOQ, POQ
  - Silver Meal, Wagner Whitin
- Control systems for the inventory level:
  - (s, Q), (s, S), (R, s, S)
- Customer Service Planning:
  - Probability of NO stockouts
  - Fill Rate
- Inventory deployment along the Supply Chain

Models to calculate the order quantity and the safety stock

- Models for deterministic demand:
  - EOQ
  - EOQ balanced by period
  - Silver Meal
  - Lot for Lot
- Models for probabilistic demand (safety stock calculations):
  - Based on service level:
    - Probability of NO stock outs (Type I)
    - Fill Rate (Type II)
  - Based on cost minimizing:
    - Sequential
    - Parallels

Impact of forecasting accuracy in inventory and warehousing management.



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Impact of forecasting accuracy in inventory

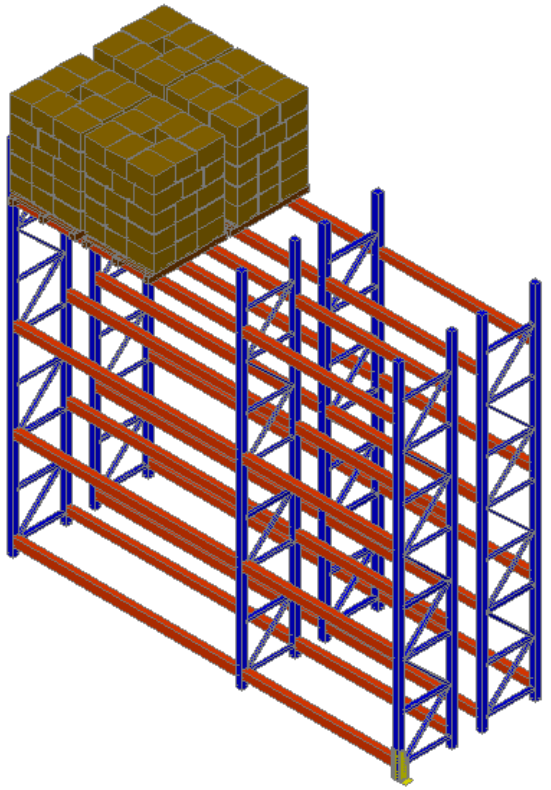
- The error measurements can be related with the models to calculate the order quantities and the safety stocks
- For example, the MAD can be related with the safety stock in the following way (assuming that the demand during the lead time has a normal distribution):
- $\sigma_1 = \sqrt{\frac{\pi}{2} * MAD}$
- The safety stock can be calculated the following way:
- $ss = k * \sqrt{L} * \sigma_1$

- This means that the less the forecast error, the less need for inventory and thus, less need for warehousing capacity and higher cash flow.

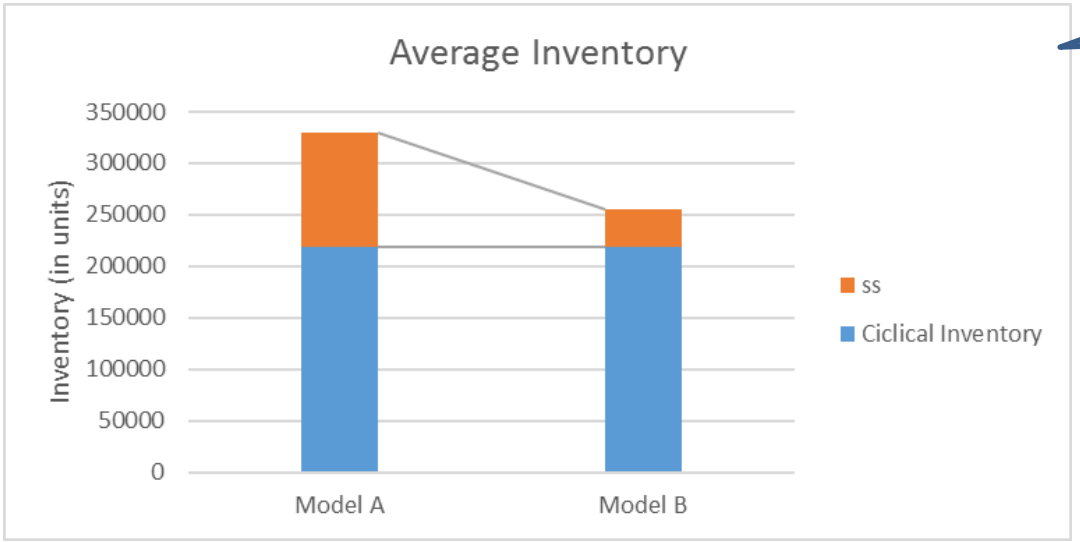
Example
The name of the spreadsheet is: Impact of Forecasting.xlsx

This example uses ForecastPRO and MS Excel

- Evaluate the forecast accuracy with the model used by the Company.
- Using ForecastPRO, change the statistical model and analyze the increase in the forecast accuracy.
- Study the decrease in the inventory level due to the better forecasting method.
- Analyze the warehousing capacity needs.
- What's the financial impact of the better forecasting accuracy?



Results



22% reduction in the average inventory, with the same customer service level

	Model A	Model B	Savings $
Capital invested in Inventory	6.583.114	5.105.330	-1.477.783
Inventory carrying cost	1.645.778	1.276.333	-369.446

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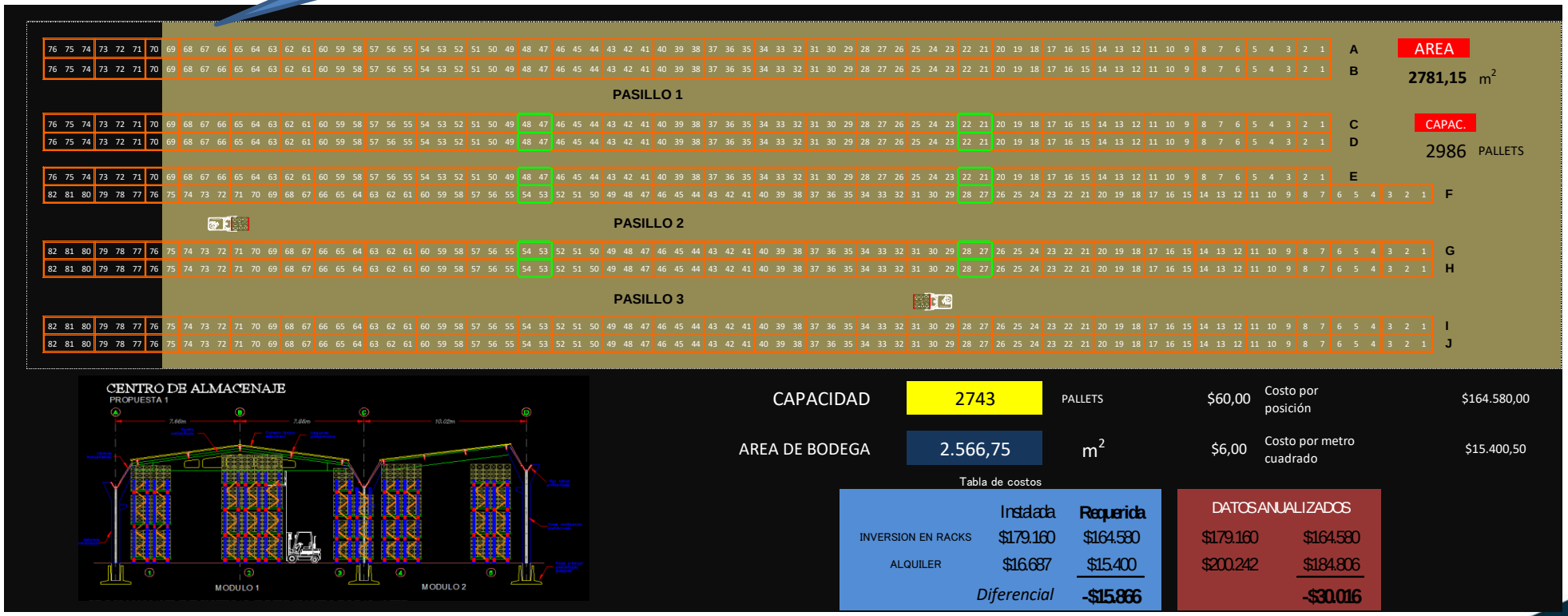
Results

With the forecasting model A, they need 2567 m2 in the warehouse.



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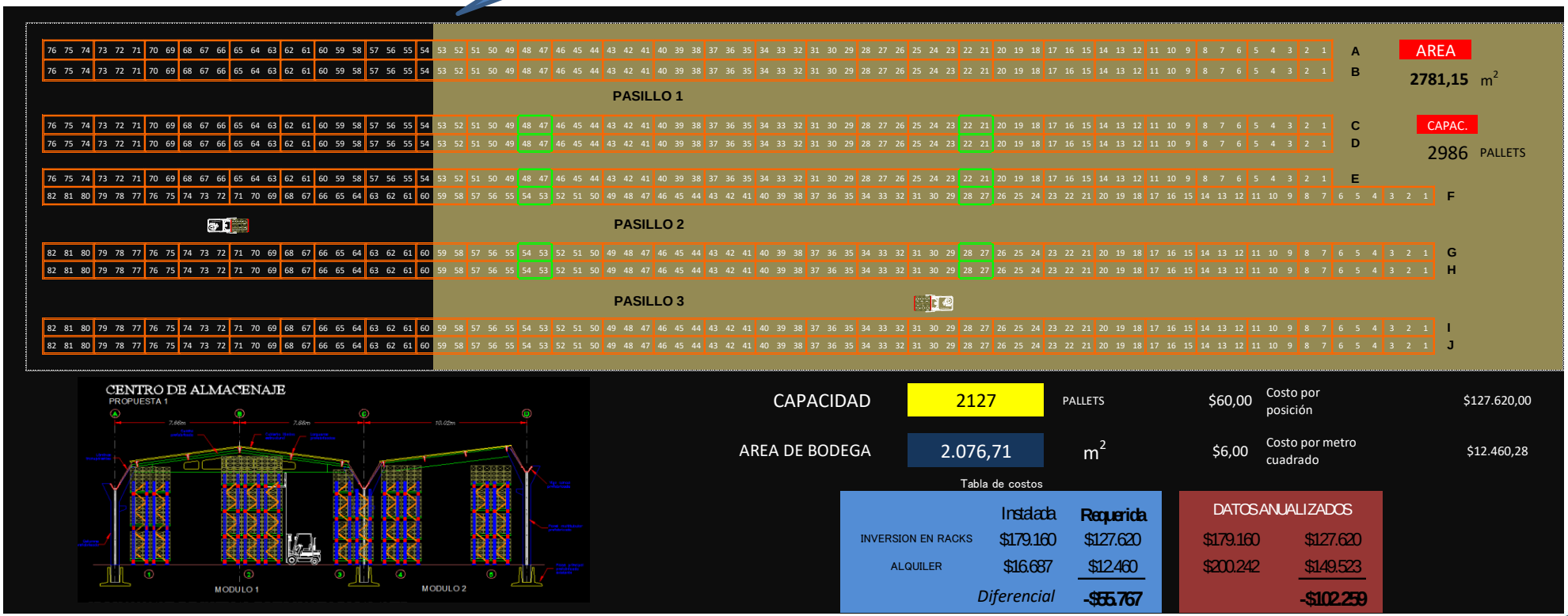
Results

With the forecasting model B, they would need 2076 m2 in the warehouse, a 19% decrease



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THANK YOU!!

Marco Arias V., IE, MBA, M.Sc., CPIM.

marco.arias@macrologistica.co.cr
www.macrologistica.co.cr